Asset Prices and Monetary Policy in the Euro Area: a tentative model

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ASSET PRICES AND MONETARY POLICY IN THE EURO AREA: A Tentative Model

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ABSTRACT

The nature of the relationship between asset price movements and monetary policy is a currently hotly debated topic in macroeconomics. This paper examines empirically if monetary policy in the euro-area, since 1987, has been influenced by high valuations of the equity and housing markets. A first aim of the paper is to assess the performance of Taylor-type rules and to evaluate whether alternative specifications, including asset prices, can better track the interest rate setting in the euro area. The general finding is that a Taylor-like rule, with an interest rate smoothing term but without including asset prices, seems to be helpful in describing monetary policy in the euro-area in the last fifteen years. Next, in the context of a simple macro model, extended with asset prices, we derive the optimal reaction function for the monetary authorities. Through a simple calibration of that model, we find that asset prices inclusion in the monetary authority's reaction function implies a larger volatility for the interest rate and destabilizes the economy. That is, apart from demand shocks, the rule incorporating asset prices implies more volatility than a simple rule. The effect of the disturbances dies out after some periods, but the observed volatility in the variables is greater in the extended model.

Keywords: European Central Bank, Asset Prices, Monetary Policy, Inflation Targeting.
JEL Codes: E52, E58

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1. Introduction

We live in a period of stabilised inflation in almost all industrialised countries. With the inflation problem contained, the monetary authorities centred their attentions on the issues of financial markets stability. The development of financial markets, and their globalisation, is the main driving force behind that change of focus. Associated with that development and increasing interdependence we have a growing uncertainty and volatility in asset markets. So, these factors lead to question the role of financial markets in the transmission of monetary policy and the response of the monetary authorities to that interdependence.

Perhaps the clearest statement about these concerns was the "irrational exuberance" danger proclaimed by US Federal Reserve Chairman Alan Greenspan in 1996. Is the "irrational exuberance" of the markets a reason for the central bank intervention? That is the main question that we deal with in this paper.

Concomitant to the process just described, there has been a renewed interest in the rather large literature on monetary policy rules. Since the publication of John Taylor's seminal paper on the interest rate setting by the Federal Reserve (Taylor, 1993), it has become common practice to describe monetary policy using reaction functions which link the level of the nominal short-term interest rate to inflation and economic activity[1]. Such Taylor rules are of interest both from a central bank and an academic perspective. For central bank purposes, Taylor rules illustrate how, given economic conditions, interest rates would have been set in the past, which can provide background information for policy decisions. From an academic perspective, Taylor rules are attractive because they provide an extremely simple model that captures the main considerations underlying central bank's interest rate setting.

In the next section we present some preliminary considerations to the models that we are going to use. Sections 3 and 4 present the different models and possibilities for the instrument rule, as well as its estimation and calibration. Section 5 concludes with suggestions for future research.

2. Asset prices and the Central Bank's reaction function

In most of central bank's macroeconometric models the transmission mechanism of monetary policy is modelled as an interest rate transmission process. The central bank sets the short-term interest rate, which influences interest rates over the whole maturity spectrum, other asset prices, and the exchange rate. These changes in financial variables then affect output and prices through the different spending components. Because asset prices have an increasing weight on the balance sheet position of firms and individuals and because of asset price volatility, their potential effects on the real economy are certainly more acute today[2].

While it is consensual that asset prices contain valuable information for forecasting inflation, it is more controversial whether central banks should actively control asset price inflation. The explicit inclusion of asset prices in the central bank's reaction function raises some issues. The most important one is: will that help the stabilization efforts of the central bank?

Whatever the considered indicator, it is necessary to search for the nature of its predictive power, before including it in the central bank reaction function. In this paper we will allow asset prices to affect inflation albeit in an indirect way. Thus, through wealth and balance sheet effects, asset prices will widen the output gap, raising fears of inflation. On this matter, Federal Reserve Bank Chairman Alan Greenspan, in a 2000 testimony, has stated that wealth-induced consumption growth has partly been responsible for generating aggregate demand in excess of potential (Greenspan, 2000). So, the central bank will react to asset prices not because their evolution has

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[1] See, among others, Clarida *et al.* (1998), Peersman and Smets (1998), Levin *et al.* (1999) and Gerlach and Schnabel (2000). Orphanides (2001) presents some practical difficulties in the actual implementation of such rules.

[2] See Cecchetti *et al.* (2000). Asset price movements can be transmitted to the real economy through four possible channels: the household's wealth effect, the consumer uncertainty effect, the Tobin q' effect and the firm's balance sheet channel.

direct inflationary consequences, but because they create an excess demand that has inflationary consequences.

The general reason to include asset price fluctuations in monetary policy rules is that an asset price bubble is socially unwanted, due to its disruptive effects on consumption and investment and in the soundness of the financial system. Several authors argue that asset prices should be given some sort of an explicit role in the formulation of monetary policy, albeit there is some disagreement on the exact type of role. The disagreement goes from the inclusion of asset prices in a broader price index (Goodhart, 2000)[1], to their inclusion in inflation forecasts (Bernanke and Gertler's [1999 and 2001] financial accelerator model) and to stabilizing their value around fundamentals (Cecchetti *et al.,* 2000). Finally, Filardo (2001) argues that a central bank should respond to asset price movements as long as they provide some information about inflation or output, even if prices are driven by bubbles or not. Additionally, we can also refer here the papers from Rigobon and Sack (2003) and Bullard and Schaling (2002). The former shows that the Federal Reserve does appear to react to movements in stock market valuations with some vigour and the latter finds that adding equity prices to the policymaker's Taylor type rule and leaving all else constant, in general, will not improve economic performance and might possibly do considerable harm, relative to a policy of simply ignoring fluctuations in equity prices altogether. Bean (2003), on the question whether monetary policy should explicitly react to asset prices, asserts that inflation targeting is enough provided it is flexible. Nevertheless, little empirical research has been done on the predictive power of housing and real stock prices for inflation[2].

This section furnished the rationale for the inclusion of an asset prices effect in a standard model of the economy. The next two sections present the models.

3. Taylor rules and the conduct of monetary policy

With the adoption of the euro in January 1999, a euro-area model has become a *sine qua non* condition by which to evaluate the monetary policy of the European Central Bank (ECB henceforth)[3]. Of course, an important difficulty with any empirical investigation of the policy choice faced by the Eurosystem, is the lack of a complete data set with which to estimate an empirical model of the euro-area[4].

3.1 Stylized facts for the Euro-area economy

This sub-section presents some stylised facts for some euro-area economic variables. We use quarterly data for the period 1987Q1 to 2003Q2. This sample excludes the desinflationary period of the early 1980s, and is characterised by a rather stable monetary policy regime. We use the database provided by Fagan *et al.* (2001), extended with recent data published in the ECB's Monthly Bulletin.

The output gap is the percent deviation of real GDP from its potential. We use three different methods to obtain potential GDP (linear adjustment, quadratic adjustment and a Hodrick-Prescott filter). The values obtained for the output gap by the three methods are shown in Appendix A

[1] Goodhart's (2000) logic is based on work by Alchian and Klein (1973) and argues that a better monetary policy performance might result if policymakers used broader measures of inflation that include asset prices.

[2] One exception is Goodhart and Hofmann (2000, p. 122), that analysing the explanatory power of asset prices, find that "*housing price movements do provide useful information on future inflation, with equity prices and the yield spread being somewhat less informative*". Filardo (2000) also concludes on the benefits of considering house prices inflation in the prediction of future consumer price inflation. Nevertheless, it is worth recalling the difficulty of establishing significant and stable econometric relationships between asset prices and subsequent movements in output or inflation (see Stock and Watson [2001] for a survey).

[3] Few models have been built so far for the euro-area. For instance, Coenen and Wieland (2000) estimate a small model of the euro-area to evaluate the performance of alternative monetary policy strategies. Coenen, *et al.* (2001) assess the role of money to forecast output in a small rational-expectations framework. Fagan *et al.* (2001) manage to build a medium-sized model detailed enough to include agent's behaviour separately.

[4] Additionally, a drawback of the euro area estimation is that the data are averaged over the member economies, which experienced different monetary policy regimes prior to the formation of EMU.

(Figure A1). As we can see, we have obtained three similar sets of results, being the series obtained with the HP filter less volatile. The output gap shows major declines at the time of the Exchange Rate Mechanism crisis in 1992/1993 and from 2001 onwards.

The inflation rate is the annualised growth rate of the Harmonized Index of Consumer Prices (HICP). The interest rate is an annualised 3-month money market rate. The evolution of these two variables is shown in figure A2. The inflation rate rose at the end of the 1980s, declined continuously from 1990 to 1998 and increased from 1999 to 2000 before falling again. The short-term interest rate moves in a similar way, with the exception of a peak in 1994/95 that followed a tightening of monetary policy in the US in the spring of 1994.

To describe the share prices evolution in the euro-area we use the Dow Jones Stoxx Broad (Europe) index, taken from Eurostat's NewCronos database. The data on housing prices is aggregated from country data published by the Bank for International Settlements (BIS)[1]. In the historic performance of these two asset prices, we highlight the growth in house prices in the early nineties and also at the end of the decade and the spectacular increase in share prices (and the subsequent fall) in the last seven years of the sample. These indexes and their respective percent deviations from a HP trend are shown in figure A3.

Having presented the data, we turn in the next sub-section to the estimation of a set of traditional and alternative Taylor rule specifications.

3.2 A simple model accompanied by an extended Taylor rule

Previous work suggests that a so-called Taylor rule, which relates the short-term interest rate to its past values, inflation and the output gap, fits euro-area data surprisingly well[2]. The aim of this section is to study how best to model the behaviour of short-term interest rates in the euro-area, extending the Taylor rule with two additional variables related with the behaviour of asset markets (equities and housing prices). The rationale behind that was explained in section 2. We estimate the Taylor rules in the context of a simple macro model, consisting of two optimal behavioural equations: a Phillips curve linking inflation to the output gap, and a IS curve that relates output inversely to the real interest rate. Finally, inspired in Djoudad and Gauthier (2003), we close the model by specifying a reaction function for the "fictitious" euro-area monetary authorities in line with the seminal paper from Taylor (1993).

3.2.1 The Phillips curve

Several studies continue to find empirical support for the traditional strictly backward-looking Phillips curve[3]. We will model the supply side of the economy by the Phillips curve described by equation (3.1), where π_t is the inflation rate, x_t is the output gap (obtained with an HP filter) and ε_t is a structural error:

$$\pi_t = \sum_{j=1}^{4} \alpha_{0j} \cdot \pi_{t-j} + \alpha_1 \cdot x_t + \varepsilon_t \tag{3.1}$$

Given the correlation of inflation the coefficients on its backward-looking component are constrained to sum one ($\sum_{j=1}^{4} \alpha_{0j} = 1$). In the steady-state, inflation is constant, so we can easily express output as a function of steady-state inflation as follows:

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[1] The BIS data ends at 2001:3 and only comprises six euro-area countries (Belgium, Finland, Ireland, Italy, the Netherlands and Spain). We construct an euro-area housing prices index for these six countries, weighting their values by their relative GDP importance (Belgium = 9,1%; Finland = 3,9%; Ireland = 2,6%; Italy: 47,5%; the Netherlands = 13% and Spain = 23,9%).

[2] We find estimates of reaction functions for the euro area in Peersman and Smets (1998), Gerlach and Schnabel (2000), Clausen and Hayo (2002) and Gerdesmeier and Roffia (2003), among others.

[3] That is the case, among others, of Rudebusch and Svensson (1999), Rudd and Whelan (2001), Dennis (2001), Ozlale (2003) and, for European countries, Peersman and Smets (1999), Taylor (1999) and Aksoy *et al.* (2002).

$$y = \bar{y} + \pi_t \cdot \left(\frac{1-\alpha_0}{\alpha_1} \right) \qquad (3.2)$$

where y is real output and $\bar{y}$ is potential output. The long run slope of the Phillips curve, $[(1-\alpha_0)/\alpha_1]$, measures the response of output to changes in the long-run rate of inflation, after the economy has made the transition from one inflationary steady-state to another. With α_0 close to unity, equation (3.2) implies that there is a negligible long-run trade-off between inflation and output. The mainstream theory (e.g., King and Wolman, 1996), suggests that the long-run effect of inflation on output is very small. So, we will assume that there is no long-run trade-off between real output and inflation, i.e., $\alpha_0 = 1$[1]. The specification that we are going to estimate is:

$$\pi_t = \alpha_{01} \cdot \pi_{t-1} + \alpha_{02} \cdot \pi_{t-2} + \alpha_{03} \cdot \pi_{t-3} + (1 - \alpha_{01} - \alpha_{02} - \alpha_{03}) \cdot \pi_{t-4} + \alpha_1 \cdot x_t + \varepsilon_t \qquad (3.3)$$

3.2.2 The IS curve

Our extended backward-looking IS curve is illustrated in equation (3.4):

$$x_t = \beta_0 \cdot x_{t-1} - \beta_1 \cdot (i_t - \pi_t - r) + \beta_2 \cdot dsp + \beta_3 \cdot dhp + \mu_t \qquad (3.4)$$

where x_t is the output gap, π_t the inflation rate, r the equilibrium real interest rate, i_t the nominal short-term interest rate, dsp_t and dhp_t the deviations of share and housing prices from a trend obtained with the Hodrick-Prescott filter and μ_t a structural error. The asset prices variables appear in (3.4) to incorporate wealth, balance sheet and other effects on aggregate demand. This equation implies a negative relationship between the real interest rate and the output gap and can be rearranged to:

$$x_t = c_x + \beta_0 \cdot x_{t-1} - \beta_1 \cdot (i_t - \pi_t) + \beta_2 \cdot dsp_t + \beta_3 \cdot dhp_t + \mu_t \qquad (3.5)$$

where $c_x = r \cdot \beta_1$, being the interest rate at equilibrium consistent with a closed output gap and stability of asset prices.

3.2.3 The monetary policy reaction function

The original Taylor rule formulation takes the following form:

$$i^*_t = r + \pi^* + \lambda_0 \cdot (\pi_t - \pi^*) + \lambda_1 \cdot x_t \qquad (3.6)$$

where i_t is the nominal short-term interest rate set by the central bank period to period, r is the equilibrium real interest rate and * denotes target variables[2]. Capturing the actual behaviour of the main central banks, we add to (3.6) the possibility that the monetary authority is concerned with changes in the interest rate, so that the actual rate adjusts according to[3]:

$$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot i^*_t + \eta_t \qquad (3.7)$$

where ρ is the interest rate smoothing parameter degree and η_t is a structural error[4], so that:

$$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\, r + \pi^* + \lambda_0 \cdot (\pi_t - \pi^*) + \lambda_1 \cdot x_t \,] + \eta_t \qquad (3.8)$$

Under this specification, the interest rate moves gradually toward the rate i*, closing $(1-\rho)$ of the gap in each quarter. However, it is worth noting that i* is not necessarily the desired level of the

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[1] Also, the hypothesis of dynamic homogeneity in the Phillips curve is not rejected in an unconstrained estimation and has the additional advantage of reducing by one the number of coefficients.

[2] Taylor (1993) proposed that a central bank should adjust its real interest rate in response to three variables: the current value of the output gap, the current deviation of inflation from its target and a measure of the equilibrium real interest rate (inflation and output are given equal weights of 0,5).

[3] This behaviour helps to reduce output and inflation variability as McCallum and Nelson (1999) have pointed out. Also concern about the stability of financial markets may lead the monetary authorities to smooth interest rate changes. Smoothing may also indicate responsiveness of policy actions to inflation and output gaps observed over several quarters rather than just a single quarter. Alternatively, smoothing may be justified when the impact of changes in interest rates is uncertain due to an imperfect knowledge of the transmission mechanism (on these topics see Goodfriend [1991], Rudebusch [1995], Woodford [1999], Orphanides [1998], Sack and Wieland [1999], Rudebusch [2002] and Castelnuovo [2003] for a survey).

[4] η_t is a i.i.d. disturbance representing exogenous shocks to the short-term interest rate, arising, for instance, in the market for reserves or in the exchange rate risk.

interest rate, and in fact the interest rate may never reach i*, as output and inflation may respond to the movement in the interest rate before i* is reached.

Considering now the possibility that the monetary authorities take explicitly into account in their reaction function the potential inflationary effects of asset prices, we are going to estimate the following equation:

$$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\, r + \pi^* + \lambda_0 \cdot (\pi_t - \pi^*) + \lambda_1 \cdot x_t + \lambda_2 \cdot dsp_t + \lambda_3 \cdot dhp_t \,] + \eta_t \qquad (3.9)$$

That is equivalent to:

$$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\, c_i + \lambda_0 \cdot \pi_t + \lambda_1 \cdot x_t + \lambda_2 \cdot dsp_t + \lambda_3 \cdot dhp_t \,] + \eta_t \qquad (3.10)$$

where $c_i = r + \pi^* \cdot (1 - \lambda_0)$. Regarding the question of whether an interest rate response to the forecast of inflation would work better than an interest rate response to the actual inflation rate, Taylor (1999) has argued that forward-looking rules are based on current and lagged data, since forecasts are based on them. So, according to Taylor, inflation forecast rules are not more forward-looking than rules that explicitly react to current or lagged variables[1]. It is also possible to use the estimated value of c_i and λ_0 to compute a central bank's implicit inflation objective (π^*), that is:

$$\pi^* = \frac{c_i - r}{1 - \lambda_0} \qquad (3.11)$$

Naturally that this implies an assumption about the long-run equilibrium real interest rate (r)[2]. We are also going to test more simple specifications of equation (3.10).

3.2.4 Estimation and Results

Equations (3.3), (3.5) and (3.9) are estimated separately using the Generalized Method of Moments (GMM) (Hansen, 1982), with lagged variables as instruments[3]. To the extent that the number of instruments exceeds the number of parameters to be estimated, the model is overidentified. In that case it is straightforward to use the J-statistic in order to test the over-identifying restrictions and assess the validity of our specification and the set of instruments used[4].

Appendix B presents the results for the different estimated equations. We begin by observing that based on Hansen's overidentifying J-test, we cannot reject the orthogonality conditions in all our estimations.

Concerning the Phillips curve [equation (3.3)], we highlight the significant and positive output gap coefficient (0,13), being absent the counterintuitive effect of the output gap on inflation that was found in some previous literature (e.g., Gali and Gertler [1999] and Gali *et al.* [2001]).

The IS curve [equation (3.5)] estimated coefficients are all significant and have the expected signs. A one percent increase in the real interest rate will lower the output gap by 0,09 per cent. Notice also the significant effect of asset prices on the output gap. Nevertheless, those effects are of minor magnitude, with the strongest effect coming from housing prices. The estimation implies an equilibrium real interest rate of 2,64 per cent. We tried an alternative estimation without housing prices (3.5B). Now, the results are more robust with a lower real interest rate coefficient

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1 Several authors have claimed that the forward-looking reaction function is consistent with the observed behaviour of central banks (Mehra [1999], Clarida and Gertler [1997], Clarida *et al.* [1998] and Orphanides [2001]). However, Fair (2001) strongly rejects the forward-looking specification for the Fed reaction function.

2 Here we could use the value obtained in the IS curve estimation or, more simply, the real interest rate average over the sample (3,97 per cent). Naturally those two values shouldn't differ too much. While this method has the advantage of deriving the value of the inflation objective consistently with the Taylor rule framework, it however suffers from the fact that it is based on constant parameters and on a fixed value for the real interest rate, thus resulting on a constant value for the inflation objective.

3 Note that, the output gap is measured with error and the inflation rate is a major determinant of both inflation and the output. That may possibly imply cov(π_t, error) $\neq$ 0 and / or cov(x_t, error) $\neq$ 0, which results in biased and inconsistent OLS estimates (simultaneity bias).

4 Under the null hypothesis that the overidentifying restrictions are satisfied, the J-statistic times the number of regression observations is asymptotically χ^2 distributed with degrees of freedom equal to the number of overidentifying restrictions. We use this test to evaluate the validity of our instrument set, since a rejection of those restrictions would indicate that some variables in the information set fail to satisfy the orthogonality conditions.

and an implied equilibrium real interest rate of 3,34 per cent[1]. In this last estimation the positive and significant effect of share prices in the output gap persists.

The estimation of equation (3.10) yields significant results, except for the asset prices variables. The interest rate smoothing coefficient is equal to 0,66 and using our estimates and expression (3.11) we obtain an estimate of the central bank's inflation objective equal to 2,77 per cent. Next we estimate simple specifications for the Taylor rule. Equation (3.10B) excludes housing prices and its results are also presented in the Appendix. The coefficient on the share prices deviations is not significant but the coefficient associated with inflation is greater than one and statistically significant. An increase in inflation of one per cent leads the monetary authority to raise the real interest rate by 0,87 per cent. We also find that the monetary authorities respond aggressively to excess demand or supply pressures: a one per cent increase in the output gap leads the monetary authority to raise the interest rate by 0,23 per cent. Our estimate for the central bank's inflation objective is now equal to 3,26 per cent[2]. Equation (3.10C) in the Appendix corresponds to the traditional Taylor rule (a "flexible inflation targeting" regime), in which both inflation and the output gap enter in the reaction function. All coefficients are significant and have the expected signs: an increase in inflation of one per cent leads the monetary authority to raise the real interest rate by 0,89 per cent and a one per cent increase in the output gap leads the monetary authority to raise the interest rate by 0,43 per cent. Our estimate for the central bank's inflation objective is now equal to 2,97 per cent, which seems rather plausible. Thinking of the euro-area as having a pure inflation targeting regime, we estimate equation (3.10D). As we see in the Appendix the interest rate smoothing coefficient is smaller and the monetary authorities respond very aggressively to inflation: an increase in inflation of one per cent leads the monetary authority to raise the real interest rate by 1,80 per cent. Albeit the non-significant coefficient for the constant, this estimation provides also a plausible value for the central bank's inflation objective: 2,39 per cent. As a final observation, the explanatory power of all the (3.10) specifications is rather high. In the literature this is usually attributed to the inclusion of smoothing in interest rates[3].

So, summing up this section, in a historical perspective we find little support for the inclusion of asset prices in the monetary authority's reaction function, albeit their influence on the output gap. In terms of the traditional variables, the output gap coefficient is significant and positive and the inflation coefficient is well above unity. The different Taylor-type rules seem to describe very well the past behaviour of interest rates, implying an inflation objective a little under 3 per cent. Our results seem to indicate that the monetary regime in the euro-area, rather than deflating large deviations of asset prices from their long-run trend, has simply ignored them. Nevertheless, we admit that these results could be reversed with higher frequency data.

Concluding, using the estimated parameters and the expected values for all the variables, we calculate the forecasted series in sample. We can also see that the different Taylor type rules track rather well the historical evolution of the interest rate series in the euro-area (Figure C1), implying rule 3.10C a better fit. They capture the late 80s increase in interest rates and the subsequent fall in the 90s as well the up and down process in the last three years. Calculating the deviations of rule recommendations from historical interest rates we can confirm the higher volatility implied by rule 3.10D and the better fit of rule 3.10C[4].

4. An extended Taylor rule within a simple model

We turn next to the alternative of considering the optimal reaction function derived from a specific model. Svensson (1999) shows that the traditional Taylor rule is the optimal reaction

[1] These high levels for the equilibrium real interest rate are common in the literature, being motivated by the type of monetary policy pursuit by central banks in the late 80s (see Djoudad and Gauthier, 2003, p. 12).

[2] Only for indicative purposes, the sample average value of inflation is equal to 2,69 per cent.

[3] Nevertheless, the high degree of smoothing in the policy interest rate might reflect a possible misspecification of the model (e.g., omitted variables which are autocorrelated or to serially correlated shocks).

[4] Deviations are calculated as the difference between a rule recommendation and actual policy with positive deviations occurring in periods where the rule would have recommended tighter policy. For instance, rule 3.9C would have recommended setting the interest rate roughly 0,8 percentage points higher over the period 2001Q1-2002Q2.

function for a central bank which targets inflation in a simple backward-looking two-equation model of the economy, with the coefficients on the Taylor rule being convolutions of policymaker's preferences and the parameters in the IS and the Phillips curves. One interesting finding of this model is that policymakers react to the output gap (x_t) even if they are strict inflation targeters since x_t is useful in forecasting future inflation. We are going to extend that model including two equations for the determination of share and housing prices, showing that policymakers react also to these prices evolution even if they continue to be strict inflation targeters.

4.1 Baseline model

Our baseline model, despite its simplicity, contains the main ingredients of richer frameworks that have been used for policy analysis. It will be a very simple model consisting of four optimal behavioural equations (here we follow and develop the original model presented in Ball [1999] and Svensson [1997, 1999])[1].

$$\pi_{t+1} = \pi_t + \alpha \cdot x_t + \varepsilon_{t+1} \tag{4.1}$$

$$x_{t+1} = \beta_0 \cdot x_t - \beta_1 \cdot (i_t - \pi_{t+1|t}) + \beta_2 \cdot dsp_{t+1} + \beta_3 \cdot dhp_{t+1} + \mu_{t+1} \tag{4.2}$$

$$dsp_{t+1} = \gamma_0 \cdot \varepsilon_{t+1} + \gamma_1 \cdot dsp_t - \gamma_2 \cdot (i_t - \pi_{t+1|t}) + \theta_{t+1} \tag{4.3}$$

$$dhp_{t+1} = \rho_0 \cdot \varepsilon_{t+1} + \rho_1 \cdot dhp_t - \rho_2 \cdot (i_t - \pi_{t+1|t}) + v_{t+1} \tag{4.4}$$

where $\pi_t = p_t - p_{t-1}$ is the inflation rate in period t, p_t is the log of price level, x_t is the output gap, i_t is the monetary policy instrument (a short-term rate), $\pi_{t+1|t}$ is the inflation in period t+1 expected in period t, dsp_t and dhp_t are some measure of asset prices deviations (equities and housing, respectively), from their fundamental values. These last two variables appear here to incorporate the asset prices effects on aggregate demand, as described in section 2. Finally, ε_{t+1}, μ_{t+1}, θ_{t+1} and v_{t+1} are i.i.d. shocks in period t+1 that are not known in period t.

We now describe the different equations. Equation (4.1) is an inflation dynamics equation (Phillips curve) that links inflation positively to the output gap. The larger is α, the stronger is the adjustment of prices to deviations of output from its potential (or the more flexible are prices). The backward-looking term (π_t) reflects the existence of firms that employ a "rule of thumb" procedure to set their prices[2]. The inclusion of ε_{t+1} can be seen as a normal supply (productivity) exogenous shock. Equation (4.2) is an aggregate demand equation (IS curve) that allowing for a transmission lag of monetary policy, relates the output gap inversely to the real interest rate and positively to asset prices deviations. The coefficients β are assumed to be positive, and also β_0 is bounded in [0, 1][3]. Equations (4.3) and (4.4) have their roots in standard dividend models of asset pricing. Share prices deviations [Equation (4.3)] are a function of next period dividends (assumed to depend on the productivity shock) and the real interest rate. Housing prices deviations [Equation (4.4)] are also a function of the productivity shock and of the real interest rate. We also add a backward-looking term in the two equations.

As we see, the real interest rate affects output with a one-period lag, and hence inflation with a two period lag. On the other hand, asset price increases widen the output gap through wealth effects on consumption and raise inflationary threats, affecting inflation with a one-period lag. Share and housing prices don't directly affect the future path of inflation. Nevertheless, they are predictors of future inflation.

Inflation expectations in period t are, by (4.1):

$$\pi_{t+1|t} = \pi_t + \alpha \cdot x_t \tag{4.5}$$

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[1] Applied, among others, by Rudebusch and Svensson (1999) and Jondeau and Le Bihan (2000). We inspire ourselves also in Alexandre and Bação (2003).

[2] We consider that the coefficient on π_t is equal to one, which signifies that last period's inflation is very important for the formation of current inflation. According to Peersman and Smets (1998), this coefficient is equal to 0,92 for five European countries and Rudebusch and Svensson (1999), as ourselves in last section estimations, impose the restriction that the sum of the lag coefficients of inflation equals one.

[3] In a closed economy model, β_1 can be interpreted as the intertemporal elasticity of substitution for consumption. The rationale for including a lag of the output gap is to account for habit persistence in consumption as well as adjustment costs and accelerator effects in investment.

Using (4.5) in (4.2), we obtain the following reduced form aggregate demand equation:

$$x_{t+1} = \beta_4 \cdot x_t - \beta_1 \cdot (i_t - \pi_t) + \beta_2 \cdot dsp_{t+1} + \beta_3 \cdot dhp_{t+1} + \mu_{t+1} \tag{4.6}$$

where $\beta_4 = \beta_0 + \beta_1 \cdot \alpha$. Additionally, equations (4.3) and (4.4) must be transformed into:

$$dsp_{t+1} = \gamma_0 \cdot \varepsilon_{t+1} + \gamma_1 \cdot dsp_t + \gamma_2 \cdot \alpha \cdot x_t - \gamma_2 \cdot (i_t - \pi_t) + \theta_{t+1} \tag{4.7}$$

$$dhp_{t+1} = \rho_0 \cdot \varepsilon_{t+1} + \rho_1 \cdot dhp_t + \rho_2 \cdot \alpha \cdot x_t - \rho_2 \cdot (i_t - \pi_t) + v_{t+1} \tag{4.8}$$

Thus, the model can be represented by (4.1) and (4.6) to (4.8)[1].

Monetary policy is conducted by the Central Bank with an annual inflation target π^* of two per cent. This implies that the central bank's objective is to choose a path for current and future interest rates $\{i_t\}_{\tau=t}^{\infty}$ so as to minimise:

$$E_t \sum_{\tau=t}^{\infty} \delta^{\tau-t} L(\pi_\tau) \tag{4.9}$$

Where E_t denotes expectations conditional upon the central bank's information available in period t, the discount factor δ fulfils $0 < \delta < 1$, and the period loss function $L(\pi_t)$ is:

$$L(\pi_t) = \tfrac{1}{2} (\pi_t - \pi^*)^2 \tag{4.10}$$

That is, the central bank, as a strict inflation targeter, wishes to minimize the expected sum of discounted squared future deviations of inflation from the target. Thus, the central bank will minimise this objective function by choosing a path of real short-term interest rates and the first-order condition will define a monetary policy reaction function.

Since the interest rate affects inflation with a two-period lag, we can express π_{t+2} in terms of period t variables and t+1 and t+2 disturbances:

$$\begin{aligned}
\pi_{t+2} &= \pi_{t+1} + \alpha \cdot x_{t+1} + \varepsilon_{t+2} \\
&= [\, \pi_t + \alpha \cdot x_t + \varepsilon_{t+1} \,] + \alpha \cdot [\beta_4 \cdot x_t - \beta_1 \cdot (i_t - \pi_t) + \beta_2 \cdot dsp_{t+1} + \beta_3 \cdot dhp_{t+1} + v_{t+1}] + \varepsilon_{t+2} \\
&= [\, 1 + \alpha \cdot (\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2)\,] \cdot \pi_t + \alpha \cdot (1 + \beta_4 + \alpha\beta_2\gamma_2 + \alpha\beta_3\rho_2) \cdot x_t - \\
&\quad - \alpha \cdot (\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2) \cdot i_t + \alpha\beta_2\gamma_1 \cdot dsp_t + \alpha\beta_3\rho_1 \cdot dhp_t + [\varepsilon_{t+1} \cdot (1 + \alpha\beta_2\gamma_0 + \\
&\quad + \alpha\beta_3\rho_0) + \alpha \cdot (\beta_2\theta_{t+1} + \beta_3 v_{t+1} + \mu_{t+1}) + \varepsilon_{t+2}\,] \\
&= a_0 \cdot \pi_t + a_1 \cdot x_t - a_2 \cdot i_t + a_3 \cdot dsp_t + a_4 \cdot dhp_t + u_{t+1}
\end{aligned} \tag{4.11}$$

where: $a_0 = [\, 1 + \alpha \cdot (\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2)\,]$; $\quad a_1 = \alpha \cdot (1 + \beta_4 + \alpha\beta_2\gamma_2 + \alpha\beta_3\rho_2)$;

$a_2 = \alpha \cdot (\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2)$; $\quad a_3 = \alpha\beta_2\gamma_1$; $\quad a_4 = \alpha\beta_3\rho_1$

$$u_{t+1} = [\alpha \cdot (\beta_2\gamma_0\varepsilon_{t+1} + \beta_3\rho_0\varepsilon_{t+1} + \beta_2\theta_{t+1} + \beta_3 v_{t+1} + \mu_{t+1}) + \varepsilon_{t+1} + \varepsilon_{t+2}\,] \tag{4.12}$$

The interest rate in period t will not affect the inflation rate in period t and t+1, but only in period t+2, t+3, and so on. And the interest rate in period t+1 will only affect the inflation rate in period t+3, t+4, and so on. So, we can find the solution to the optimisation problem by assigning the interest rate in period t to hit, in an expected basis, the inflation target for period t+2, the interest rate in period t+1 to the inflation target for period t+3, etc. Thus, the central bank can find the optimal interest rate in period t as the solution to the simple period-by-period problem:

$$\min_{i_t} E_t \delta^2 L(\pi_{t+2}) \tag{4.13}$$

The first-order condition for minimising (4.13) with respect to i_t is:

$$\frac{\partial E_t \delta^2 L(\pi_{t+2})}{\partial i_t} = E_t \left[\delta^2 (\pi_{t+2} - \pi^*) \frac{\partial \pi_{t+2}}{\partial i_t} \right] = -\delta^2 \alpha (\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2)(\pi_{t+2|t} - \pi^*) = -\delta^2 a_2 (\pi_{t+2|t} - \pi^*) = 0$$

where $\pi_{t+2|t}$ denotes $E_t\, \pi_{t+2}$. It follows that the first order condition can be written:

$$\pi_{t+2|t} = \pi^* \tag{4.14}$$

That is, the interest rate in period t should be set so that the forecast of the one-period forward inflation rate from period t+1 to period t+2, conditional upon information available in period t, equals the inflation target. This two-period forecast can be considered an explicit intermediate target.

It follows that the inflation targeting loss function (4.10) can be replaced by an intermediate loss function $L^i(\pi_{t+2|t})$, the inflation "forecast" targeting loss function:

---

[1] Now asset prices deviations depend on contemporaneous shocks to inflation, the output gap and the real interest rate, which is more appealing since asset market participants presumably look at all available and relevant information when determining the appropriate price of the assets.

$L^i(\pi_{t+2|t}) = ½ (\pi_{t+2|t} - \pi^*)^2$ (4.15)

Instead of minimising the "expected" squared deviations of the "future" two-period inflation rate π_{t+2} from the inflation target as in (4.13), the central bank can minimise the squared deviation of the past two-period inflation forecast $\pi_{t+2|t}$, from the inflation target:

$$\min_{i_t} L^i(\pi_{t+2|t}) \quad (4.16)$$

Since the first-order condition is the same, it results in the same optimal interest rate[1]. The two-period inflation forecast given by (4.11) depends on the current state of the economy, π_t, x_t, dsp_t, dhp_t and the instrument i_t:

$$\pi_{t+2|t} = a_o \cdot \pi_t + a_1 \cdot x_t - a_2 \cdot i_t + a_3 \cdot dsp_t + a_4 \cdot dhp_t \quad (4.17)$$

Setting this equal to the inflation target, (4.14), leads to the central bank's optimal reaction function:

$$a_0 \cdot \pi_t + a_1 \cdot x_t - a_2 \cdot i_t + a_3 \cdot dsp_t + a_4 \cdot dhp_t = \pi^* \Leftrightarrow$$

$$\Leftrightarrow i_t = (1/a_2) \cdot [- \pi^* + a_0 \cdot \pi_t + a_1 \cdot x_t + a_3 \cdot dsp_t + a_4 \cdot dhp_t] \Leftrightarrow$$

$$\Leftrightarrow i_t = \pi_t + b_0 \cdot (\pi_t - \pi^*) + b_1 \cdot x_t + b_2 \cdot dsp_t + b_3 \cdot dhp_t \quad (4.18)$$

where: $b_0 = \dfrac{1}{\alpha(\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2)}$; $b_1 = \dfrac{1 + \beta_4 + \alpha\beta_2\gamma_2 + \alpha\beta_3\rho_2}{\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2}$;

$b_2 = \dfrac{\beta_2\gamma_1}{\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2}$; $b_3 = \dfrac{\beta_3\rho_1}{\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2}$

This reaction function is of the same form as the Taylor rule (1993, 1996), except that it also depends on the asset price variables. The real interest rate (i_t-π_t) is increasing in the excess of current inflation over the inflation target, in current output gap and in the current deviation of asset prices from their trend. The instrument depends on current inflation because current inflation together with the output gap and the asset prices deviations help predict future inflation. Thus, asset prices enter the rule because of their impact on the future path of output (since x_t is useful in forecasting future inflation).

Note that the instrument rule can also be written as a function of the predetermined one-period inflation expectations, $\pi_{t+1|t}$, rather than in terms of current inflation [using (4.5)]:

$$i_t = \pi_{t+1|t} - \alpha \cdot x_t + b_0 \cdot (\pi_{t+1|t} - \pi^*) - b_0 \cdot \alpha \cdot x_t + b_1 \cdot x_t + b_2 \cdot dsp_t + b_3 \cdot dhp_t \Leftrightarrow$$

$$\Leftrightarrow i_t = \pi_{t+1|t} + b_0 \cdot (\pi_{t+1|t} - \pi^*) + b_4 \cdot x_t + b_2 \cdot dsp_t + b_3 \cdot dhp_t \quad (4.19)$$

where $b_4 = \dfrac{\beta_0}{\beta_1 + \beta_2\gamma_2 + \beta_3\rho_2}$

With the reaction function (4.18) the two-period inflation forecast will equal the inflation target, for all values of π_t, x_t, dsp_t and dhp_t. If the inflation forecast exceeds the inflation target, the interest rate should be increased and vice-versa, until the inflation forecast equals the target. If the current inflation increases, the output gap widens or the asset price deviations increase, the interest rate should be increased, in order to keep the inflation forecast equal to the inflation target. In equilibrium, actual inflation in year t+2 will be:

$$\pi_{t+2} = a_o \cdot \pi_t + a_1 \cdot x_t - a_2 \cdot it + a_3 \cdot dspt + a_4 \cdot dhp_t + [\alpha \cdot (\beta_2\gamma_0\varepsilon_{t+1} + \beta_3\rho_0\varepsilon_{t+1} + \beta_2\theta_{t+1} + \beta_3 v_{t+1} + \mu_{t+1}) + + \varepsilon_{t+1} + \varepsilon_{t+2}]$$

$$= \pi_{t+2|t} + [\alpha \cdot (\beta_2\gamma_0\varepsilon_{t+1} + \beta_3\rho_0\varepsilon_{t+1} + \beta_2\theta_{t+1} + \beta_3 v_{t+1} + \mu_{t+1}) + \varepsilon_{t+1} + \varepsilon_{t+2}]$$

$$= \pi^* + [\alpha \cdot (\beta_2\gamma_0\varepsilon_{t+1} + \beta_3\rho_0\varepsilon_{t+1} + \beta_2\theta_{t+1} + \beta_3 v_{t+1} + \mu_{t+1}) + \varepsilon_{t+1} + \varepsilon_{t+2}]$$

$$= \pi^* + u_{t+1} \quad (4.20)$$

So, actual inflation in equilibrium will deviate from the inflation target and the two-period inflation forecast by the forecast error due to the disturbances that occur within the control lag, after the central bank has set the instrument.

4.2 Calibration and model dynamics

To illustrate the model's properties in an *ad hoc* and simple manner, we calibrate and submit it to various types of temporary shocks. Table C1 in Appendix C presents the coefficients used in our

[1] This is of course a straightforward application of standard certainty-equivalence in linear-quadratic models (Svensson, 1997, p. 1118).

simulations[1]. We consider also that the monetary authorities have an inflation target (π^*) of 2% per year and that the economy is initially in a steady state. We compare our model with a simple model without asset prices influence on aggregate demand ($\beta_2 = \beta_3 = 0$) and therefore on the instrument rule[2].

There are four types of shocks that can hit the economy each period: a supply / inflation shock (ε_{t+1}), a demand / output gap shock (μ_{t+1}), a share prices shock (θ_{t+1}) and a housing prices shock (v_{t+1}). These last two shocks don't affect the path of all the other variables when $\beta_2 = \beta_3 = 0$. We consider also the possibility of an interest rate shock[3]. In Appendix C we show, respectively, the responses of inflation, output gap, asset prices deviations and the interest rate in the wake of the various types of temporary positive shocks[4].

Figure C2 shows the responses of inflation, the output gap and the asset prices to a temporary positive 25 basis points shock in the interest rate. By construction, after an interest rate shock (Panel A), there is no immediate response of inflation. The output gap responds immediately and from t=1 onwards more quickly than inflation. After three periods the effects of the disturbance are eliminated. The interest rate shock opens up negative gaps in asset prices that are closed also after three periods. The model without asset prices influence on the policy instrument yields smaller volatility in the various responses. Specifically, the interest rate response in the extended model is always more volatile when compared with the simple model. The smoother path of the interest rate is due to the fact that the monetary authorities don't have to be concerned with the potential effects of asset prices on the economy, thus the interest rate doesn't have to decrease as much as in the extended model to obviate the decreasing asset prices. Panel B presents the results of an inflation shock in moment t=1 (a 0,25 percentage points shock). The subsequent increase in the interest rate to fight inflation (see Panel F) opens up significant negative gaps in output and in the asset prices, which are diluted after four periods. With the exception of the asset prices, we observe a greater volatility in the extended model. As we see in Panel C, after an output gap shock in moment t=1 (a 0,25 percentage points shock), the central bank must allow the positive output gap transformation into a negative one in order to fight the inflationary impulse. Both models display similar responses for these two variables and imply a large persistence for the asset prices responses. Panels D and E present also, respectively, the effects of share and housing prices shocks (a one percentage point shock), with housing prices, by construction, having stronger effects. Concluding, only in the case of an output gap shock does the extended model seem to imply a significant lower variability of the interest rate and the asset prices. We think this preliminary conclusion deserves further attention in future research[5].

The next steps in this model would be to introduce output stabilisation and interest rate smoothing in the central bank's loss function and measure the losses associated with the different scenarios as well as the implications for the inflation/output variability trade-off. In the presented graphs we observed large fluctuations in the interest rate which goes against the central bank's desire to abstain from disrupt the financial markets.

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[1] We use benchmark values for the calibration. The presented values result from various papers (e.g., Ludvigson and Steindel [1999], Estrella and Fuhrer [2002], Alexandre and Bação [2003] and Djoudad and Gauthier [2003]) and from our own previous estimations. We notice that the basic nature of our results does not hinge on any particular calibration of the model.

[2] For the parameter settings, the optimal response coefficients take on values that are considerably higher in magnitude than in Taylor (1993). Hence our baseline calibration exercise confirms a common result in the literature that the optimal policy rule calls for a stronger response to inflation and the output gap than is recommended by "Taylor-type" rules estimated for macroeconomic data (this point was first made by Ball [1999]).

[3] The interest rate disturbance is not part of the model. However, we can consider an artificially interest rate shock by assuming that the interest rate is unexpectedly raised by 25 basis points for one period.

[4] Notice that this is an annual discrete time model and the magnitude of the deviations is dependent upon the model's calibration, nevertheless, the model's general dynamics is independent of that.

[5] Albeit here we are in a more simple framework, this conclusion seems to be in line with Alexandre and Bação (2003, p. 25): "*(...) the desirability of reacting to asset prices as a mean to stabilise the economy depends crucially on the persistence and relative importance of the different shocks that hit the economy*".

5. Conclusions

This paper tried to analyse the reaction function of a "fictitious" European central bank that incorporated also the potential effects of asset prices developments in economic activity. The estimated Taylor-type rules seem to describe very well the past behaviour of interest rates in the euro-area. Nevertheless, in that historical perspective we found little support for the inclusion of asset prices in the monetary authority's reaction function. That is, the data suggest that the European monetary authorities has had no intentions, beyond possible some rhetoric, to actually orchestrate a rapid correction of the asset markets overvaluation because of their potential destabilising effects on the economy. Note that, an important caveat to the presented exercise is that the present analysis has been done *ex-post* and it refers in large part to a period where the ECB had not been established yet. We think that, as more data for the euro-area becomes available, it will be interesting to see whether there is a change of attitude on the part of the ECB. Also, the estimation of the rules doesn't take into account that when central banks have to make their decisions the information on some variables is not available in real time.

After the definition of the optimal reaction function for the central bank in the context of a simple model, we saw that under inflation targeting the target rule is very simple. Any shock causing a deviation between the conditional inflation forecast and the inflation target should then be met by an instrument adjustment that eliminates the deviation. The calibration of the model and its sensivity to shocks yield the result that, apart from demand shocks, the rule incorporating asset prices implies more volatility than a simple rule. The effect of the disturbances dies out after some periods, but the observed volatility in the variables is greater in the extended model. After this exercise we think that further research should enrich the monetary authorities loss function with output and interest rate stabilization, improve the calibration of the model and try alternative measures of asset markets overvaluation. In the present context of asset markets volatility, we are sure that the issues tackled in this paper will remain in the agenda for both monetary economists and central bankers for many years to come.

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Appendix A

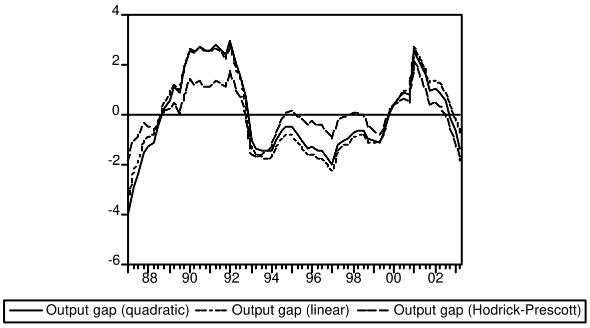


Figure 1: Output gap in the euro-area

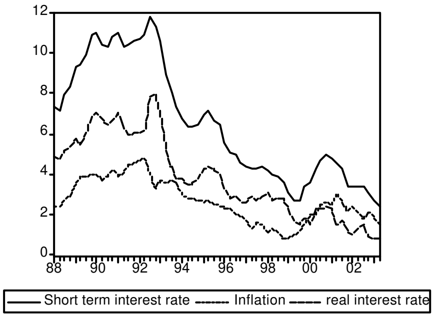


Figure 2: Inflation and the short-term interest rate in the euro-area

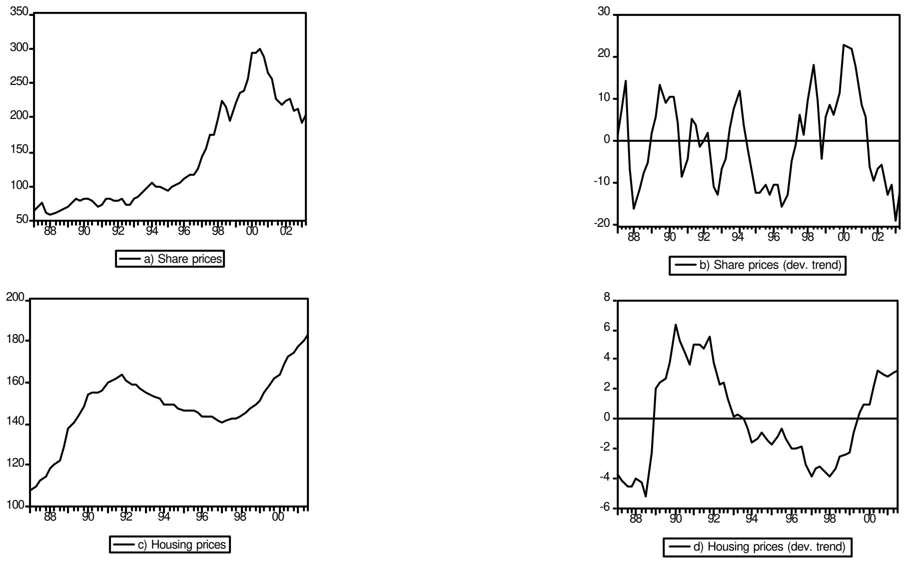


Figure 3: Share prices and Housing prices in the euro-area

APPENDIX B

Table B1: Phillips curve estimation [equation (3.3)]

$\pi_t = \alpha_{01} \cdot \pi_{t-1} + \alpha_{02} \cdot \pi_{t-2} + \alpha_{03} \cdot \pi_{t-3} + (1- \alpha_{01} - \alpha_{01} - \alpha_{01}) \cdot \pi_{t-4} + \alpha_1 \cdot x_t + \varepsilon_t$

Variable	Estimated coefficient	P-value
π_{t-1}	0,922	0,00
π_{t-2}	0,020	0,85
π_{t-3}	0,536	0,00
x_t	0,129	0,00
J-stat	5,45	0,61
Adjusted R^2	0,91	

Note: The equation is estimated by GMM using as instruments past values of inflation (4 lags), the output gap (4 lags), and the interest rate (2 lags). The coefficients on the lagged inflation rates are constrained to sum to one.

Table B2: IS curve estimation [equation (3.5)]

$x_t = c_x + \beta_0 \cdot x_{t-1} - \beta_1 \cdot (i_t - \pi_t) + \beta_2 \cdot dsp_t + \beta_3 \cdot dhp_t + \mu_t$ (3.5A)

Variable	Estimated coefficient	P-value
c_x	- 0,232	0,05
x_{t-1}	0,519	0,00
$(i_t - \pi_t)$	0,088	0,01
dsp_t	0,011	0,00
dhp_t	0,057	0,00
J-stat	6,49	0,89
Adjusted R^2	0,67	

Note: The equation is estimated by GMM using as instruments past values of inflation (2 lags), the output gap (4 lags), the interest rate (4 lags), the share prices deviations (4 lags) and the housing prices deviations (2 lags).

Alternative specification:

$x_t = c_x + \beta_0 \cdot x_{t-1} - \beta_1 \cdot (i_t - \pi_t) + \beta_2 \cdot dsp_t + \mu_t$ (3.5B)

Variable	Estimated coefficient	P-value
c_x	- 0,288	0,00
x_{t-1}	0,775	0,00
$(i_t - \pi_t)$	0,086	0,00
dsp_t	0,016	0,00
J-stat	4,93	0,94
Adjusted R^2	0,75	

Note: The equation is estimated by GMM using as instruments past values of inflation (2 lags), the output gap (4 lags), the interest rate (4 lags) and the share prices deviations (4 lags).

Table B3: Taylor rule estimations [equation (3.10)]

$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\ c_i + \lambda_0 \cdot \pi_t + \lambda_1 \cdot x_t + \lambda_2 \cdot dsp_t + \lambda_3 \cdot dhp_t\ ] + \eta_t$ (3.10A)

Variable	Estimated coefficient	P-value
i_{t-1}	0,663	0,00
c_I	1,657	0,00
π_t	1,801	0,03
x_t	1,211	0,01
dsp_t	0,022	0,36
dhp_t	0,102	0,40
J-stat	5,88	0,75
Adjusted R^2	0,96	

Note: The equation is estimated by GMM using as instruments past values of inflation (4 lags), the output gap (2 lags), the interest rate (4 lags) and the share prices deviations (4 lags).

Alternative specifications:

$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\ c_i + \lambda_0 \cdot \pi_t + \lambda_1 \cdot x_t + \lambda_2 \cdot dsp_t\ ] + \eta_t$ (3.10B)

Variable	Estimated coefficient	P-value
i_{t-1}	0,832	0,00
c_I	1,050	0,03
π_t	1,870	0,00
x_t	2,331	0,00
dsp_t	0,014	0,61
J-stat	5,49	0,86
Adjusted R^2	0,98	

Note: The equation is estimated by GMM using as instruments past values of inflation (6 lags), the output gap (2 lags), the interest rate (4 lags) and the share prices deviations (2 lags).

$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\ c_i + \lambda_0 \cdot \pi_t + \lambda_1 \cdot x_t\ ] + \eta_t$ (3.10C)

Variable	Estimated coefficient	P-value
i_{t-1}	0,777	0,00
c_I	1,231	0,00
π_t	1,888	0,00
x_t	1,913	0,00
J-stat	3,89	0,92
Adjusted R^2	0,97	

Note: The equation is estimated by GMM using as instruments past values of inflation (8 lags), the output gap (2 lags) and the interest rate (4 lags).

$i_t = \rho \cdot i_{t-1} + (1 - \rho) \cdot [\ c_i + \lambda_0 \cdot \pi_t\ ] + \eta_t$ (3.10D)

Variable	Estimated coefficient	P-value
i_{t-1}	0,751	0,00
c_I	- 0,353	0,47
π_t	2,795	0,00
J-stat	5,97	0,31
Adjusted R^2	0,96	

Note: The equation is estimated by GMM using as instruments past values of inflation (2 lags), the interest rate (2 lags) and the share prices deviations (2 lags).

APPENDIX C

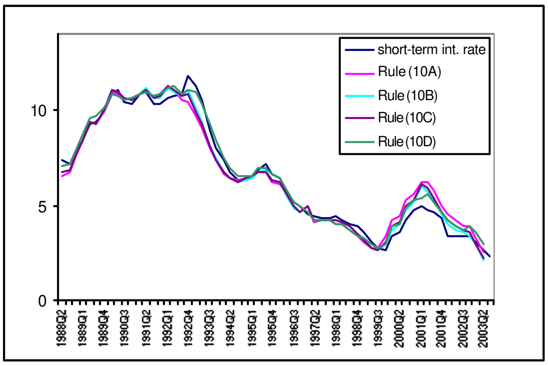
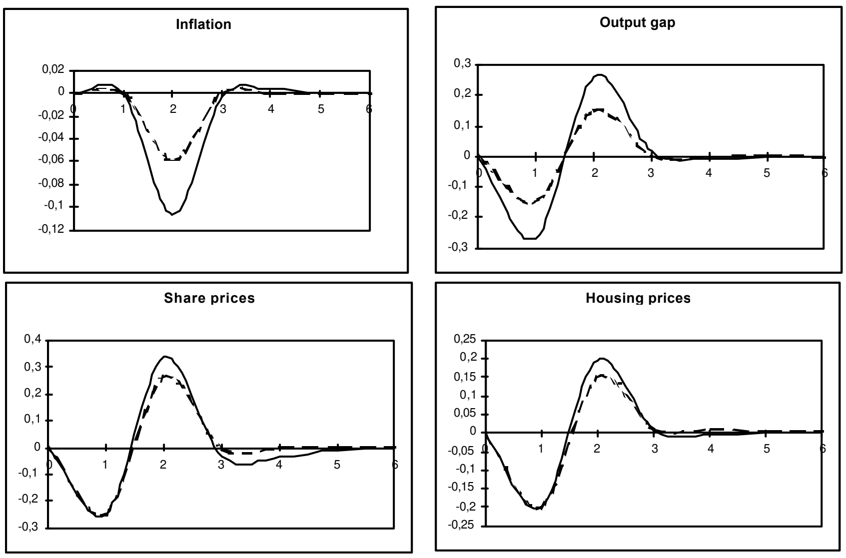


Figure C1: Short-term interest rate and forecasted interest rates (4 rules)

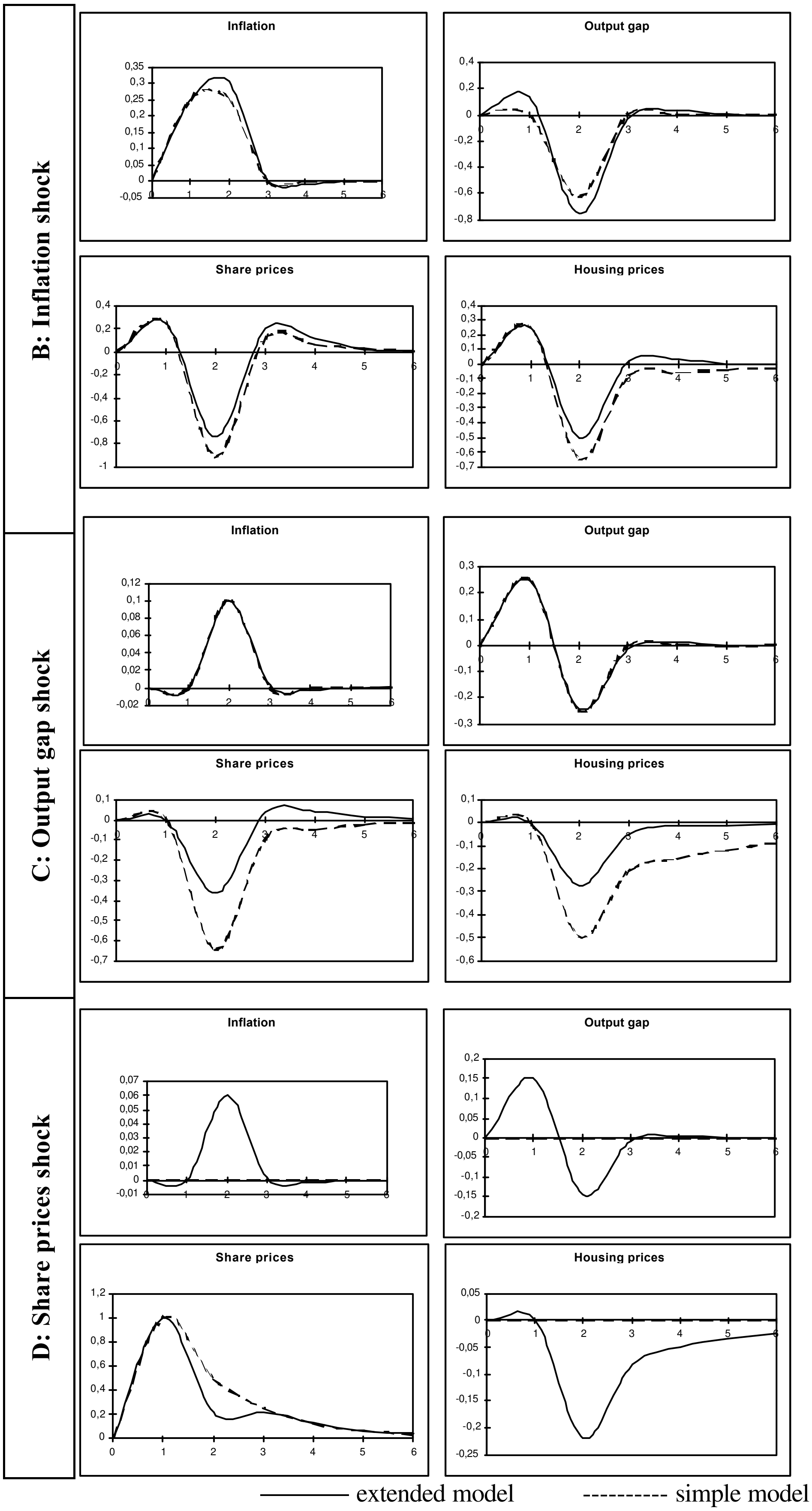
Table C1: Parameter values

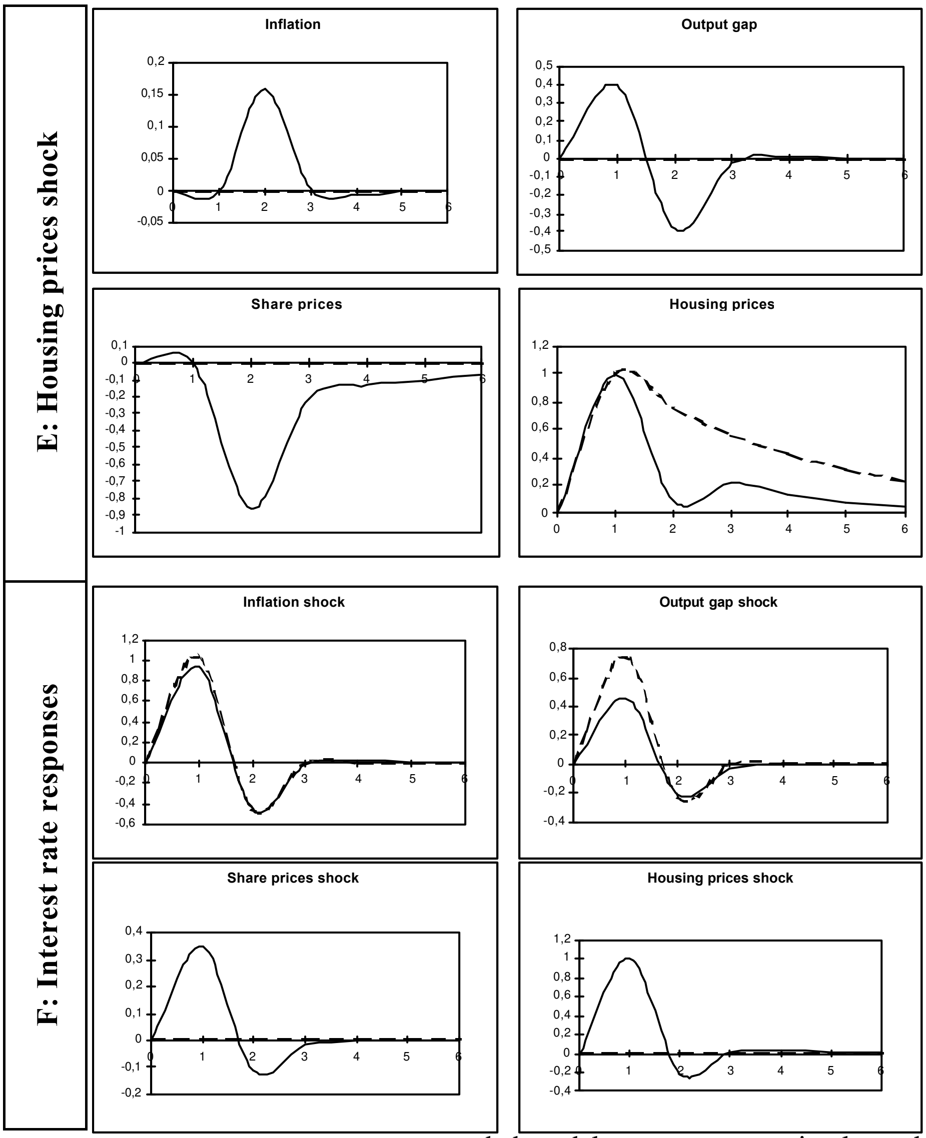
Coefficient	Values	
	Extended model	Simple model
α	0,40	0,40
β_1	0,60	0,60
β_2	0,15	0
β_3	0,40	0
β_4	0,85	0,85
γ_0	1	1
γ_1	0,50	0,50
γ_2	1	1
ρ_0	1	1
ρ_1	0,75	0,75
ρ_2	0,80	0,80

A: Interest rate shock



——— extended model ---------- simple model


B: Inflation shock
Inflation
Output gap
Share prices
Housing prices
C: Output gap shock
Inflation
Output gap
Share prices
Housing prices
D: Share prices shock
Inflation
Output gap
Share prices
Housing prices
extended model
simple model



——— extended model ---------- simple model

Figure C2: Responses in the two models