A structural model for the analysis of the impact of monetary policy on output and inflation

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Introduction

Monetary policy plays an important role in stabilising economic fluctuations and, especially, in controlling the rate of inflation in an economy. This paper analyses the monetary transmission mechanism in Spain by carrying out a series of simulation exercises using a macroeconomic model with a high degree of aggregation. These exercises serve to compare the behaviour of the rate of inflation and the rate of growth of GDP in the base scenario with their behaviour in various alternative monetary policy settings.

Using these simulation exercises, this study evaluates the response of inflation and the rate of growth, once all other endogenous variables (the exchange rate, the real long-term interest rate, the demand for real balances, etc.) have been appropriately adjusted. In the macroeconomic model used, no explicit distinction is made between the various components of expenditure or income. A high degree of aggregation makes it difficult to perform a detailed analysis of monetary transmission channels, but it does offer answers to some major questions that are less sensitive to alterations in the model's specifications; in particular, the response of demand to variations in the interest rate, the importance of competitiveness in monetary transmission, and the speed with which expectations are adjusted.

The simulation model's specifications take into account the new Spanish monetary policy regime adopted in the setting of European economic integration. Institutionally, that change is manifest in a stronger gearing of monetary policy towards price stability. In this context, monetary policy is understood to mean the determination of a short-term nominal interest rate consistent with the central bank's inflation target. As for the way financial markets operate, the gradual opening up of the Spanish economy and its incorporation into international markets mean that economic agents expectations play an important part in determining nominal and real variables in the economy.

The rest of the paper is structured as follows. Section 1 summarises the most salient aspects of the monetary transmission mechanism and the development of the concrete model. Section 2 presents the results of the simulations of various disinflationary strategies. The final section summarises the main conclusions.

1. Monetary policy transmission: an aggregate supply and demand model

Monetary policy affects inflation, the unemployment rate or the rate of growth of an economy by altering aggregate supply and demand. The set of channels influencing supply and demand is what is known as the monetary transmission mechanism. Before describing its main features, it is worth making two specific points. First, it is necessary to specify the environment in which monetary policy operates. Generally speaking, monetary policy has no major real impact in an

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economy in which all markets are in equilibrium and economic agents act rationally, given the immediate response of prices to excess demand. For that reason, we shall focus on the effects of monetary policy, in the first instance, on nominal variables. If, additionally, some kind of nominal rigidity exists, monetary policy will, at least temporarily, affect real magnitudes in the economy.[2]

Secondly, the relative speed with which monetary measures have an impact on prices and quantities determines the cost associated with each monetary policy strategy and hence its viability. Nevertheless, in this paper we will not study the determinants of the speed of responses to monetary impulses. The main point of reference in this regard is built into the dynamic structure of the empirical model, which conditions the results of the simulations.

The nature of the transmission channels depends on the way monetary policy is formulated. Thus, a central bank may employ strategies based on targets for a particular monetary aggregate or else it may choose to determine a path for short-term interest rates consistent with its goal of price stability or stability for any other nominal variable (the exchange rate, for instance).[3] As is generally recognised, the type of uncertainty prevailing in an economy affects optimal selection of one or other monetary strategy (see Poole (1970)). Nevertheless, the instability of the demand for monetary aggregates weakened their reputation as a reliable guide to the stance of monetary policy in many countries and relegated them to the role of important indicators only. Two reasons have been put forward in the literature to explain the short-term instability of the demand for money (Taylor (1995)). One is the development of financial markets and their deregulation. The other is the gradual opening up of economies and the consequent impact of new variables on the relationship between monetary aggregates and the expenditure decisions taken by economic agents. The following sections deal with the transmission mechanism under each of these monetary strategies.

1.1 The transmission mechanism based on a monetary aggregate

Table 1 depicts the main effects of monetary policy on the (cyclical component of) GDP and on inflation, via the various markets in an economy. Most of these effects are independent of whether monetary policy is defined in terms of a monetary aggregate or a specific interest rate, but let us assume, for the time being, that the monetary measure is understood to be the establishment of a monetary aggregate target (M_t).[4] In an economy in which the existence of some market imperfection generates insufficient demand, the effectiveness of monetary policy depends, fundamentally, on its impact on relative prices: the interest rate, the exchange rate, and real wages. Changes in the real interest rate allow alterations in the structure of demand over time, causing, in the event of a monetary contraction, a "delay" in certain consumption and investment decisions. Apart from this intertemporal substitution effect, interest rates can also have an impact on demand via their income and wealth effects. Likewise, the fact that domestically produced goods become relatively more expensive implies that companies lose market share through lower external demand. Aggregate supply (prices and wages) will also be affected by the cheapening of imported goods and by economic agents' expectations.

The most conventional monetary policy channel is the one that operates via the interest rate (*liquidity effect*). Restrictive monetary policy produces a temporary increase in the short-term nominal interest rate (usually its impact in the interbank market is immediate). In their calculations

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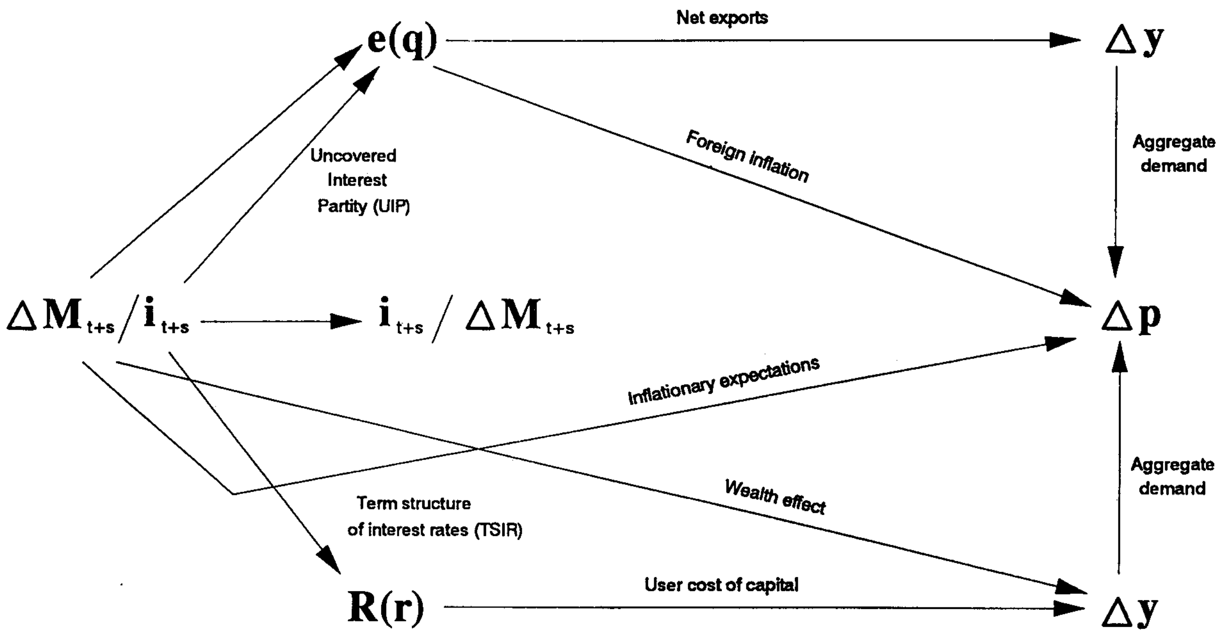
2 It is assumed that productive capacity is fixed and that it does not respond to changes in the interest rate. This being so, monetary policy has no impact on potential growth. The presence of hysteresis could generate long-term effects that are not dealt with in this paper.

3 None of these frameworks should be ascribed to a specific set of monetary policy instruments.

4 Economic agents take this value as the basis for their expectations of the future behaviour of the monetary authorities. This objective could also be defined in terms of rates of growth of the money stock.

of the user cost of capital for long-term expenditure decisions, companies and consumers use some long-term interest rate or the bank lending rate as a benchmark. The mechanism by which short-term rate signals affect the long-term rate is complex, since it is conditioned by the nature and degree of competitiveness of the financial system, the structure of short and long-term loans in corporate liabilities, and by financial markets' own perception of how temporary the change in the interest rate is likely to be. Furthermore, monetary policy can alter the relative risk premia attached to certain assets. However, monetary impulse transmission through the whole structure of assets takes time, even when the various interest rates tend to move together, and does not always proceed in a linear way.

Table 1
Money supply, output and inflation



Changes in the money supply also affect the exchange rate. How this effect operates depends notably on the degree of openness of the economy and, in particular, on the degree of international financial integration. If capital mobility is very high, the only sustainable exchange rate will be that which, risk premia aside, guarantees equality in the returns expected on domestic and similar foreign assets, when compared using the same currency. "Uncovered interest parity" is one way to represent this condition, so that the nominal interest rate differs from the expected rate depending on expectations as to the future behaviour of the interest rate differential and risk premium. Variations in a monetary aggregate affect nominal parity via three channels. First, the relative level of domestic money supply affects exchange rate projections. Secondly, the interest rate differential caused by temporary changes in the supply of real balances determines the rate of depreciation. Finally, the way monetary policy is conducted is one of the factors influencing the risk premium that investors require as an incentive to invest in domestic assets.

Generally speaking, restrictive monetary policy temporarily increases the interest rate differential, which contributes to an appreciation of the currency to an extent that creates expectations of an upcoming depreciation.[5] In addition, such a policy may lead to a reduction in the

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5 As a result of which the exchange rate would overreact and thereby attain a higher level than that pertaining after a period of depreciation.

exchange rate risk for foreign investors that helps capital inflows. Appreciation sets in motion two types of effects that help control inflation. On the one hand, the loss of competitiveness leads to a decline in net exports, and to a drop in demand pressure. On the other, the relative cheapening of imported goods reduces imported inflation and tempers wage demands.

Changes in the money supply also have an effect on aggregate supply and demand that does not operate exclusively via relative prices. Monetary policy affects the net wealth of the private sector because of its impact on the level of net assets held by that sector and on their market value via the relative price structure of financial and real assets. This *wealth effect* is the main channel in monetarist models (Metzler (1995)). There is also a direct relationship between the volume of credit to the private sector and the level of expenditure of companies and consumers. In the event of some kind of market imperfection due to asymmetric information, the marginal costs of the different forms of corporate (and consumer) financing are not equal. Specifically, a monetary policy that causes increases in the interest rate also raises the relative cost of external financing for less financially solvent firms. The *credit channel* is manifest in the restriction on the supply of bank loans associated with monetary contraction, and in the difficulty in gaining access to other external funds, both of which possibly reduce private expenditure.[6]

Finally, monetary policy may have a direct impact on inflation if the central bank is capable of influencing economic agents expectations. In the case of a restrictive monetary policy, this *expectations effect* impacts on aggregate supply, through a dampening of wage demands and of the growth in nominal costs; on the demand side, it reinforces the increase in real interest rates associated with monetary contraction. How long this increase lasts depends on how stable the drop in inflation is. As inflation falls, real balances recover with the nominal interest rate dropping in line with the new rate of inflation.

1.2 The transmission mechanism based on interest rates

The above section described the main channels through which monetary impulses are transmitted to the real economy and affect inflation. Monetary policy in Spain is more geared to a framework in which the central bank steers the current nominal interest rate (i) in accordance with its inflation target, making use of the various instruments at its disposal to make sure that the rate stays within the desired bounds.[7] In this case, i becomes the exogenous monetary policy variable and M endogenous. For a given interest rate value, the monetary transmission channels operate more or less as described in the previous section, as Table 1 shows. Nevertheless, this definition of monetary policy gives rise to at least three particularities which are worth noting.

The first refers to the type of policies that can be applied to lower inflation in an economy with higher initial levels of inflation and nominal interest rates than the countries in its immediate environment (with which it is financially integrated). Transmission of a permanent reduction in the rate of growth of the money supply operates via an increase in interest rates that may ultimately fall when inflation declines and the supply of real balances recovers. For that reason, the equivalent of a *permanent reduction* in the rate of growth of the money supply is a *temporary*, not a permanent, increase in interest rates.

This observation leads us to a second particularity in the interest rate transmission mechanism. In financially integrated economies, capital mobility tends, in the medium and long term, to make real interest rates homogeneous. Thus, in that time frame, the reduction in the inflation

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6 Bernanke and Gertler (1995) offer empirical evidence and theoretical arguments in support of the existence of this effect. Also Hernando (1997) analyses the importance of the credit channel in monetary policy transmission in Spain.

7 See, Bank of Spain (1994):"Objetivos e instrumentalización de la política monetaria en 1995" in Boletín Económico, December.

differential is associated with a corresponding decline in the nominal interest rate differential.[8] When the central bank uses the money supply, this is achieved "automatically" if monetary contraction succeeds in lowering inflation. When the monetary authorities use the interest rate as an instrument, they can apply a policy emulating the effect of a permanent drop in the money supply by temporarily increasing the interest rate (vis-à-vis a starting point) and then reducing it later in line with the international rate. However, in theory, the possibility of an immediate and permanent reduction in the nominal interest rate, as an anti-inflationary strategy, cannot be discarded although in practice, as we argue in the following section, it turns out to be inviable.

The third main characteristic associated with a framework in which the monetary authorities control the interest rate is the difficulty of correctly determining the value of the nominal variables. When the money supply is exogenously determined, it constitutes the nominal anchor for the economy. Nominal indeterminacy with an interest rates rule appears in a wide range of models. In a closed economy with fixed prices, the price level will be determined by past history. However, when prices are fixed rationally, Sargent and Wallace (1975) demonstrated that the price level is indeterminate.

In an open economy, in which the exchange rate is determined according to rational expectations, the absence of a nominal anchor gives rise to a basic lack of determination of the exchange rate and of the other nominal variables in the economy. The main effect of this lack of determination, both theoretically and empirically, is the difficulty of correctly evaluating the cost of alternative anti-inflationary strategies. The following sections will address this point in greater detail, once the economic model has been specified.

1.3 A macroeconomic aggregate supply and demand model

We consider an open economy model, with a given level of external output and international trade.[9] The government determines fiscal policy exogenously.[10] There are four financial assets: money, short-term domestic bonds, long-term domestic bonds, and foreign assets, which means that three financial market equilibrium conditions are required to determine the relative prices of those assets. The short-term interest rate is established by the monetary authorities. The model can be expressed as a function of the following set of equations showing the behaviour of aggregate demand[11] and supply:

$$y_t - y_t^p = \alpha_{10} + \alpha_{11} r_t + \alpha_{12} q_t + \alpha_{13} g_t + \alpha_{14} a_t + \alpha_{15} y_t^* + \varepsilon_{yt} \qquad \text{IS (1)}$$

$$m_t - p_t = \alpha_{20} + \alpha_{21} R_t + \alpha_{22} i_t + \alpha_{23} y_t + \varepsilon_{mt} \qquad \text{LM (2)}$$

$$r_t \equiv R_t - E\left[\Delta p_{t+1/t}\right] \qquad \text{RIR (3)}$$

$$R_t = (1-b) i_t + bE\left[R_{t+1/t}\right] + \varepsilon_{it} \qquad \text{TSIR (4)}$$

$$i_t = i_t^* + E\left(e_{t+1/t}\right) - e_t + \varepsilon_{et} \qquad \text{UIP (5)}$$

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8 The real interest rate is determined at the international level. In a closed economy, it also depends on preferences and technology, but it is possible to alter it in the short term.

9 See Dornbusch (1976), Duguay (1994), Buiter and Miller (1981) and Taylor (1995).

10 To simplify the model, one fiscal policy indicator is defined and the public sector budget restriction is not explicitly included. The interaction between monetary policy and fiscal policy is discussed, for example, in Canzoneri and Diba (1996) or Marín and Peñalosa (1997).

11 The variables in equation (1) should be understood as deviations from their long-term level or trend.

$$\Delta P_t^d = \alpha_{60} + \alpha_{61} E\left[\Delta p_t^d\right] + a_{62} E\left[\Delta e_t + \Delta p_t^*\right] + \alpha_{63}\delta\left(y_t - y_t^p\right) + \varepsilon_{pt} \qquad \text{AS (6)}$$

$$\Delta p_t = \alpha_{70} + \alpha_{71}\mu_t + \alpha_{72}\Delta p_t^d + \alpha_{73}\left(\Delta p_t^* + \Delta e_t\right) + \varepsilon_{pt} \qquad \text{CPI (7)}$$

The endogenous variables are: cyclical output[12] ($y_t - y_t^p$), the change in domestic prices measured by the GDP deflator (Δp_t^d), the money stock in real terms ($m_t - p_t$), the long-term nominal interest rate (R_t), the real interest rate (r_t), the exchange rate (e_t), and the inflation rate (Δp_t) as measured by changes in the CPI. The exogenous variables are: potential output (y_t^p), the fiscal policy indicator (g_t), world income (y_t*), the short-term interest rate (i_t), external inflation (Δp_t*) and the share of imports in income (μ_t). The exchange rate is defined as the value of the foreign currency in local currency terms, and q_t is the real exchange rate. The definition of wealth (a_t) only includes real balances for lack of other quarterly asset figures. All the variables are expressed as logarithms, except the interest rates. We assume that the expectations in the financial equations ((3), (4) and (5)) are fully anticipated by economic agents. Conversely, the supply-side rigidities (equation (6)) imply that expectations are formed by past values of the explanatory variables. Before describing the estimations of the equations in the model, we shall briefly explain the specifications chosen for each of them.

Equation (1) represents aggregate demand as a function of the long-term real interest rate, the real exchange rate, a fiscal indicator, the level of wealth, and world income. Thus, changes in relative prices operate through three channels in aggregate demand: the substitution effect between consumption and saving and between domestic and foreign goods; the negative income effect for economic agents who are net creditors; and, finally, a wealth effect which increases the value of residents' assets in the event of declines in the interest rate or depreciations of the local currency.

The econometric evidence for Spain reveals a negative effect of real interest rates on the components of final demand for goods and services. That is the finding of estimations made using annual investment functions (Andrés et al. (1992)) and consumption functions (Estrada (1993)). Similar evidence is obtained using quarterly data on the demand for durable and nondurable consumer goods and on the demand for domestic housing and private sector productive investment (see Estrada et al. (1997)). The results of these calculations reveal a moderate impact of the real interest rate (compared to the effect of other variables) appearing after a certain time lag. This significant impact of the real interest rate on consumption and investment is not to be found in the same degree of intensity on the more aggregate magnitudes: output and inflation. The available evidence suggests that short-term interest rates are much less of a guide to the level of economic activity and price behaviour than changes in the money stock (Alvarez et al. (1995)). Our model reflects the direct impact of the money stock by including the stock of liquid assets held by the public (ALP) in the determinants of aggregate demand.[13]

The real exchange rate is an important variable in analysing the monetary transmission mechanism. The gradual opening up of the Spanish economy has increased the possibilities of substituting external demand for domestic demand depending on how our prices behave vis-à-vis

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[12] For which the rate of growth of GDP would be another approximation. In this case, however, the model is not neutral in the traditional sense because monetary policy affects the level of GDP in the long term as well as its composition. Nevertheless, after the adjustments in the nominal variables, the economy recovers the rate of growth considered to be that pertaining to a steady state.

[13] However, this inclusion can be interpreted in two different, albeit not mutually exclusive, ways. We might be dealing with a credit channel in monetary transmission or else with a wealth effect reflecting the influence of changes in monetary policy on the relative prices of the set of assets.

those abroad.[14] Moreover, in an economy that is fully integrated with the outside world, the possibilities of influencing aggregate demand in the short term are not just limited to the real (after-tax) interest rate: they include the exchange rate as well. In the long term, nevertheless, the real interest rate will be determined by that prevailing abroad and the real exchange rate will be determined by structural parameters in the economy.

The other two variables determining aggregate demand are external output and the government's fiscal position. The variations in external output may be reflected in total demand via declines or increases in exports. At the same time, it is to be expected that the public deficit has a direct impact on aggregate demand, quite apart from indirect effects via the interest rate[15] and competitiveness.

As for the other equations, the demand for real balances (equation (2)) depends on the level of income and the two types of nominal interest rates: short and long-term. Equation (3) defines the real interest rate. Equations (4) and (5) complete the financial structure of the model and relate the interest rate controlled by the monetary authorities to those interest rates variables and exchange rates that influence economic agents' expenditure decisions.

Variations in the intervention interest rate are initially transmitted to the money market and from there to the equilibrium rate in the lending and deposit markets. According to Ayuso et al. (1994), the interbank rate in Spain responds fully and relatively swiftly to shifts in the intervention rate. That finding justifies using a short-term interbank rate as an exogenous rate.[16] The transmission of monetary policy signals to the rates that determine spending by economic agents will depend on the structure of the financial sector. Among other determining factors, of particular importance are the liquidity and degree of maturity of the different assets and the degree of competition among financial institutions. The fact that much of the spending by economic agents in Spain depends on external funding and that the composition of bank assets is sensitive to monetary policy could lead one to consider the lending rate of financial institutions as a relevant interest rate in expenditure equations. Nevertheless, in this paper we have opted to take the long-term debt rate as an indicator of the cost of capital in consumption and investment decisions, owing to the similar influence that both variables exert in the demand equation. The term structure of interest rates (equation (4)) is represented in the model as an arbitrage condition between short and long-term nominal interest rates: the long-term interest rate being the present value of expected short-term interest rates.

Our model uses the uncovered parity of interest rates (equation (5)) to reflect the way monetary policy affects the exchange rate. This implies that perfect capital mobility is the best way to represent the degree of financial integration of our economy with the outside world. The error term in this relationship allows for possible temporary shifts in the exchange rate due to the emergence of risk premia or speculative runs in exchange markets that are unrelated to macroeconomic variables.

We shall assume that the financial sector makes rational predictions of future changes in monetary policy. The developments expected in short-term interest rates determine both the long-term interest rate – through the term structure of interest rates – and the behaviour of the exchange rate through uncovered interest rate parity. The inclusion of this arbitrage condition has some additional advantages. First, it allows us to attribute a predominant role in monetary transmission to economic agents' expectations regarding future monetary policy. The second advantage is that this

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[14] This appears to be an important variable in the Spanish economy, since the effective exchange rate is one of the main determinants of net exports (see, for instance, Buisán and Gordo (1993) and Bajo and Montero (1995)).

[15] In Spain, the evidence in this regard is not conclusive. Thus, whereas Ballabriga and Sebastián (1993) do not find a causal relationship between interest rates and the deficit, Raymond and Palet (1990) do report a direct effect.

[16] For the purposes of this paper, we prefer this to the alternative of endogenising the interest rate as a function of the reaction of the monetary authorities (see, for instance, the estimations by Escrivá and Santos (1991)).

obviates the need for a more complex model, which would have to incorporate other assets and a study of the productive structure of the financial sector.

Aggregate supply in the economy is represented by equations (6) and (7). Equation (6) is a Phillips curve which relates domestic inflation to inflationary expectations and demand pressure. Inflationary expectations are represented in the model as a function of past price variations, for both domestic and foreign goods. Inclusion in the equation of a variable reflecting the business cycle situation of the economy makes it possible to measure the response of prices to excess supply or demand in goods markets. Equation (7) is a dynamic version of the consumer price index definition. In the long-term solution of (6) and (7), nominal homogeneity is assumed.[17] The current version of the model does not include possible supply shifts, such as variations in raw materials prices, changes in indirect taxation, or deviations in the relationship between wages and productivity. For the sake of simplicity, we have also eschewed incorporating a set of price and wage equations, even though this means sacrificing data regarding determinants of the degree of nominal rigidity influencing monetary transmission.

2. Monetary policy simulations

2.1 The estimated model

The estimated long-term version of the model is presented in Table 2, and the short-term estimations are to be found in the Appendix A. The explanatory variables were selected on the basis of lags in those same variables and of contemporary and past values of the other endogenous and exogenous variables. The maximum number of lags considered was eight, the idea being to register correlations within and between annual periods. The selection criteria were the significance of each variable, on its own and as part of the set, and its stability. Each equation was estimated using instrumental variables for the sample period 1970Q1-1994Q4. Past values of all the endogenous and exogenous variables of the model were taken as instruments.[18]

When estimated, equation (1), corresponding to IS, shows a persistent rate of growth of output over four periods. The external output cycle (y^*) affects Spanish output after a two-quarter lag. While the real rate of exchange (q) has an impact on aggregate output in the same period, an increase in the long-term real interest rate (r) only contracts demand after a seven-quarter lag. The wealth effect is reflected here in the rate of growth of real monetary balances (m/p). This wealth effect is represented in the model by excluding assets abroad and making a separate estimation of demand for ALP.

The fiscal impulse variable in the IS equation is measured according to the second differences in public consumption (g).[19] The econometric specifications chosen limited the dynamics of variable g in such a way as to restrict its long-term elasticity in the model to zero.[20] There are various reasons for restricting the fiscal variable to have only a transitory impact. First, the sample

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17 So that an increase in domestic inflation and in imported inflation gives rise to an equivalent increase in the CPI inflation rate.

18 These estimations would have been more efficient if the residual correlation between equations had been taken into account (estimating 3SLS, for instance). We will leave that task for future research.

19 This is the only variable available in Quarterly National Accounts.

20 This differs from the elasticity estimated for the sample period (0.6), which coincided with a period in which the growth of government consumption far exceeded that of GDP.

period was characterised by a steady increase in the ratio of government consumption to GDP that is unlikely to be repeated in future. Secondly, we know that shifts in government consumption are not the only relevant variable for measuring all the effects of the government's budgetary restrictions. Finally, the fiscal policy exercises carried out in the unrestricted model generate a very high and implausible value[21] for the fiscal multiplier.

Table 2
The estimated model: long-run solution

$\Delta y_t = 1.89\Delta^2 g_t - 0.08\Delta r_t + 0.11\Delta q_t + 0.33\Delta(m_t - p_t) + 0.47\Delta y_t^* + \varepsilon_{yt}$	IS (1)
(4.4) (1.2) (3.3) (4.8) (2.5)	
$m_t - p_t = -5.5 - 0.03\Delta R_t - 0.15\Delta i_t + 1.25 y_t + \varepsilon_{mt}$	LM (2)
(0.8) (1.7) (23.5)	
$r_t \equiv R_t - E[\Delta p_{t+1/t}]$	RIR (3)
$R_t \equiv (1 - 0.91) i_t + 0.91 E[R_{t+1/t}] + \varepsilon_{it}$	TSIR (4)
(*) (13.4)	
$i_t = i_t^* + E(e_{t+1/t}) - e_t + \varepsilon_{et}$	UIP (5)
$\Delta p_t^d = 0.98E\left[\Delta p_t^d\right] + 0.02E\left[\Delta e_t + \Delta p_t^*\right] + 0.25\Delta y_t + \varepsilon_{pt}$	AS (6)
(1.5) (*) (3.7)	
$\Delta p_t = -0.57\Delta^2 p_t^d + 0.14(\Delta^2 p_t^* + \Delta^2 e_t) + \Delta P_t^d + \varepsilon_{pt}$	CPI (7)
(3.4) (3.7) (*)	
(*): restricted	

Definition of endogenous variables:
Δy_t: rate of growth of GDP; Δp_t^d: GDP deflator inflation; Δp_t: CPI inflation; e_t: nominal exchange rate (q_t real exchange rate); R_t: nominal long-term interest rate; r_t: real interest rate; $m_t - p_t$: supply of real balances.

Definition of exogenous variables:
g_t: government consumption; y_t^*, world income; i_t: short-term interest rate; i_t^*: external short-term interest rate; Δp_t^*: external inflation.

In the demand for real balances (equation (2)), (*m-p*) corresponds to a broad monetary aggregate, ALP2, which includes commercial paper as well as short-term public debt. This is the aggregate used as a relevant indicator by the Banco de España for monetary planning purposes. A long-term relationship is estimated between income and real balances, which implies an elasticity somewhat greater than one. The short-term variables are, apart from a lag in the variable itself, lags in the long-term nominal interest rate (R) -which measures the return on assets other than money – and accelerations in the inflation rate ($\Delta^2 p$). The three-month interbank rate (i) figures weakly in this relationship, also with a minus sign. This may measure the effect on demand of a change in the money supply that is not reflected in longer-term rates. For reasons of simplicity, such demand for money is not assumed to reflect the interaction between the return on assets included in ALPs and

[21] Compared to the values generated by other models, such as the NIGEM, for the Spanish economy and economies similar to ours.

the return on alternative assets that in earlier estimations proved to be important for the Spanish economy (Cabrero et al. (1992) and Vega (1997)).

A linear approximation has been estimated for the arbitrage condition between the interbank interest rate and the long-term debt rate (equation (4)). The parameter estimated compares the return on two assets with different maturities, assuming risk neutrality and rational expectations by economic agents.[22] The existence of a relationship of cointegration between short and long-term interest rates was tested and accepted, and parameter b of equation (4) was subsequently estimated, with a value very similar to the steady-state value for the long-term interest rate obtained for other countries (Taylor (1993)). Equation (5), which assumes interest rate parity, incorporates a risk premium.

Equation (6) on domestic prices (Δp^d) proxies inflationary expectations by lagged values of foreign and domestic prices, and demand pressure by the lagged coefficient of GDP growth. Price accelerations appear as additional regressors. This calculation yields a figure for the impact of external prices of 0.03, for a sample period in which the Spanish economy opened up considerably, so that a much higher figure is likely in the future with a more integrated economy. For the simulation, we took a higher figure (0.13), which, in our opinion, is closer to the current weight of imports in the national economy. This greater responsiveness of economic agents to expected changes in external prices accelerates the convergence between domestic and foreign variables.

The last equation estimated in Table 2 deals with the consumer price index (Δp), for which cointegration with domestic prices was found. The equation was therefore estimated taking ($\Delta p - \Delta p^d$) as the explanatory variable. External prices have only a transitory effect on the consumer price index and their permanent impact on inflation will be via expectations of domestic prices. The long-term restrictions contained in this equation (coefficient of 1 for domestic prices and 0 for external prices) are accepted statistically.

2.2 The determination of the nominal magnitudes and the monetary policy strategy

The financial structure of the model described in the previous section allows us to analyse the behaviour of the central bank in its goal of controlling inflation by establishing an interest rate path. Despite its simplicity, this framework underscores certain basic issues that the central bank faces in designing monetary policy and which affect the use of the model for simulation purposes.

The long-term solution of equations (1) - (7) can be represented as:

$$i = i^* + \Delta e \tag{8}$$

$$\Delta p = \Delta p^* + \Delta e \tag{9}$$

this last condition reflecting that the economy cannot systematically gain or lose competitiveness.[23] Equations (8) and (9) determine the level of the long-term real interest rate, which should be at the international level. Hence, reducing domestic inflation to the international level requires setting the domestic interest rate (i) at the international level (i^*).

$$i - \Delta p = i^* + \Delta p^* \tag{10}$$

In light of this long-term condition, one query concerns the path that the domestic interest rate must follow from a starting-point in which the economy has a positive inflation

22 See the article by Ayuso and Núñez (1997) to obtain a term structure with zero coupon assets.

23 In addition, the output gap has to close in the long run.

differential vis-à-vis external inflation. As pointed out earlier, an immediate and permanent reduction of the nominal interest rate cannot be dismissed out of hand. A central bank move in this direction gives rise to an immediate expansion, which in turn produces a generalised loss of competitiveness via an initial increase in inflation. If the central bank were able to maintain this policy indefinitely, sooner or later the deterioration in the trade balance would end up producing a recession and, along with it, a decline in inflation. Now, in practice, a temporary increase in inflation may erode the credibility of the ultimate objective, which makes this strategy completely inviable. This suggests the need for a more suitable, in the end equivalent, monetary strategy (that is: $\Delta p = \Delta p^*$), which involves a temporary increase in the domestic interest rate – thereby encouraging a contraction – and then a gradual reduction to its long-term level as the inflation goal is attained. Unlike the previous case, the goal of controlling inflation is attained more rapidly, although the costs in terms of output and employment are brought forward in time.

The existence of two quite opposite interest rate paths that lead, nevertheless, to the same long-term objective, indicates that there are indeed numerous intermediate alternatives, the relative advantages of which have to be assessed. In order to make an assessment of these or other economic policy strategies, it is necessary to know how the nominal exchange rate reacts to shifts in the economic environment. The greater the sensitivity of the nominal exchange rate to interest rate movements, the more intensely inflation will respond in the short term to changes in the nominal interest rate. What does the model represented in equations (1) - (7) tell us about the behaviour of the exchange rate when confronted with a change in the pre-announced interest rate path? Unfortunately, not enough. Fulfilment of the uncovered interest rate parity condition indicates that the current exchange rate value differs from the expected value by an amount equal to the interest rates differential, but that tells us nothing about the expected value itself. This value is determined by, among other factors, the level of the domestic money supply in relation to the supply of foreign currency. When the central bank fixes the interest rate, the money supply is endogenous and how it moves depends on the behaviour of the price level, which in turn depends on the behaviour of the exchange rate. In this way, the level of the nominal variables remains undetermined and it is not possible to predict the response of the exchange rate to a specific monetary policy measure (see Appendix B). Thus, while it is possible to calculate the exact level that real variables will reach, the existence of multiple solutions for the nominal variables implies that the transition path between two long-term equilibria is not unique.

Nominal indeterminacy is a feature of a wide range of models. A solution to this problem involves incorporating another equation into the model which, in one form or another, fixes the value of some nominal value. The generic form of such an equation is that of a feedback rule, according to which the monetary authorities react by varying the interest rate when some variable (X) deviates by more than a desired margin from its target value.[24] This way of constructing the model nevertheless poses some problems, particularly in respect of the choice of target variable.[25] If X stands for the *price level or parity of the peseta*, the feedback rule could be understood as an equation fixing a target of the monetary authority in terms of these variables (in either direction).

[24] This type of rule takes up McCallum's proposed solution to the non-uniqueness problem. Application of monetary policy by fixing an intermediate objective in quantitative terms would indeed be a specific instance of such rules, in which X is the money supply.

[25] At the same time, inclusion of a feedback rule appears to be logical in a model representing, from the outside, the behaviour of the monetary authorities, but not as an element to be taken into account in monetary policy decisions. Moreover, choice of an optimal rule implies first tackling the ever-complex question of the definition of a target function of the monetary authorities.

However, this would be an inappropriate representation of monetary policy in Spain.[26] For the simulation exercises we discuss below, a further condition has been added to the model. Specifically, it is assumed that an immediate reduction in interest rates leads to a depreciation of the peseta. Conversely, the peseta appreciates when the central bank raises interest rates. This assumption does not, however, solve the issue of how large is the magnitude of the exchange rate response. We will return to this point in our description of the simulation exercises.

2.3 Simulations

This section will assess the relative importance of the channels through which monetary policy operates by simulating the impact associated with alternative interest rate (and exchange rate) paths. These exercises have not been carried out in order to lay down how the Banco de España's monetary policy should be implemented; our goal is more modest and restricted to analysing within a given framework the importance of certain monetary policy transmission mechanisms. Consequently, no attempt has been made to establish optimum inflation targets or plausible ranges of fluctuation around them.[27] All the simulations are compared with a hypothetical scenario, independent of the model itself, in which it is assumed that domestic and foreign economic activity grows by 2% a year, domestic prices by 5% per annum, and external prices by 3% annually. The simulations reflect the transition between an equilibrium with 5% inflation to another with 3% inflation. The object of the exercise is to establish the procedures and costs of eliminating the inflation differential vis-à-vis the rest of the world. The linearity of the model, at least with regard to the variables expressed as logarithms, makes it possible to isolate these responses from the baseline, which thus becomes of secondary importance. The simulations were carried out by solving forward the financial variables, which means that the values for those variables anticipated by economic agents coincide with what was actually simulated. All the equations employ residuals, in such a way that each equation reproduces, for each period, the data given in the scenario.

Given the structure of the model, the 2-point reduction in domestic inflation requires an equivalent, long-term, reduction in the domestic interest rate. First, we shall simulate the effects of an *immediate and permanent reduction of interest rates of 2-points* (simulation 1). As discussed in the previous section, the instantaneous response of the exchange rate has to be imposed on the basis of criteria independent of the model. A reasonable hypothesis is that the 2-point lowering of interest rates goes together with an initial nominal exchange rate depreciation of 5%.[28] Charts 1 and 2 show the behaviour of inflation and GDP growth after application of this policy. The most notable feature of this simulation emerges in the inflation rate profile for the time period under consideration. Although this monetary policy measure ultimately leads to the targeted level of inflation, the reduction in interest rates and the nominal depreciation produce a temporary increase in inflation which may endanger the disinflation process itself. Despite the modest exchange rate depreciation, its short-term impact on inflation is considerable: for over a year, inflation remains higher than 6% and only starts declining after three years.[29] This effect is due to the increase in external prices, which swiftly and strongly raises inflationary expectations and affects demand pressure, albeit not to the same extent.

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26 Nominal stability targets are generally expressed in terms of the inflation rate, which is compatible with very different price level values. Establishing an *inflation rate* target does not solve the indeterminacy problem (Dhar et al. (1994)).

27 See, for example, Haldane et al. (1995).

28 All these figures exclude the risk premium (which is exogenous) and are, moreover, approximate, given that the original movements are expressed as logarithms.

29 While generating a small expansion of GDP for two years (Chart 2).

Chart 1
Alternative interest rate strategies
Inflation (CPI) rate, annualised

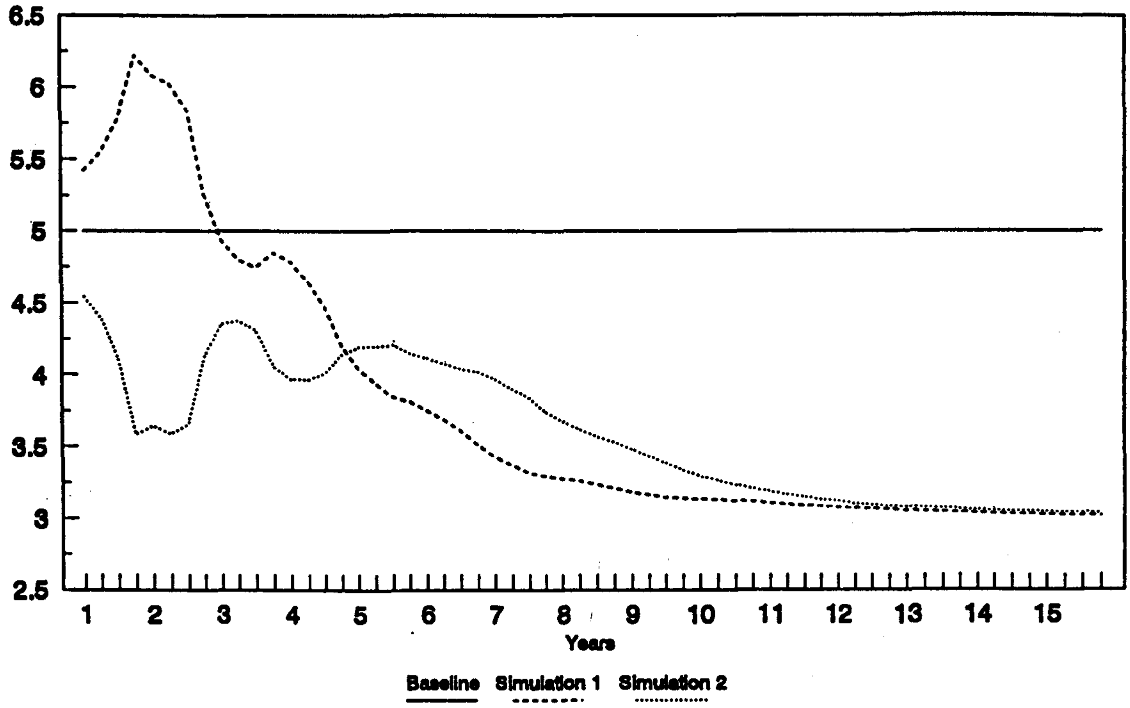
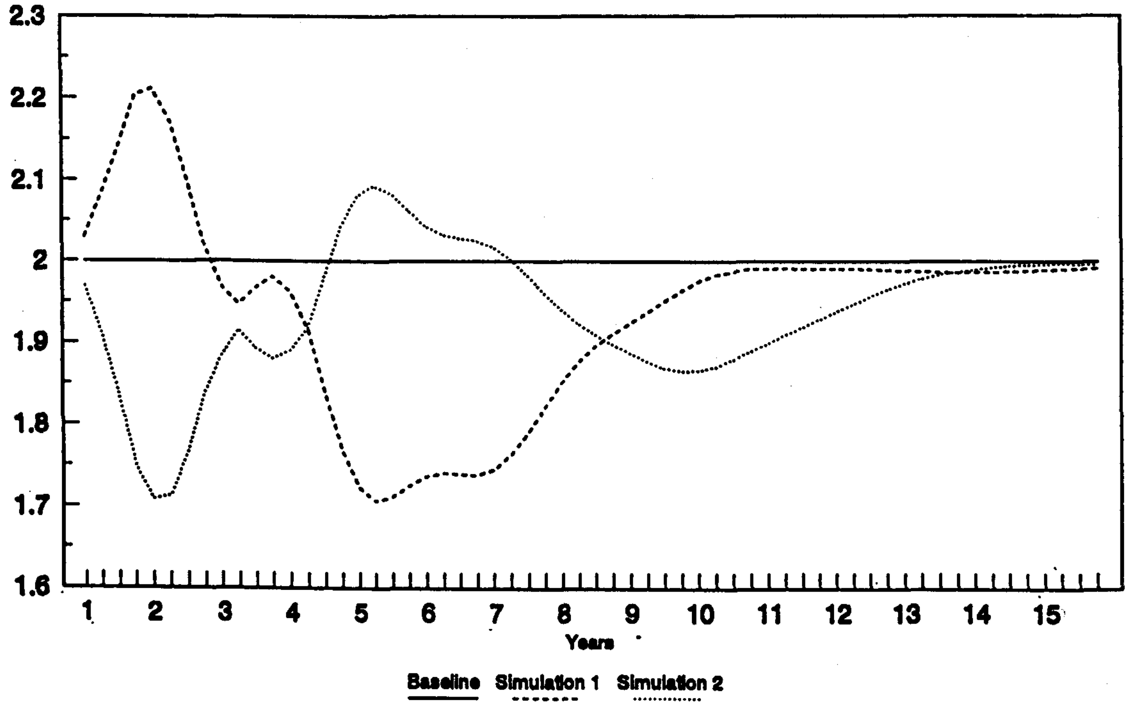


Chart 2
Alternative interest rate strategies
GDP growth, annualised



Simulation 1: Immediate reduction of interest rate with a 5% depreciation.
Simulation 2: Temporary increase, with a 5% appreciation.

Chart 3
Simulation of monetary policy: behaviour of the interest rate and exchange rate

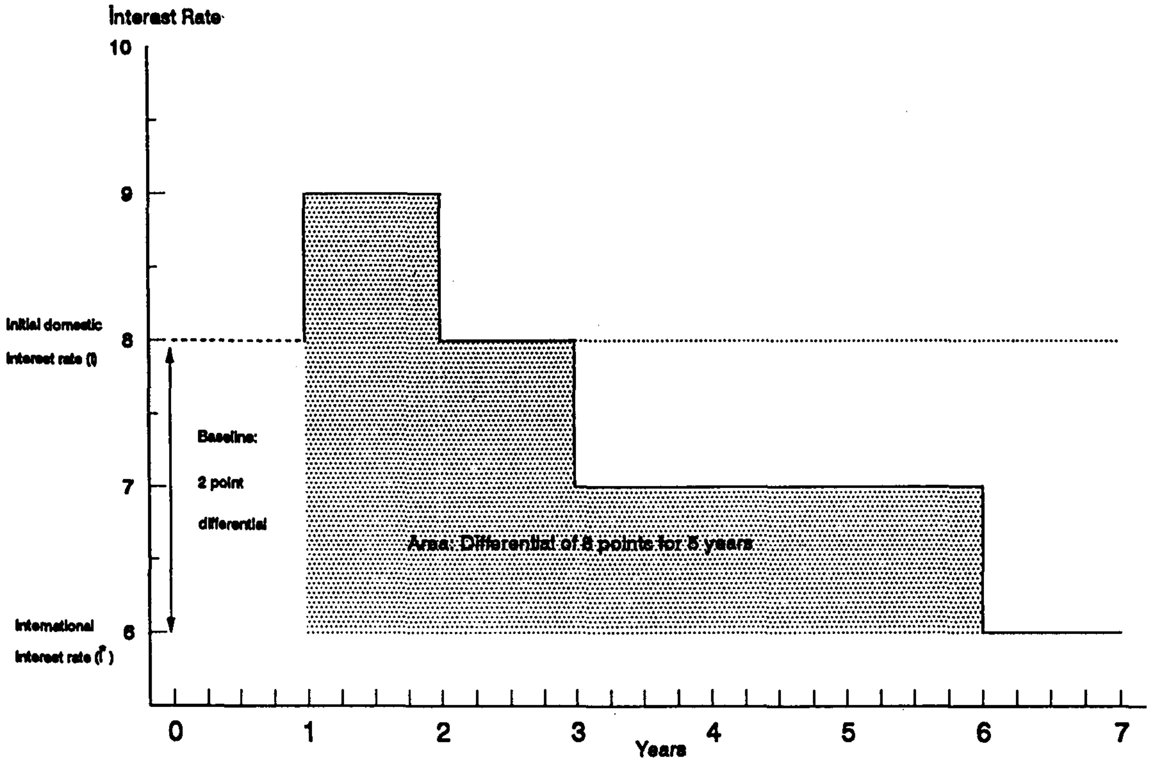
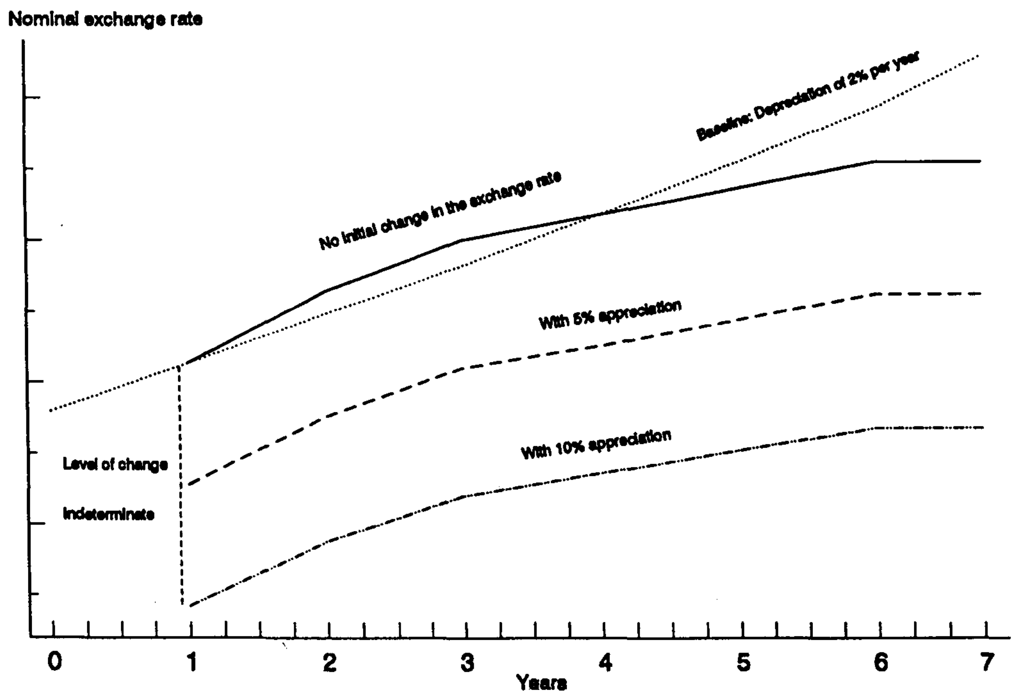


Chart 4
Exchange rate consistent with the interest rate differential



The initial depreciation of the currency is, therefore, inflationary. How does a decline in inflation take place later? The elimination of the interest rates differential over time leads the nominal exchange rate to stabilise around the new value obtained after the 5% drop on impact. Thereafter, on the supply side, imported inflation drops immediately from the 5% envisaged in the base scenario[30] to 3% (the pace at which external prices increase), thereby helping to dampen inflationary expectations and, thus, domestic inflation. Moreover, with domestic prices still rising faster than those of our competitors, our products become more expensive, which reduces external demand and sparks off a temporary recession, which also moderates inflation. Reduction of the nominal interest rate works in the opposite direction, but this effect is not sufficient to offset the loss in competitiveness. Later on, the reduction in inflationary expectations allows the real interest rate to recover and this, too, helps moderate inflation.[31]

A reduction in the nominal interest rate ensures, in principle, a reduction of inflation in the long run, but if, as a result of the initial currency depreciation, the process of transition requires a higher inflation than that prevailing at the outset, a *legitimate doubt* arises as to the *credibility* of this policy. If economic agents are sceptical about achieving the objective of ultimately reducing inflation and consider that this policy is not sustainable, it may take time for inflation to fall or it may not do so at all, and this in turn would prevent the planned reduction in nominal interest rates. The policy has to be credible. One way to minimise these risks is to effect *a temporary increase in interest rates, before reducing them permanently* to the international level. Thanks to this temporary increase, there is less risk of generating higher inflation in the short and medium term, which strengthens the credibility of the anti-inflationary policy itself. Let us observe how this policy works in the context of the model.

Take a monetary policy measure which consists of raising by 1 point the intervention interest rate for one year and then returning the following year to the level of the base scenario; the interest rate is then reduced by 1 point for another three years, ending up with a permanent reduction of 2 points. Charts 3 and 4, respectively, show the behaviour of the nominal interest rate and the nominal exchange rate, making three alternative assumptions regarding the appreciation in impact.

In accordance with uncovered interest parity, this exercise unequivocally determines the behaviour of the nominal exchange rate. This is consistent with an 8-point depreciation during the years of the transition (equal to the sum of the interest rates differentials during the first five years of the simulation), stabilising when the domestic interest rate is at the international level. However, given nominal indeterminacy, it is not known at what level the exchange rate is established. To solve this indeterminacy, an instantaneous *appreciation of 5%* is assumed to accompany the increase in the interest rate (simulation 2).[32] The findings of simulation 2 are also shown in Charts 1 and 2 to facilitate comparison. Charts 5 and 6 show the behaviour of the real interest rate and the real exchange rate in both simulations. Inflation declines in the first year by a little more than 1 point, stabilising at around 4% for the following 5 years, and beginning thereafter a gradual decline to its new long-term level of 3%. The first year, GDP grows by ¼% less than in the base scenario, gradually recovering thereafter to reach its long-term growth level in 4 years, followed by a small cycle.

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30 Resulting from 3% external price inflation, plus 2% permanent depreciation of the domestic currency.

31 The behaviour of the real interest rate and the real exchange rate are reflected in Charts 5 and 6, which we comment on below.

32 The history of the variable itself can give us an idea of the jump: only very occasionally has the currency appreciated or depreciated by more than 5% in nominal terms (on 6 occasions in our sample period). In fact, this jump is almost twice the standard deviation in the nominal exchange rate. Almost the same is true of the real exchange rate which has only occasionally registered variations of that magnitude within a single quarter.

Chart 5
Real interest rate

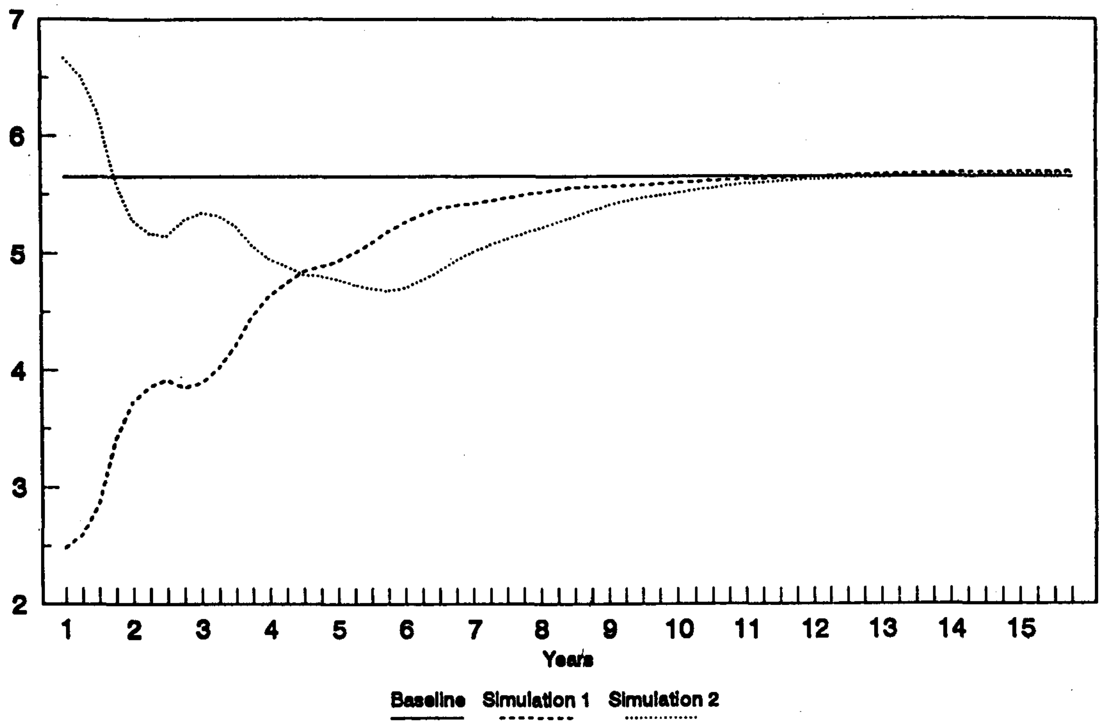
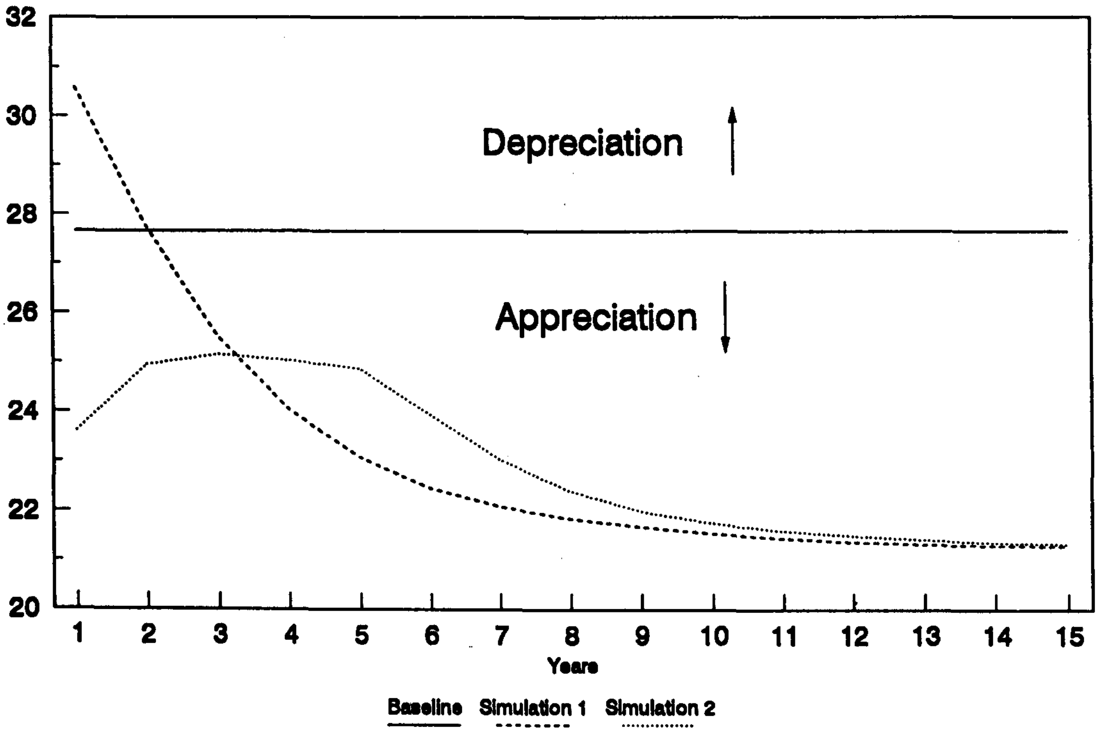


Chart 6
Real exchange rate



Simulation 1: Immediate drop and 5% depreciation.
Simulation 2: Temporary increase and 5% appreciation.

Chart 7

Temporary increase in the interest rate, dropping subsequently to the international level
Inflation (CPI) rate, annualised

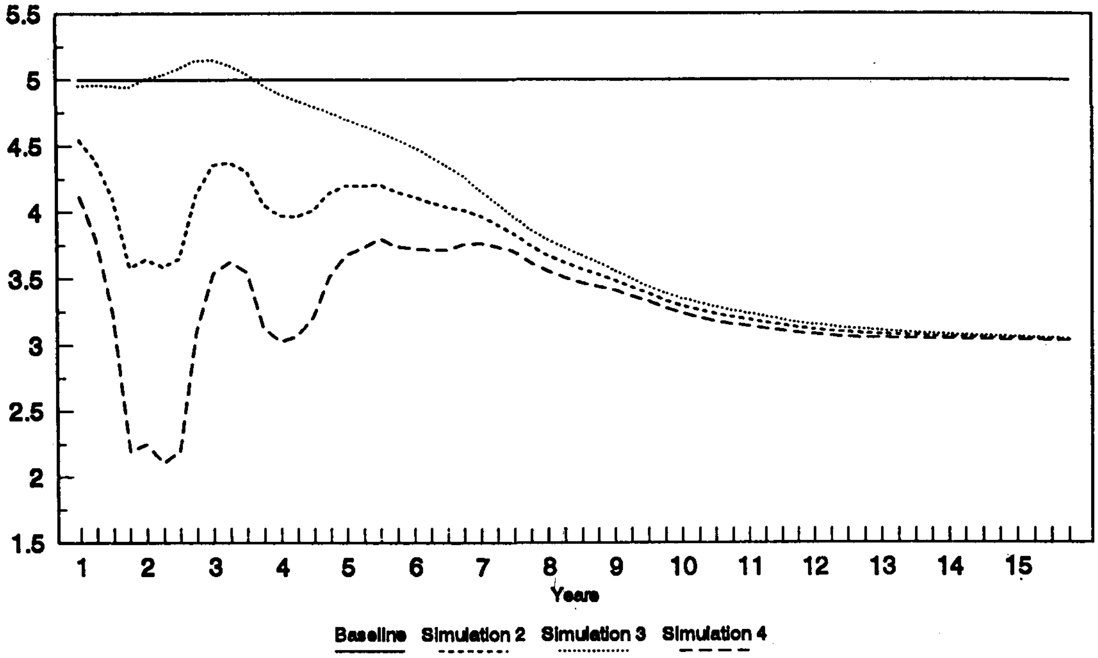
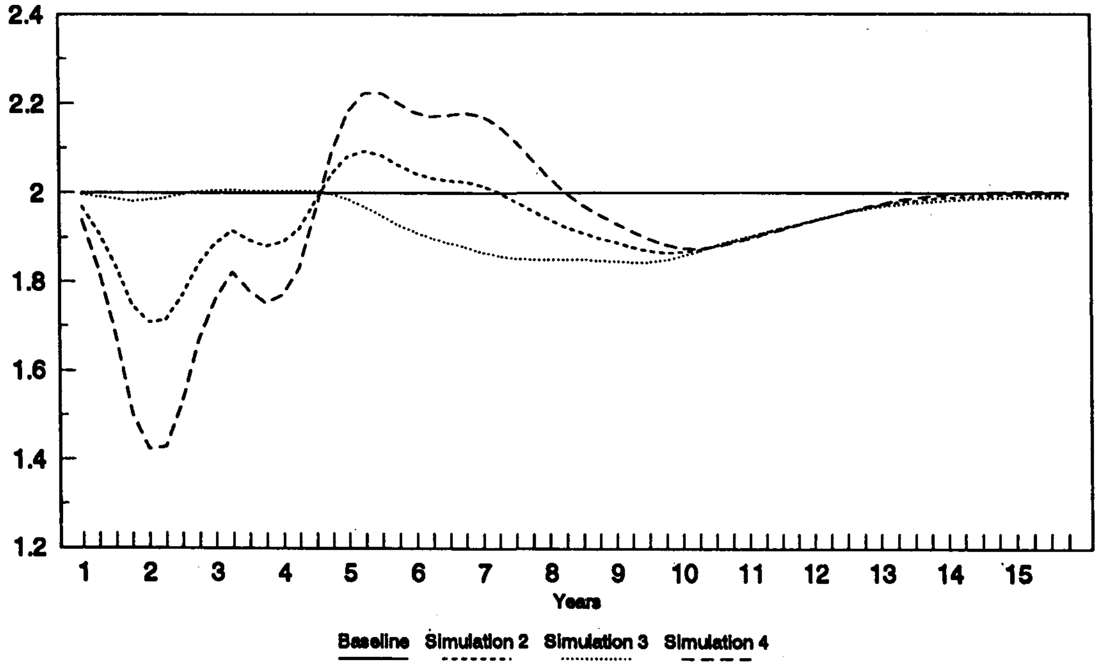


Chart 8

Temporary increase in the interest rate, dropping subsequently to the international level
Growth of GDP



Simulation 2: Temporary increase with initial appreciation of 5%.
Simulation 3: Temporary increase with no initial change in the exchange rate.
Simulation 4: Temporary increase with initial appreciation of 10%.

The initial drop in inflation is mainly due to the (expected) cheapening of imported goods: a supply effect that dampens inflationary expectations. The tiny recession thereby induced serves to keep inflation below its initial level in the following periods in which parity no longer helps moderate inflation. This contraction is basically caused by the demand inertia following upon the initial appreciation (Chart 6), not via interest rates (Chart 5), since economic agents very quickly anticipate that they will fall in long-term nominal values. The comparison with simulation 1 clearly shows that inflation responds more quickly to a temporary increase in interest rates, although the convergence towards the long-term inflation rate target of 3% is faster if the reduction in interest rates is immediate. This apparent asymmetry is explained almost completely by the different pattern of response of the nominal exchange rate and it confirms the predominance of the competitiveness channel in the monetary transmission mechanism in the case of Spain.

In the exercise shown in simulation 1, the initial depreciation had an inflationary impact; later on, as the nominal exchange rate stabilises, a swift drop in competitiveness occurs,[33] which helps dampen inflation. When, on the contrary, the temporary increase in interest rates causes the exchange rate to over-react (simulation 2), the strong initial appreciation has an immediate deflationary impact. However, after the initial phase, and while the interest rates differential with the outside world continues to be positive (and even higher than in the baseline), the national currency depreciates and part of the competitiveness lost is recovered. This helps cushion the impact of recession and induces a slight rise in inflation.

Even when the monetary authorities opt for a temporary increase in interest rates to induce a rapid drop in inflation, it definitely seems that the best thing to do is to shorten the period during which an interest rate differential causes a temporary depreciation (see Chart 6). If the central bank bears full credibility on its efforts to reduce inflation, then it will be able to proceed quickly to lower interest rates in a manner compatible with that objective. One way of increasing credibility is to carry out supply-side structural reforms.[34] Another way would be to obtain fiscal policy backing. This paper does not, however, go into such coordinated strategies.

Given that the assumption in the simulations regarding the initial response of the currency remains arbitrary, two further simulations were carried out in order to compare the sensitivity of the findings to the behaviour of the exchange rate. On the assumption that there is an initial variation in the nominal interest rate analogous to that in simulation 2, the nominal exchange rate is allowed to appreciate *immediately by 0%* (simulation 3) and *10%* (simulation 4), respectively. Following this initial reaction, there is a subsequent depreciation of 8 points derived from the accumulated interest rates differential. The behaviour of the rate of inflation and the rate of growth of GDP are also shown in Charts 7 and 8, along with the results of simulation 2 (appreciation of 5 percent). With an effective 10% appreciation of the peseta, we note that inflation declines by more than two points in the first year, in part due to a slight 0.3% recession compared to growth at the outset, but mainly due to the rapid decline in external inflation and its favourable impact on domestic price formation. On the other hand, if we assume no appreciation, monetary policy induces a path in which inflation declines, but more slowly.

The short and long-term output costs of the various monetary policy strategies are summarised in Table 3. The long-term costs are obtained by adding the GDP losses incurred each year. Having constructed the model with GDP growth rates, our measure for assessing costs is given

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33 Chart 6 shows an appreciation of the real exchange rate from the first period onwards.

34 Which the model could take into account by altering the constant term in equation (6), for instance, or via an autonomous reduction in inflationary expectations.

by the GDP level itself, which does not necessarily have to return to the original level.[35] By this criterion, the long-term cost of the permanent 2-point drop in inflation is the same in all the simulations: a little under 1% of the original GDP[36] per year. The results in the table also show, in each simulation, the importance of short-term behaviour as the key factor to be borne in mind in assessing the relative advantages of each kind of monetary policy. The sacrifice ratio (growth in output divided by the change in inflation) in the first two years of simulations 2, 3, and 4 indicates that the lower the exchange rate appreciation associated with the temporary increase in interest rates, the lower the cost of the policies in those years.

Table 3
Impact and real cost of the simulations

Simulation	**Initial change in the exchange rate[1]**	**Inflation differential**				**Growth of output differential**				
		year 1	year 2	year 3	year 4	year 1	year 2	year 2	year 4	long term[2]
Monetary policies										
1. Immediate reduction of interest rates with initial depreciation	5%	1.24	0.29	-0.16	-0.77	0.20	0.01	-0.01	-0.22	-0.92
2. Temporary increase in interest rates and initial appreciation	-5%	-1.41	-0.87	-0.90	-0.86	-0.25	-0.15	-0.13	0.04	-0.92
3. Temporary increase in interest rates	0%	-0.07	0.15	-0.02	-0.24	-0.01	0.00	0.00	-0.01	-0.92
4. Temporary increase in interest rates and initial appreciation	-10%	-2.79	-1.93	-1.82	-1.51	-1.51	-0.31	-0.27	0.08	-0.92

[1] A positive figure denotes a depreciation. [2] Accumulated sum of the growth in output once the model reaches the steady-state solution.

[35] As was argued earlier on, a transitory response of the rate of growth to deflationary policy assumes that there is a permanent effect on the level of output. In that sense, the model is not strictly neutral, even though it returns to the initial rate of growth of GDP.

[36] This drop in GDP is the result of a corresponding 5% loss of competitiveness.

Conclusions

We have focused on an aggregate model of the monetary transmission mechanism in the Spanish economy, designed to evaluate, by simulations, alternative monetary policy strategies. The model incorporates the main channels through which central bank policy can affect the inflation rate. The parameters for the model were based on data for the 1973-94 period. Nonetheless, the model was specifically construed to reflect the main features of monetary transmission today. Thus, monetary policy is defined as a short-term interest rate path geared to achieving an inflation target. At the same time, the increasing openness of the economy reinforces the role of competitiveness in the transmission of monetary impulses. Finally, the efficiency of financial markets means that the impact of economic agents' expectations regarding the future behaviour of asset prices must be taken explicitly into account.

Solving the model has drawn attention to a few consequences of abandoning the establishment of an intermediate objective in terms of some monetary aggregate. Automatic adjustment of the money supply, aimed at keeping the interest rate within established values, leads to the indeterminacy of nominal magnitudes, particularly the price level and interest rate. Although it is true that this indeterminacy has no impact on the value of real variables, the short-term responses of inflation and competitiveness are indeed affected. To sidestep this problem, the model imposes a terminal exchange rate value, which has a considerable effect on the short-term cost of the different disinflationary policies. With due caveats from this limitation, the simulations do show a series of regularities, which are summarised very briefly in Table 3.

The achievement of a permanent reduction of the Spanish rate of inflation to the average level of inflation prevailing in Spain's trading partners presupposes, sooner or later, reducing nominal interest rates by at least as much as the current inflation differential. A policy in which that reduction in nominal interest rates is carried out immediately runs the risk of generating a short-term resurgence of inflation, unless it is accompanied by tougher fiscal policy or appropriate supply-side policies. If these policies are not promptly and forcefully applied, the currency depreciates and this leads to a period of temporarily higher inflation. That, in turn, could seriously erode the anti-inflationary credibility of the monetary policy strategy being pursued, making the ultimate objective harder to attain.

Judging by the simulations carried out, the most credible way to reduce inflation is by temporarily increasing interest rates, which leads to a temporary slowing down of the rate of output growth. In this case, inflation converges towards its long-term value, remaining below the initial figure, while the magnitude of the initial response depends on the degree of appreciation of the nominal exchange rate. The simulations also show that the degree of competitiveness plays a very important part in monetary transmission. Moreover, this effect acts powerfully on the supply side, lowering expectations of imported inflation and, with them, wage demands.

Although the long-term effects of all the anti-inflationary strategies analysed are similar, the structure over time of the response of inflation and GDP depends crucially on how competitiveness develops. Indeed, variations in the real exchange rate appear to be the most important of the channels making up monetary transmission mechanism in our country. The fact that tradable goods become relatively more expensive as a result of a more restrictive monetary policy induces a fall in aggregate demand and dampens inflationary expectations. The magnitude of this expectations or supply effect is one of the key determinants of the strength of the transmission mechanism and more empirical evidence has to be gathered concerning it. Likewise, it is necessary to broaden our knowledge of the response of the nominal exchange rate to variations in the expected path of interest rates in order to overcome one of the main limitations in the study of the monetary transmission mechanism within a framework of direct inflation targets.

Appendix A: The estimated model

The sample period is 1970Q1 - 1994Q4. All the equations have been estimated using instrumental variables such as the lags of the variables up to the eighth period as well as deterministic variables. The figures in brackets indicate the t-statistical for regressions and, for autocorrelation tests, the degree of marginal significance.

Equation IS (1):

$$\Delta y_t = \underset{(0.50)}{0.001} + \underset{(16.77)}{1.1489}\Delta y_{t-1} - \underset{(2.49)}{0.2610}\Delta y_{t-2} + \underset{(1.80)}{0.1498}\Delta y_{t-3} - \underset{(3.79)}{0.2502}\Delta y_{t-4} + \underset{(4.83)}{0.0706}\Delta\left(\frac{m}{p}\right)_{t-1}$$

$$+\underset{(3.31)}{0.0521}\Delta^2\left(\frac{m}{p}\right)_{t-6} + \underset{(1.69)}{0.0506}\Delta y^*_{t-2} + \underset{(3.41)}{0.0887}\Delta y^*_{t-4} - \underset{(1.82)}{0.0390}\Delta y^*_{t-8} + \underset{(4.09)}{0.0232}\Delta q_t - \underset{(3.87)}{0.0134}\Delta^2 q_{t-6}$$

$$+\underset{(2.76)}{0.0462}\Delta r_{t-1} - \underset{(3.58)}{0.0631}\Delta r_{t-7} + \underset{(6.87)}{0.2441}\Delta^2 g_t - \underset{(3.11)}{0.1089}\Delta^2 g_{t-1} + \underset{(3.57)}{0.1076}\Delta^2 g_{t-2} + \underset{(3.57)}{0.1076}\Delta^2 g_{t-7}$$

$$+\underset{(3.65)}{0.0042}\,dummy\,80Q1 - \underset{(13.04)}{0.0165}\,dummy\,80Q2 - \underset{(2.20)}{0.0025}\,dummy\,92Q3$$

$\overline{R}^2 = 0.95$; standard error $= 0.0010$; first-order autocorrelation test:

$\underset{(0.09)}{X^2(1) = 2.7099}$; first to fourth-order autocorrelation test: $\underset{(0.41)}{X^2(4) = 3.927}$

Money demand equation LM (2):

$$\Delta\left(\frac{m}{p}\right)_t = -\underset{(4.66)}{2.2652} + \underset{(6.66)}{0.5519}\Delta\left(\frac{m}{p}\right)_{t-1} - \underset{(1.60)}{0.1953}\Delta R_t + \underset{(2.54)}{0.2746}R_{t-1} - \underset{(2.29)}{0.2265}\Delta R_{t-2} - \underset{(1.62)}{0.0551}\Delta i_{t-3}$$

$$-\underset{(3.11)}{0.4256}\Delta^2 p_t - \underset{(5.33)}{0.406}\left(\frac{m}{p}\right)_{t-1} + \underset{(5.06)}{0.5105}y_{t-1} + \underset{(5.13)}{0.0016}\,trend - \underset{(5.16)}{0.0163}\,seasonal\,T1$$

$$-\underset{(2.34)}{0.0067}\,seasonal\,T2 - \underset{(2.30)}{0.0117}\,step92Q1 + \underset{(2.06)}{0.0111}\,step93Q4$$

$\overline{R}^2 = 0.72$; standard error $= 0.0047$; first-order autocorrelation test:

$\underset{(0.12)}{X^2(1) = 2.3647}$; first to fourth-order autocorrelation test: $\underset{(0.004)}{X^2(4) = 15.02}$

Interest rates term structure equation TSIR (4):

$$\left(R_t - i_t\right) = 0.91\left(R_{t+1} - i_t\right)$$

(13.3)

$\overline{R}^2 = 0.72$; standard error = 0.8731; first-order autocorrelation test:

$X^2(1) = 11.10$; first to fourth-order autocorrelation test: $X^2(4) = 14.41$

(0.0008) (0.006)

Aggregate supply equation AS (6):

$$\Delta p_t^d = 0.8061\Delta p_{t-1}^d + 0.1563\Delta P_{T-7}^d - 0.2003\Delta^2 p_{t-1}^d + 0.0241\left(\Delta p_{t-1}^* + \Delta e_{t-1}\right) + 0.0185\left(\Delta^2 p_{t-5}^* + \Delta^2 e_{t-5}\right)$$

(14.85) (3.05) (1.96) (1.56) (1.52)

$$+0.26.7\Delta_{t-1} - 0.0021\, seasonal\, T1 - 0.0014\, seasonal\, T2 - 0.0021\, seasonal\, T3$$

(3.73) (1.65) (1.19) (1.72)

$\overline{R}^2 = 0.87$; standard error = 0.0045; first-order autocorrelation test:

$X^2(1) = -0.09396$; first to fourth-order autocorrelation test: $X^2(4) = 2.6964$

(0.60)

CPI equation (7):

$$\left(\Delta p_t - \Delta p_t^d\right) = -0.1453\Delta^2 p_{t-2} - 0.1598\Delta^2 p_{t-3} + 0.1481\Delta^2 p_{t-6} + 0.1823\Delta^2 p_{t-8} - 0.6957\Delta^2 p_t^d$$

(1.85) (2.16) (2.30) (2.85) (2.62)

$$+0.0497\Delta^2 p_t^* + 0.9458\Delta^2 p_{t-1}^*$$

(1.30) (1.70)

$\overline{R}^2 = 0.29$; standard error = 0.0045; first-order autocorrelation test:

$X^2(1) = 3.4001$; first to fourth-order autocorrelation test: $X^2(4) = 6.09$

(0.06) (0.19)

Appendix B: Model dynamics

Let us consider the following model of a small open economy, simpler than the one estimated but containing the same basic properties:

$$y = \delta\left(e - p + p^{*}\right) - \gamma(r - \dot{p}) \tag{B.1}$$

$$\dot{p} = \pi + \phi y \tag{B.2}$$

$$\dot{\pi} = \beta(\dot{p} - \pi) \tag{B.3}$$

$$\dot{e} = r - r^{*} \tag{B.4}$$

$$m - p = \kappa y - \lambda r \tag{B.5}$$

The log of output (y) is a decreasing function of the (ex-post) real interest rate $(r - \dot{p})$ and an increasing function of the log of real exchange rate ($e - p + p^*$). Price inflation depends on expectations (π) and the output gap. The log of the demand of real money balances (m-p) is a function of income and the nominal interest rate. Inflation expectations $(\dot{\pi})$ react to past forecast errors. We also assume that the uncovered parity condition holds and that there is perfect foresight in the foreign exchange market, as widely used in many open economy models.

When the central bank follows an interest rule (setting r to r^0) the money supply is endogenous, and the economy is left without a nominal anchor. The state space representation of the system (B.1) - (B.5) can be written as in (B.6),

$$\begin{bmatrix} \dot{p} \\ \dot{\pi} \\ \dot{e} \end{bmatrix} = \begin{bmatrix} \dfrac{-\phi\delta}{1-\phi\gamma} & \dfrac{1}{1-\phi\gamma} & \dfrac{\phi\delta}{1-\phi\gamma} \\ \dfrac{-\beta\phi\delta}{1-\phi\gamma} & \dfrac{-\beta\phi\gamma}{1-\phi\gamma} & \dfrac{\beta\phi\delta}{1-\phi\gamma} \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} p \\ \pi \\ e \end{bmatrix} + \begin{bmatrix} \dfrac{\phi\delta}{1-\phi\gamma} & 0 & \dfrac{-\phi\gamma}{1-\phi\gamma} \\ \dfrac{\beta\phi\gamma}{1-\phi\gamma} & 0 & \dfrac{-\beta\phi\delta}{1-\phi\gamma} \\ 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} p^{*} \\ r^{*} \\ r^{0} \end{bmatrix} \tag{B.6}$$

Since the determinant is zero, the system has one zero root and the long-run value of the endogenous variables remains indeterminate. A closer look at the dynamic system reveals the cause of this indeterminacy. According to the uncovered parity condition, the exchange rate has a unit root that cannot be removed; hence, the bottom row of the first matrix in (B.6) is a row of zeroes. Solving the third row of the system (B.6) as an arbitrage condition gives the following expression for the exchange rate:

$$e(t) = -\int_{t}^{T}\left(r^{0}(s) - r^{*}(s)\right)ds + e^{e}(T) \tag{B.6'}$$

The nominal exchange rate is a non-predetermined or forward-looking variable, whose value at a particular point in time cannot be tied down by its initial condition. The money supply is endogenous and so is its value at T ($m(T)$). Hence the terminal value $e(T)$ is not independent of the particular path the economy follows and cannot be used to fix the current value $e(t)$. In other words, under rational expectations, the expected interest rate differential fixes the slope (the rate of change) of the nominal exchange rate, but not its level.

The fixed interest rate rule implicit in the model is perhaps too extreme, but it should be clear that the problem of indeterminacy would arise whatever the monetary rule we introduce as long as it is defined in real, rather than in nominal terms. A feedback rule like (B.7),

$$\dot{r} = \eta\left(r^0 - r\right) \tag{B.7}$$

such that the central bank smoothes its interest rate policy to achieve a target level (r^0), does not remove the zero root in the dynamic system as can be seen in the state space representation (B.8):[37]

$$\begin{bmatrix} \dot{p} \\ \dot{e} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} \dfrac{-\phi\delta}{1-\phi\gamma} & \dfrac{\phi\delta}{1-\phi\gamma} & 0 \\ 0 & 0 & 1 \\ 0 & 0 & -\eta \end{bmatrix} \begin{bmatrix} p \\ e \\ r \end{bmatrix} + \ldots \tag{B.8}$$

It should be clear that despite the nominal indeterminacy problem, the model can still be used to study the long run. Although the nominal system is indeterminate, the real system is not. In fact, a change of variables in (B.6) and (B.8) would render the system well defined in terms of the real exchange rate (and inflation expectations). For example, the dynamic system in (B.6) could be rewritten as:

$$\left(\dot{e} - \dot{p}\right) = \frac{-\phi\delta}{1-\phi\gamma}\left(e - p\right) + \ldots$$

from which it is trivial to obtain the steady-state solution of the model:

$$\dot{e} = \dot{p} = \pi = r^0 - r^* \qquad y = \dot{\pi} = 0 \qquad r - \dot{p} = r^0 - \dot{p} = r^* - \dot{p}^* = r^*$$

Price level indeterminacy and disinflation

The problem of price indeterminacy under interest rate rules and rational expectations, is well known since the work of Sargent and Wallace (1975) and so are its solutions. It can be shown that any fixed or feedback rule defined in nominal terms would tie down a unique path for the nominal variables under the assumptions of convergence to the steady state. A monetary rule making *the level of the money supply* exogenous (Dornbusch (1976)) removes the source of indeterminacy. Similarly, the unit root in the nominal system might be removed if the central bank sets its interest rate rule so as to achieve a *target price level*. For instance, if the bank sets its interest rate according to the feedback rule (B.9), all the roots in the system (B.10) have non-zero real parts,

$$\dot{r} = \eta\left(p - p^0\right) \tag{B.9}$$

[37] Hereafter, the inflation expectations state variable (π) has been excluded from the dynamic system, since it is the interaction among the dynamics of p, e and r that causes the indeterminacy problem.

$$\begin{bmatrix} \dot{p} \\ \dot{e} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} \frac{-\phi\delta}{1-\phi\gamma} & \frac{\phi\delta}{1-\phi\gamma} & \frac{-\phi\gamma}{1-\phi\gamma} \\ 0 & 0 & 1 \\ \eta & 0 & 0 \end{bmatrix} \begin{bmatrix} p \\ e \\ r \end{bmatrix} + \ldots \tag{B.10}$$

The target level of nominal money balances or of the price level become, in these settings, the nominal anchor that is lacking once the monetary authority moves to an interest rate rule. By the same token, the problem of nominal indeterminacy would disappear once a country has pegged its currency within a monetary union; the fixed *level of the exchange rate* would become the nominal anchor, pinning down the path of nominal prices at any point in time.

Nominal-targeting interest rules are not very common in central banking, however. Feedback rules are most often designed in terms of real variables, as in equation (B.7). The increasing concern about price stability has led most central banks to set the inflation rate at the heart of monetary policy making. Inflation-targeting has then become the most popular way of conducting the interest rate policy. A natural question arises at this point: does inflation-targeting get rid of the problem of nominal indeterminacy? The answer is that, under fairly general circumstances, it does not. Let us consider a feedback interest rule as in (B.11),

$$\dot{r} = \eta\left(\dot{p} - \dot{p}^0\right) \tag{B.11}$$

Some authors have already pointed out the differences of price-targeting versus inflation-targeting in monetary policy. Kerr and King (1996) argue that, in a closed economy model even with an expectations-augmented IS schedule, a unique rational expectations equilibrium may be pinned down as long as the interest rate response to deviations of inflation from its target is "sufficiently aggressive" (i.e. if η is big enough). Unfortunately, a high η does not help to get a unique path for the nominal variables in a model with forward looking nominal variables. In our framework, it is easy to show that, despite its similarity with (B.9) an interest rate rule such as (B.11) does not help to remove the unit root from the dynamic nominal system in (B.12):

$$\begin{bmatrix} \dot{p} \\ \dot{e} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} \frac{-\phi\delta}{1-\phi\gamma} & \frac{\phi\delta}{1-\phi\gamma} & 0 \\ 0 & 0 & 1 \\ \frac{-\eta\phi\delta}{1-\phi\gamma} & \frac{\eta\phi\delta}{1-\phi\gamma} & 0 \end{bmatrix} \begin{bmatrix} p \\ e \\ r \end{bmatrix} + \ldots \tag{B.12}$$

It could be argued that the nominal exchange rate path might be unique even if the central bank sticks to a monetary policy rule like (B.11), when the economy is operating close to its inflation target $\left(\dot{p}^0\right)$. Since the central bank would only have to react to small temporary deviations of the inflation rate, it would seem fair to assume that $e^e(T)$ should not deviate too much from the value that was expected before the change in the interest rate was announced. When a country is well above its target inflation, matters are rather different. In this case, bringing inflation down requires a permanent change in the interest rate differential; i.e. a permanent change in the rate of depreciation. Following this, it is no longer justified to assume that the steady state value of $e(e^e(T))$ remains unchanged. In such a case, unless the monetary authority sets a reaction function in terms of some nominal target, the initial reaction of the nominal exchange rate cannot be signed. Furthermore, even if the financial markets would interpret the movement in the interest rate as a tightening in the monetary policy, so that we could expect an instantaneous appreciation of the currency, the model in (B.1) - (B.5) would still be silent about the size of this loss of competitiveness and hence about the path of inflation and prices.

Stability of the model

We analyse the stability conditions of the real system, written as (B.13) for convenience.

$$\begin{bmatrix} \dot{e}-\dot{p} \\ \dot{\pi} \end{bmatrix} = \begin{bmatrix} \dfrac{-\phi\delta}{1-\phi\gamma} & -\dfrac{1}{1-\phi\gamma} \\ \dfrac{\beta\phi\delta}{1-\phi\gamma} & \dfrac{\beta\phi\gamma}{1-\phi\gamma} \end{bmatrix} \begin{bmatrix} e-p \\ \pi \end{bmatrix} + \begin{bmatrix} \dfrac{-\phi\delta}{1-\phi\gamma} & -1 & \dfrac{1}{1-\phi\gamma} \\ \dfrac{\beta\phi\delta}{1-\phi\gamma} & 0 & \dfrac{-\beta\phi\gamma}{1-\phi\gamma} \end{bmatrix} \begin{bmatrix} p^* \\ r^* \\ r^0 \end{bmatrix} \tag{B.13}$$

The determinant of the matrix is positive, so that the two roots (solutions of (B.14)) are equally signed. Since one of the variables is non-predetermined (*e-p*) and the other is predetermined (π), the transversality condition is not sufficient to pin down a unique dynamic path.

$$\lambda = \frac{1}{2}\left[\frac{\phi(\beta\gamma-\delta)}{1-\phi\gamma} \pm \left[\left(\frac{\phi(\beta\gamma-\delta)}{1-\phi\gamma}\right)^2 - 4\frac{\beta\phi\gamma}{1-\phi\gamma}\right]^{\frac{1}{2}}\right] \tag{B.14}$$

The system can be either globally stable or globally unstable, depending on the sign of $(\beta\gamma - \delta)$. When the system is stable ($\beta\gamma < \delta$), setting the interest rates suddenly and permanently to the international level is a feasible deflationary policy. This is the assumption that was made in the main text. Furthermore, without loss of generality, it has also been assumed that the roots have imaginary parts (i.e. in B.14, the square root term is negative).

Conversely, an unstable model will rule out a sudden and permanent drop in the interest rate to the international level. Rather, the only possible monetary policy will consist of an increase in the interest rate to bring inflation down, followed by a permanent fine-tuning of the policy to keep inflation within bounds.

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Comments on: "A structural model for the analysis of the impact of monetary policy on output and inflation" by Javier Andrés, Ricardo Mestre and Javier Vallés

by Palle Andersen

The main purpose of this paper is to simulate the effects of various changes in monetary policy, using an aggregate macroeconomic model for Spain. The first two sub-sections review the various transmission channels of monetary policy, starting with a change in a monetary aggregate and then turning to changes in interest rates. In this respect three principal differences are highlighted: (i) a *permanent* reduction in monetary aggregate growth is equivalent to a *temporary* change in interest rates; (ii) to emulate the effects of a *reduction* in monetary growth, the equivalent change in interest rates requires an initial *increase*, followed by a reduction later on; and (iii) contrary to an intermediate aggregate target, a framework based on interest rate control lacks a nominal anchor. This is, of course, true but, as discussed below, I would not consider this to be such a serious problem.

The paper then presents the aggregate model, with actual estimates given in Annex A and discussed in Section 1.1. I have some problems with this part. The discussion of wealth effects is not very clear and it is hard to understand how a net debtor country like Spain experiences a rise in net wealth when the currency depreciates. The arbitrage condition applied in estimating the yield curve is also hard to understand and the actual estimate looks rather implausible. Finally, it seems rather odd to have import prices influencing domestic inflation (the GDP deflator) and then estimating the CPI equation using a cointegration relation.

These are, however, minor concerns. My major problems with the paper lie elsewhere:

1. As already indicated, I do not share the authors' concern about the lack of a nominal anchor when the central bank is targeting a nominal exchange rate or the rate inflation. It is, of course, true that an inflation rate target leaves the price level undetermined but I am tempted to say: "So what?". When inflation is as low as it now is in Spain it is hard to believe that anybody would be much concerned about the price level. Moreover, I do not quite understand the authors' treatment of the central bank reaction function. While they recognise that a reaction function would create the nominal anchor, they rule it out on the grounds that this is not the way that Bank of Spain operates. I do not dispute that, but if the Bank has an inflation or exchange rate target, it surely must be reacting to *something* and that *something* must be the equivalent of a reaction function. Finally, the authors seem to slightly misrepresent the policy relevance of a nominal anchor. When a central bank targets the rate of inflation, it essential attempts to anchor expectations to the inflation target. In other words, with such a policy I would view the rate of inflation and not the price level as the policy relevant nominal anchor.[1]

2. My second major problem concerns the conclusion about the transmission of policy changes via movements in the exchange rate. When stating the conclusion, the authors seem to forget that exchange rate response was *imposed* and not the estimated result of a gradual opening of the Spanish economy. Moreover, their assumption that a 2 percentage point change in the interest rate generates a 5 percentage point change in the exchange rate seems *very* high. Would it not have been possible to estimate an exchange rate equation (other economists at the Bank of Spain have been quite successful) and get some solid ground for this conclusion?

[1] It is, of course, true that the rate of inflation is made stationary through targeting, the price level could be I(1). However, it might be recalled that with an aggregate money supply growth target, the money stock is equally likely to be I(1) ("base drift"). Moreover, if a central bank were to target the price level rather than the rate of inflation, there is a high risk of a very volatile monetary policy.

3. My third problem is perhaps a minor one but concerns the simulations based on an initial *reduction* in interest rates as an anti-inflationary strategy. If the ultimate aim is to reduce inflation, an action which initially generates higher inflation, is, as the authors themselves say, unlikely to be regarded as credible. So why have it? I think the paper would have gained by concentrating on the effects of relevant and credible policy changes.

4. Finally, I find an implied sacrifice ratio of only 0.5 much too low for a country like Spain with well known and large labour market rigidities. Given the aggregate nature of the model, labour market rigidities have not been included but for the next version of the model it might be a good idea to extend it to include the labour market and thus enable it to generate more plausible and credible sacrifice ratios.

In short, I regard the paper as a valid attempt to provide simulations in a transparent way for which the authors deserve credit. However, the paper suffers from some self-inflicted problems and overly strong assumptions.