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ISSN: 0213-2710
ISBN: 84-7793-460-6
Depósito legal: M-9885-1996
Imprenta del Banco de España

ABSTRACT

This paper presents a simple macroeconomic model based on Svensson (1994). The model incorporates innovations that provide for a simultaneous explanation of the three basic findings in the empirical literature concerning the effects of the EMS on the levels of exchange rate risk and interest rate risk: the reduction in exchange rate variability when the degree of rigidity in the exchange rate commitment increases; the indetermination in the sign of the behaviour of exchange rate risk when this commitment eases; and, lastly, the possibility that, in some cases, a trade-off exists between exchange rate risk and interest rate risk, and that, in other cases, both move in the same direction.

1. INTRODUCTION

The European Council's Resolution of December 5, 1978 that laid the foundations of the future Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) stated that the System should encourage the creation of "an area of stability in Europe" through "closer monetary cooperation". Stability has generally been understood to mean nominal stability, and, from this standpoint, attention must be paid not only to exchange rate stability but also to the System's impact on the stability of interest rates.

In particular, it is worth asking whether the price for the lower exchange rate risk that presumably occurs within the EMS could be a higher interest rate risk. The possible transfer of risk from exchange rates to interest rates, rests on a fairly simple argument. On the one hand, Bachelor (1983, 1985) argues that modern economies generate a fixed amount of risk, and, therefore, the risk that disappears from the foreign exchange market should reappear in some other macroeconomic variable. On the other hand, the standard monetary models for determining exchange rates point towards the interest rate as the most obvious candidate to receive this transfer.

In any event, the relevance of the problem is underscored when we consider that the possible existence of a trade-off between exchange rate risk and interest rate risk could have important regulatory implications if, as Bachelor (1985) and Artis and Taylor (1993) suggest, the group of economic agents influenced by interest rate risk is larger than the group of agents negatively affected by exchange rate risk.

The possible existence of a trade-off between exchange rate risk and interest rate risk has received appreciable attention in the literature, albeit invariably from an exclusively empirical perspective[1]. However,

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[1] See, for example, European Commission (1982), Padoa-Schioppa (1983), Ungerer el al. (1983, 1986), Rogoff (1985), Artis and Taylor (1988, 1993), Ungerer el al. (1990), Ayuso (1991, 1995), and Pesaran and

there are at least two factors that make it worthwhile to design a theoretical framework to complement the empirical findings.

First, empirical tests run up against the difficulty to isolate the true effect of the exchange rate commitment from other effects, derived not only from the changes in other areas of domestic economic policy but also from the significant changes in the economic setting worldwide. In short, a pure test would require the impossible: a comparison of the risk levels in a given economy that belongs to the System with those in the same -but outside the ERM- economy at the same time. In these conditions, a theoretical framework capable of providing an explanation for the empirical findings can prove very useful.

Second, the empirical results are not conclusive with respect to the relationship between exchange rate risk and interest rate risk. In some cases, there appears to be a trade-off between the two; in others, however, both types of risk move in the same direction. This same indetermination also arises in the analysis of the relationship between exchange rate risk and the width of the fluctuation band allowed in the ERM: a narrower band does not always imply a higher level of exchange risk. Here, again, it is worth constructing a theoretical model that accommodates these findings to help understand their explanatory factors.

Although numerous theoretical models deal with the impact of exchange rate policies on output and price stability (Gros, 1990, Beetsma and van der Ploeg, 1992, Sutherland, 1995), none specifically focuses on an analysis of exchange rate risk or on an analysis of its relationship with interest rate risk. The most notable exception is Svensson (1994), which defends the existence of a trade-off between exchange and interest rate risk that justifies the existence of fluctuation bands around the central parity: the band allows for a certain degree of monetary independence.

In this context, the purpose of this paper is to present a simple macroeconomic model, based on the one proposed by Svensson (1994).

Robinson (1993).

The model incorporates innovations that provide for a simultaneous explanation of the three basic empirical findings obtained in the literature concerning the effects of the ERM on the levels of exchange rate risk and interest rate risk: the reduction in exchange rate variability observed when the degree of rigidity in the exchange rate commitment increases; the indetermination in the sign of the behaviour of exchange rate risk (i.e. variability corrected by credibility, see Ayuso, Pérez-Jurado and Restoy, 1994) when this commitment eases; and, lastly, the possibility that, in some cases, a trade-off exists between exchange rate risk and interest rate risk, and that, in other cases, both move in the same direction. The analysis under this model also helps to discern the relevant variables at play in these empirical findings.

The paper has five sections. In the first two, the proposed model is presented and resolved. The third and fourth sections analyse the behaviour of exchange and interest rate risk under the hypotheses of perfect and imperfect credibility of the exchange rate agreement, respectively. The final section briefly summarises the main findings of the paper.

2. A SIMPLE MACROECONOMIC MODEL

The model presented in this section takes as its starting point the model developed by Svensson (1994), and incorporates three basic innovations that are, as is later seen, decisive in explaining the usual empirical findings. First, the model allows the price level not to be completely flexible. Second, it allows differentiating between supply shocks and demand shocks and, within these, between nominal and real shocks. Lastly, in dealing with the credibility of the central parity, the model allows credibility to depend not only on the position of the exchange rate in the band but also on the level of the domestic interest rate. As discussed later, this dependence is supported by the experience of the recent ERM crises.

The model is summarised in the following set of equations:

$$m_t - p_t = ky_t - \alpha i_t - \omega_t^m \tag{1}$$

$$y_t = -\eta i_t + \delta(s_t + p_t^* - p_t) + \omega_t^y \tag{2}$$

$$p_t = p_{t-1} + \phi(y_t - \bar{y}) + \omega_t^p \tag{3}$$

$$i_t = i_t^* + E_t(s_{t+1} - s_t) \tag{4}$$

$$x_t \equiv s_t - c_t \tag{5}$$

$$E_t(c_{t+1} - c_t) = \gamma_1 x_t + \gamma_2 i_t \tag{6}$$

$$m_t = m_{t-1} + u_t \tag{7}$$

where m_t, p_t, y_t and $\bar{y}$ are (the logarithms of) the domestic money supply, price level, income level and full-employment income level, respectively, i_t is the (logarithm of one plus the) domestic interest rate, and s_t and c_t represent the (logarithm of the) market exchange rate and (the logarithm of) its central parity, each expressed in units of the domestic currency per unit of foreign currency. In turn, i_t^* and p_t^* are the corresponding foreign variables, which, assuming the country is small, will be considered exogenous. In order to include a typically external shock, the level of external prices is normalised to zero, and the foreign exchange rate is assumed to be purely random, i.e.:

$$i_t^* = \omega_t^* \tag{8}$$

The different ω's represent shocks that are independent and identically distributed over time. Lastly, all the parameters in the model are assumed to be non-negative.

The interpretation of equations (1) to (7) is simple. The first equation is a classic LM in which ω_t^m is a domestic shock of a monetary nature. The second is an IS in which, first, the relevant rate of inflation to determine the real interest rate is the equilibrium rate of inflation - which, in this case, is zero. This assumption is relatively common and avoids the possibility of explosive solutions (see, for example, Beetsma and van der Ploeg, 1992). Secondly, it allows the non-verification of the purchasing power parity relationship. And, lastly, ω_t^y is interpreted as a domestic shock of a real nature, typically as a fiscal shock[2].

Equation (3) is a Phillips curve in which an income level above that of full employment leads to inflation, and output below this level leads to deflation. The parameter ϕ measures the degree of price flexibility, and ω_t^p is interpreted as a supply shock, such as a fall in productivity or a wage shock, for example.

Equation (4) is the known relationship of uncovered interest rate parity[3], and equations (5) and (6) characterise the credibility problem, which, as demonstrated in Ayuso et al. (1994), plays a crucial role in explaining the behaviour of exchange rate risk. Thus, the exchange rate commitment becomes less credible the more the market rate moves away from the central parity. Note that, given the equation's linear nature, this method of modelling the lack of credibility is compatible both with the existence of an only partial "honeymoon" effect, in line with Krugman (1991), and with the existence of a "divorce" effect, in line with Bertola

[2] It could also be interpreted in terms of a shock to foreign prices, since these have been normalised to 0.

[3] Ayuso and Restoy (1996) find that, in the case of the ERM, the possible risk premia are quantitatively limited. In any event, the existence of a risk premium could be incorporated with no difficulty (as long as it does not depend on the levels of the endogenous variables) by reinterpreting i^* as an interest rate net of risk.

and Caballero (1992). In any case, both works provide a justification for the presence of x_t in equation (6).

In addition, credibility is made to depend on the level of the domestic interest rate. The presence of the interest rate in equation 6 reflects the economic policy dilemma that arises when the interest rate level, which the monetary authorities must maintain for the exchange rate to remain in the exchange rate commitment, is too high from the standpoint of the domestic cyclical position. If this dilemma is perceived as such by the public, a rise in the interest rate -while possibly attracting foreign capital and, in this way, causing the exchange rate to appreciate- will also lead to a loss of credibility of the current central parity, with the resulting tendency to depreciate. The crisis that shook the ERM as from the summer of 1992 is a good example of this type of situation, with attacks on the currencies of countries that had carried out as many as two devaluations (as the case of the peseta in May 1993) but had maintained relatively high interest rates amid slack, and even sliding, domestic demand. In fact, in the more recent literature on exchange rate crises, the level of interest rates figures as the pivotal variable in explaining why fixed or quasi-fixed exchange rate systems collapse. Examples of this literature are the works of Bensaid and Jeanne (1994), Obstfeld (1994), and Ozkan and Sutherland (1994).

According to equation (6), credibility depends on variables that are endogenous in the model (x_t and i_t) and is, therefore, ultimately determined by the behaviour of the central bank. It is likely that variables that are exogenous to the model (political events, natural disasters, incorporation of new members in the exchange rate agreement, etc.) also have some effect on credibility. However, at least with respect to the objectives of this paper, the exogenous component of credibility plays no role at all, whence its exclusion from this analysis.

Lastly, equation (7) depicts the behaviour of the monetary authority, who determines the money stock by means of the control variable u_t, which reflects not only open-market transactions but also possible interventions in the foreign exchange market. In this respect, it will be assumed that the central bank chooses the values of u_t that minimise the weighted sum of the fluctuations in price, income, interest rate and exchange rate levels. Concretely, since the variables have been normalised such that the mean of the different shocks is null, the function that the central bank will minimise is the following:

$$E_1[\sum_{t=1}^{\infty} \beta^t (q_p p_t^2 + q_y y_t^2 + q_i i_t^2 + q_x x_t^2)] \tag{9}$$

The behaviour of the monetary authority calls for several observations. The presence of prices and income in equation (9) probably does not require any particular comment. It should simply be noted that, in general, the greater autonomy of the central bank will tend to be reflected in a relatively larger value of q_p than that of q_y. The stabilisation of the interest rate is also a frequent target of the monetary authority (see, for example, Goodfriend, 1987 and 1991). The presence of the exchange rate -or, more specifically, of its deviation from its central parity- does, however, require a more detailed explanation.

First, it should be emphasised that the existence of fluctuation bands is not explicitly modelled in equations (1) to (9). The explicit modelling of the bands would give rise to a non-linear intervention rule that would considerably complicate the problem. Iustead, a linear credibility rule (like the one in equation 7) and the presence of x_t in the target function allow, as we shall see, for the application of dynamic optimisation tools in a linear-quadratic context. As Svensson (1994) points out, given the solution of the model with x_t in equation (9) it is possible to define implicit bands in terms of the probability assigned to the fact that the exchange rate could lie outside these bands. By way of example, if the exchange rate follows a normal distribution, a band defined as ±3 standard deviations implies a probability of less than 0.3% that the exchange rate could lie outside this band. In any event, given the central banks' common practice of intervening not so much at the limits of the bands but rather within them (see Mastropasqua, Micossi and Rinaldi, 1988), it is reasonable to believe that an approximation of the explicit bands through a linear dirty float rule and implicit bands probably suffices. The empirical works of Lindberg and Soderlind (1992) for the Swedish case confirm this impression.

Starting from this portrayal of the exchange rate commitment in terms of implicit bands, the parameter q_x reflects the width of these bands: the greater q_x , the lesser the exchange rate variability and, consequently, the lesser the width of the bands or, what is the same, the greater the rigidity of the exchange rate agreement. Thus, the exchange rate appears in equation (9) as a way of approximating the monetary authority's institutional commitment to exchange rate stability.

Second, it should be noted that, rather than the variability of the exchange rate (s_t), what appears is the variability of its deviation from the central parity (x_t). However, given equation (9), it follows that the central parity is not an instrument of monetary policy. The only instrument available to the monetary authority for meeting its objectives is u_t. Given that the central parity remains constant, both variabilities are, from its point of view, equal. But, from the public's viewpoint, the two variabilities could be different insofar as the exchange rate commitment is not perfectly credible.

The reason why the central parity stays constant in the model stems from the fact that the changes in the central parity are not relevant for the trade-off between exchange rate risk and interest rate risk, whereas the expectations of agents about these changes definitely are relevant. From this standpoint, the inclusion of a stochastic process for the central parity consistent with equation (6) would complicate the analysis without adding anything substantial. As in Svensson (1994), given the constancy of the central parity, the credibility problems depicted in equation (6) can be interpreted in terms of the central bank's difficulty in convincing agents of the sounduess of its commitment to exchange rate stability (and not in terms of the weakness of the same)[4].

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[4] Although this situation in which the central bank maintains the parity and agents do not expect it to do so in the future cannot continue indefinitely.

3. THE NUMERICAL SOLUTION OF THE MODEL

Starting from equation (9) and the restrictions imposed by the set of equations (1) to (8), it is possible to analyse whether or not a trade-off exists between exchange rate risk and interest rate risk by simply changing the value of q_x and comparing the results of the optimisation problem that the central bank faces in each case.

The minimisation of (9) subject to restrictions (1) to (8) constitutes a classic optimisation problem in a linear-quadratic context in which one variable, the exchange rate, is forward-looking. Thus, let us represent as X_t the vector of variables which, at time t, are exogenous or predetermined:

$$X_t' = [\omega_t^p, \omega_t^m, \omega_t^y, \omega_t^*, c_t, y_{t-1}, p_{t-1}, x_{t-1}, i_{t-1}, m_{t-1}]$$

and as Z_t the enlargement of this vector with the model's only forward-looking variable, x_t:

$$Z_t' = [X_t', x_t]$$

A little algebra allows the above optimisation programme to be rewritten in the following terms[5]:

$$\underset{\{u_t\}_{1\ldots\infty}}{\text{MIN}} \quad E_1\left[\sum_{t=1}^{\infty} \beta^t (Z_t'QZ_t + Z_t'Uu_t + u_t'UZ_t + u_t'Ru_t)\right]$$

subject to the linear restriction

[5] Appendix 1 gives the details of the specific form taken by the different matrices that appear below.

$$\begin{bmatrix} X_{t+1} \\ E_t x_{t+1} \end{bmatrix} = AZ_t + Bu_t + \begin{bmatrix} \omega_{t+1} \\ 0 \end{bmatrix}, \quad t=1,2,\ldots$$

The above programme is a variant of the standard minimisation programme of a quadratic function subject to a linear constraint. This variation stems from the fact that one of the variables of the state vector at time t (the deviation of the exchange rate from its central parity) is neither exogenous nor predetermined at that moment, but instead depends on the expectations about the future of other variables. Oudiz and Sachs (1985) and Backus and Driffill (1986) describe an algorithm for obtaining the numerical solution of this variant of the problem that, in the general case, cannot be resolved analytically.

The presence of forward-looking variables poses a classic problem of time consistency (see Kydland and Prescott, 1977), such that the final solution will depend on the central bank's capacity to commit itself convincingly to follow in the future the monetary rule that resolves the optimisation programme in the present[6]. Insofar as this paper does not analyse the central bank's credibility problems related to the monetary rule[7,8], it is assumed that no mechanism exists whereby the central bank can commit itself to maintaining the monetary rule in the future. In these conditions, the central bank optimises each period, and the solution of the programme corresponds to what Backus and Driffill (1986) call the discretionary solution. Appendix 2 presents a brief summary of the method proposed by these authors for resolving numerically the optimisation programme in the discretionary case.

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[6] Note that, here, time consistency refers to decisions on u_t, not the time consistency relative to decision on c_t discussed in the text.

[7] Note that the monetary rule (7) is known and believed by the public, but the "exchange rate rule" ($-c_t$ = constant) is not.

[8] In the same respect, the possible existence of an effect related to an anti-inflationary reputation gain is not taken into consideration. For this aspect, see Weber (1991, 1992), Giavazzi and Pagano (1988), and Revenga (1993).

The model's numerical solution requires specifying the values taken by its parameters and those which characterise the distribution of the different shocks. Thus, to determine whether or not a trade-off exists between exchange rate risk and interest rate risk, we carried out a series of normalisations and set certain values for the parameters in order to create a base scenario. By altering the values of this scenario, it will be possible to analyse not only the existence of the aforementioned trade-off, but also its sensitivity to changes in the basic characteristics of the economy. The values that make up this base scenario are discussed below.

To start with, the full employment income level ($\bar{y}$) , and the external price level (p^*), are normalised to zero. The variance of the different shocks is normalised to 1. As to the LM and IS parameters, both k and α are set equal to 1; η to 0.2, and δ to 0.4. Prices in this base scenario are considered to be flexible (ϕ = 1000), and the weightings of price fluctuations (q_p), the interest rate (q_i) and income (q_y) are set at 1, 0.5 and 0, respectively. Naturally, there is a certain degree of arbitrariness in the choice of the parameters' values.

An attempt is made to minimise the possible effects of this arbitrariness in two ways. First, in very broad terms, the values chosen do not excessively veer from the scant empirical evidence available. Thus, the LM parameters are consistent with the available estimations of money demand functions for several of the System's member countries. The limited sensitivity of the real variables to changes in the interest rate (less than their sensitivity to changes in real exchange rates) is also a widely accepted fact. Moreover, the absence of the variability of output in the target function (q_y =0) not only reflects the greater attention of monetary authorities to the problem of price stability that has recently been observed in EU countries, but also the increasingly greater independence of the central banks in these countries[9]. Second, an attempt is made to minimise the possible biases derived from the choice of specific parameters by carrying out a detailed analysis of the sensitivity of the results to changes in these parameters.

[9] By way of example, the Autonomy Law of the Banco de España entered into effect in June 1994.

The model's solution for different values of q_x allows us to obtain the optimum combinations of exchange rate and interest rate risk according to varying degrees of exchange rate commitment. The representation of these combinations will show whether or not a trade-off exists between the two types of risk. In principle, it will be assumed that the exchange rate commitment is perfectly credible, whence both γ_1 and γ_2 in equation (6) are considered equal to zero. As shown in Ayuso at.al (1994), under perfect credibility 'observed' variability and risk coincide. As will be commented later, this is not the case if credibility is imperfect.

4. THE RELATIONSHIP BETWEEN EXCHANGE RATE AND INTEREST RATE RISK UNDER PERFECT CREDIBILITY

4.1 On what does the existence of a risk trade-off depend?

Chart 1 shows the optimum combinations of volatility (concretely, of standard deviations) that correspond to different degrees of rigidity in the exchange rate commitment for the parameters in the base scenario. Increases in the value of q_x (narrowing of the implicit bands) cause shifts throughout the curve from right to left. As can be seen, there is a first tranche in which the increases in the commitment's rigidity reduce both the volatility of the exchange rate and the volatility of the interest rate. However, beyond a certain level of exchange rate stability, further increases in stability can only be achieved if increases in interest rate volatility are accepted. The obvious question that arises now refers to the conditions that determine whether, in terms of the curve in Chart 1, the positive or the negative slope predominates.

In this respect, since the variance in any of the variables will ultimately depend on the variance in the shocks that affect the economy, it is worthwhile inquiring about the effects of each one separately. Recall that the distinction between several types of shock is one of the innovations of this model with respect to Svensson's. Moreover, the analysis gives us a better understanding of the basic mechanisms that govern the behaviour of the relevant variables: the exchange rate and the interest rate.

Charts 2.1 to 2.3 show the relationship between the relevant variances when one of the shocks dominates[10]. Concretely, for each case, the variance in the related shock was set equal to 100. Note, first, that the comparison of Chart 2.1 with Chart 1 reveals that the domestic monetary shock is not relevant in determining whether or not the trade-off occurs. The explanation for this result is the following: equation (1) shows that a domestic monetary shock can be fully counteracted by a contrary movement in the money supply, without affecting any of the remaining variables of the equation (and, by extension, of the system). Therefore, greater monetary shocks will solely translate into a greater variability in the stock of money. Thus, the result is easily explained in terms of the central bank's capacity, within the framework of the model, to control the money supply.

In turn, the comparison of Charts 1 and 2.2 shows that, when real domestic shocks predominate, the trade-off vanishes entirely, and both variances move in the same direction. Equation (2) is the key relationship in explaining this result. Accordingly, in the event of a real shock, the monetary authority cannot simultaneously reestablish the income and interest rate levels as it could in the presence of a monetary shock. Moreover, equation (3) limits its scope for action, because, if the monetary authority allows a reduction in the interest rate, it will at the same time have to allow a depreciation in the exchange rate, which would generate expectations of a future appreciation to offset the new interest rate differential. Therefore, when the monetary authority reacts to the shock by attempting to stabilise the exchange rate, it is, in fact, stabilising the interest rate, and vice versa.

Lastly, if shocks to the external interest rate predominate (see Chart 2.3), the trade-off is total. Once again, equation (3) provides an explanation of this phenomenon. Thus, faced with a shock to a foreign interest rate, the monetary authority can choose between absorbing the

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[10] Since prices are flexible in the base scenario, ω_t^p loses the interpretation in terms of a supply shock that it was given in section 2. In any event, increases in its variance do not affect the trade-off, and, as expected, they translate exclusively into increases in the income variance.

effects of the shock by altering the domestic interest rate or by altering the exchange rate, that generates the related expectations of future movement. The greater the importance that the central bank confers to exchange rate stability, the lesser the exchange rate movements that it is willing to accept and, consequently, the greater the sacrifices in terms of interest rate instability that it will have to accept.

In sum, the simple analysis of Charts 1 and 2 sheds light on the conditions that favour the existence of a trade-off between exchange rate volatility and interest rate volatility: the greater the weight of the external interest rate shocks in relation to real domestic (demand) shocks, the greater the likelihood that a trade-off exists. Chart 3, which depicts the combinations of equilibrium variances for different values of $V(\omega^{*})/V(\omega^{Y})$, illustrates this point, and it also shows that the trade-off is more unfavourable (a higher level of interest rate volatility associated with the same level of exchange rate volatility), when the relative weight of the external interest rate shocks increases.

Given this relationship between the relative importance of the shocks and the existence of a trade-off, it is possible to interpret the changes in the degree of concern for exchange rate stability (changes in q_x) in terms of changes in the relative attention that the monetary authorities pay to the different shocks. Thus, at a null level of q_x, the central bank does not react at all to external shocks, which are absorbed by exchange rate movements, and confines itself to responding to real domestic shocks. Increases in q_x would be interpreted in terms of a progressively greater reaction to shocks to the external interest rate, to the detriment of the attention paid to domestic shocks. In an initial stage, the reaction to domestic shocks would continue to dominate, equation (2) would be the relevant expression for determining the relationship between exchange rate volatility and interest rate volatility, and there would be no trade-off. Beyond a certain level, however, the reaction to foreign interest rate shocks would come to dominate the central bank's actions, whence equation (4) would become the relevant equation for the analysis, and, consequently, the trade-off would arise. This interpretation of the changes in q_x, in the sense of the monetary authority's greater attention to nominal external shocks, is quite coherent with the general intuition regarding the significance of an exchange rate commitment.

4.2 The effects of changes in the model's parameters

In order to bring the range in which the two volatilities rise closer to the range in which the move in different directions, the quotient $V(\omega^*)/V(\omega^\epsilon)$ was given a value equal to 2. The most relevant results are summarised below.

Chart 4 illustrates the effect of the changes in one of the most relevant parameters of the model: the sensitivity of investment to the interest rate, η. As can be seen, the greater this sensitivity is, the lesser is the level of the volatility of the interest rate associated with each level of exchange rate volatility, without the relationship between the two losing its U shape. Here again, this result seems quite sensible. Given a certain level of commitment to exchange rate stability and regardless of the nature of the shock (external in the trade-off zone or domestic in the rising arm of the U), the interest rate movement that must be accepted to absorb this shock will be lesser, the greater the real effect of this movement is.

This same intuition helps to explain the results in Chart 5: the more sensitive the external balance is to changes in the level of the real exchange rate δ, the greater the real effect of the movement in the exchange rate that allows a given level of commitment to exchange rate stability and, therefore, the lesser the additional movement needed in the interest rate.

Changes in the parameters of the LM, however, do not affect the trade-off. The same reasoning that explains the irrelevance of the monetary shocks helps to explain that the greater sensitivity of money demand to changes in income (k) or in the interest rate (α) simply translates into changes in the supply of money that much be injected in or drained from the economy to achieve the desired movement.

The sacrifice in terms of interest rate volatility that must be accepted in exchange for a certain degree of exchange rate stability is all the greater, the more flexible prices are. Chart 6 shows the changes in the relationship between volatilities amid changes in the parameter ϕ. This result, which seems somewhat counter-intuitive, can be explained in the following terms. Faced with a given shock, a greater degree of price stickiness allows keeping the full employment income level at bay for a longer time. Therefore, given a certain level of exchange rate stability, the movements in the interest rate level needed to absorb the shock can be spaced over a longer time. Consequently, a significant change can be replaced by a succession of small changes, and the variance is reduced. Naturally, the counterpart is that the volatility levels of income and prices increase considerably as the value of ϕ diminishes.

Lastly, Chart 7 shows the effects of an increase in the relative importance that the central bank attaches to the stability of output in a context of sticky prices -concretely, where $\phi = 1$[11]. In this case, as seen in the chart, the terms of the relationship between volatilities become more unfavourable: higher levels of interest rate volatility for the same level of exchange rate volatility arise when there is an increase in the relative weight of real stabilisation in the target function of the central bank. Intuitively, the result is the following: faced with a given shock -real and domestic or external- and after determining the portion of the shock that can be absorbed by the exchange rate (q_x) and prices (q_p), a greater value of q_y means that the interest rate must absorb a greater portion of the shock, to the advantage of the income level.

To summarise, it can be said that, in a context of perfect credibility of the exchange rate commitment, the existence of a trade-off between interest rate volatility and exchange rate volatility will be all the more probable, the greater the relative weight of the foreign interest rate

[11] Logically, if prices are completely flexible, the income level will be stable around its full employment level, and, therefore, changes in the parameter q_y have no effect at all. The less flexible prices are, the greater the changes that arise in the relationship between exchange rate and interest rate volatility, although these changes only acquire a certain relevance for very low levels of flexibility.

shocks in terms of real domestic shocks. Likewise, the level of interest rate volatility that will have to be accepted in exchange for achieving a given level of exchange rate stability is all the greater, the less sensitive investment is to interest rates, the less sensitive net external demand is to the real exchange rate, the more flexible prices are, and the lesser the central bank's relative concern for income stabilisation.

5. IMPERFECT CREDIBILITY OF THE EXCHANGE RATE COMMITMENT

5.1 Exchange rate and interest rate volatility under imperfect credibility

In the terms of equation (6), the credibility problems are modelled through the parameters γ_1 and γ_2 . In accordance with this equation, a positive value of γ_1 implies a loss of credibility due to the exchange rate's deviation from its central parity. Chart 9 shows how the relationship between the variances in exchange and interest rates moves in response to changes in the value of γ_1 . Several effects must be distinguished.

First, focusing on the zone in which a trade-off takes place (namely, in the falling arm of the U), the greater the information value that agents assign to deviations in the exchange rate, the worse the conditions are in which the trade-off takes place. The explanation of this result is as follows: faced with a shock to the external interest rate -here we are in the trade-off zone- and given a certain level of concern for exchange rate stability, the central bank finds that the deviations which it could allow in the exchange rate under perfect credibility to prevent the interest rate from having to bear the entire weight of the adjustment lead to a loss of credibility in the maintenance of the parity. This loss of credibility amplifies the impact of the shock on the interest rate insofar as the latter must undergo a greater correction. Therefore, increases in the parameter γ_1 shift the falling arm of the U upwards and towards the right.

Second, in the zone in which both variances move in the same direction, the existence of credibility problems improves the relationship between the two. This result, counter-intuitive at first sight, is, however, consistent with the logic of the model. Thus, as noted, the rising tranche of the U can be interpreted as a tranche in which the reactions to real domestic shocks predominate. Under perfect credibility, amid a real domestic shock, a given depreciation of the exchange rate should be accompanied, as a result of equation (3), by a reduction in the interest rate which, on the one hand, absorbed part of the shock and, on the other, offset the expectations of a future appreciation generated by the movement in the exchange rate. Now, however, the very depreciation of the exchange rate generates, through equation (6), devaluation expectations that act as a counterweight to the expectations of a future appreciation. As a result, the interest rate must be reduced less, thus explaining the improvement in the terms of the relationship between the variances.

Lastly, Chart 8 shows that increases in the information content of x_t increase the range of values of q_x for which the trade-off is produced. The intuition of this result is that the less credible the exchange rate agreement is, the greater the relative attention that the central bank should pay to external shocks in dealing with the same target of economic stability.

As to the credibility problems associated with the economic policy dilemma (positive values of γ_2), Chart 9 shows how, unlike what occurred in the previous case, increases in the parameter γ_2 cause the curves to shift upwards, but without crossing each other, thus implying more unfavourable risk combinations in all cases. Note that, contrary to what occurred when credibility depended on x_t, in the rising tranche of the curve the relationship between the two tranches also worsens. In this case, amid a real domestic shock that requires, as before, a certain depreciation in the exchange rate and also a reduction in the interest rate, it turns out that, when γ_2 is positive, this interest rate movement heightens the expectations of an appreciation even more than in the case of perfect credibility. Therefore, unless there is a willingness to accept a greater alteration in the exchange rate, the interest rate must be reduced further. Naturally, for the situation not to become explosive, the parameter γ_2 must be lower than 1.

5.2 Differences between volatility and risk

Throughout the previous subsection, the term risk was avoided, using instead the term volatility. This is not a chance substitution, because the existence of imperfect credibility introduces a difference, at times substantial, between the two.

In this respect, the incorporation of equation (6) means that the central bank and individuals have a different perception of the variance in the market exchange rate s_t. Thus, whereas in the case of the former the variances of s_t and x_t coincide, in the case of individuals, who assign a non-null probability that the central parity will change, the two variances differ. This fact allows for a differentiation between the exchange rate variability that the agents "observe" -i.e. volatility-and the relevant variance for determining the risk they perceive -i.e. risk. Thus, since the monetary authority does not change the central parity, the agents observe that

$$Var(s_{t+1}) = Var(x_{t+1}+c_{t+1}) = Var(x_{t+1}) \quad (10)$$

However, the variability of the market exchange rate that they anticipate is

$$\begin{gathered} Var(s_{t+1}) = Var(x_{t+1}+c_{t+1}) = \\ Var(x_{t+1}) + Var(c_{t+1}) + 2Cov(x_{t+1},c_{t+1}) \end{gathered} \quad (11)$$

Thus, subtracting equation (10) from equation (11) yields the correction term that must be added to the term referred to as volatility (the variance obtained on the basis of the exchange rate's observed behaviour) to quantify the exchange rate risk in the presence of imperfect credibility.

Therefore, the consideration of positive values of γ_1 and γ_2 allows for an analysis of whether, in the framework of the previous model, a rise in the observed exchange rate variability and a decrease in exchange rate risk can be recorded simultaneously, as found in Ayuso et al. (1994). In principle, the existence of a trade-off between the volatilities of the exchange rate and the interest rate, together with the effects of each on credibility, points towards the possibility that, at least beyond a certain level, the improvements in credibility derived from greater exchange rate stability could be amply counteracted by the negative impact on this credibility produced by the larger swings in the interest rate. Note that, in the context of Svensson's model it is not possible for a difference to arise in the behaviour of exchange rate volatility and risk.

Equation (6) only provides information on the conditional average of the central parity. More structure must be incorporated in the model to obtain information on the conditional variance of s_t. For the sake of symmetry with the analysis in Ayuso et al. (1994), it will be assumed that the process which, in the view of agents, the central parity follows is:

$$c_{t+1} = \begin{cases} c_t , & \text{prob.}=1-q \\ c_t+d_t, & \text{prob.}=q \end{cases} \qquad (12)$$

I.e. agents assign a probability q that there will be a change in the central parity of a magnitude of d_t. For this process to be consistent with equation (6), it must therefore hold that

$$d_t = \frac{1}{q}(\gamma_1 x_t + \gamma_2 i_t)$$

Given the difficulties of endogenising this probability within the linear-quadratic context in which the study is developed, probability q is considered exogenous[12]. In the presentation of the model and, more concretely, in the discussion of equation (6), we noted the possibility that factors exogenous to the model could also affect the credibility assigned by agents to the exchange rate commitment. Consequently, q would represent the average level of the effect of these factors.

If the agents do not expect a simultaneous jump in x_t and in c_t, it is easy to prove that the term in covariances of equation (11) disappears and that the correction term which must be added in equation (10) to calculate exchange rate risk in the context of this model (the mean value of the conditional variance of the future central parity) takes the following form:

$$E[V(c_{t+1}|q\neq 0)] = (\frac{1}{q}-1)[\gamma_1^2 V(x_t)+\gamma_2^2 V(i_t)+2\gamma_1\gamma_2 Cov(x_t,i_t)]$$

Chart 10 shows the values of the observed variability of the exchange rate and the levels of exchange risk corresponding to a scenario in which $Var(\omega_t^*)/Var(\omega_t^y) = 10$ (such that a trade-off exists if credibility is perfect), and the parameters γ_1 and γ_2 take the same value: 0.4. The rest of the parameters take the values of the base scenario. As can be seen, the volatility of the exchange rate diminishes monotonously with q_x. However, the level of exchange risk is U-shaped. In other words, as of a certain level of commitment to exchange rate stability, an easing in this commitment, even though translating into a rise in exchange rate volatility, can lead to a gain in credibility that offsets the previous effect, such that the final result is a reduction -and not an increase- in the exchange rate risk. This situation will tend to occur at lower degrees of commitment (lower values of q_x), the greater γ_2 is in relation to γ_1 and the lower the probability q is.

[12] Drazen and Masson (1994) give an interesting example of the endogenisation of the probability of realignments based on an apprenticeship rule after Bayes' formula, in the framework of a Barro-Gordon model.

The obvious implication of this result is that, from the standpoint of the minimisation of exchange risk, it might be advisable to refrain from excessively tightening the degree of rigidity of the exchange rate commitment implicit in an agreement such as the ERM, if the new commitment is not credible enough to the economic agents. If there are problems of credibility, a more relaxed agreement (wider bands) could reduce the risk level even though it raises the level of volatility.

6. SUMMARY AND CONCLUSIONS

In its Resolution of December 5, 1978, the European Council set as the objective of the nascent European Monetary System the promotion of the nominal stability of the member economies. Since then there has been an obvious interest in learning, first, whether membership of the System's exchange rate mechanism has led to an easing in the risk associated with the behaviour of the participating currencies' exchange rates, and, second, if so, whether this reduction in exchange rate risk has translated into a simultaneous rise in the interest rates risk. In this paper, the above-mentioned problem is addressed from a theoretical perspective, presenting a simple macroeconomic model that allows for an estimation of the optimum risk combinations from the viewpoint of the monetary authority, starting from the numerical solution of a relatively standard linear-quadratic optimisation programme, with forward-looking variables.

The model's results indicate that the key explanatory variables in the relationship between the two types of risk and the exchange rate commitment adopted by the authorities are the degree of credibility of this commitment and the relative importance of the different shocks that affect the economy. Thus, even though the greater width of the bands (including free flotation in one particular case) inevitably increases the variability observed in the behaviour of the exchange rate, the model shows that, beyond a certain level, an additional widening of the bands could, nonetheless, entail a lesser exchange risk. This will be the case if the credibility of the new regime runs up against the existence of economic policy dilemmas derived from differences in the interest rate needed for the maintenance of exchange rate stability and the interest rate that the domestic cyclical position requires. The presence of these dilemmas -one of the model's main contributions- is supported by the attacks unleashed during the crisis in the ERM on the currencies of economies that did not see significant losses in competitiveness (or had solved them after one or two devaluations), but maintained high interest rate levels in relation to their cyclical position.

As to the relationship between exchange and interest rate risk under different degrees of rigidity in the ERM, the model's results show that a trade-off relationship will tend to appear in those cases in which external interest rate shocks predominate over real domestic shocks. Moreover, this trade-off will be all the more unfavourable, i. e. will imply a greater level of interest rate risk for the same level of exchange rate risk, the lesser the elasticities of aggregate demand to the interest rate and the real exchange rate, the greater the flexibility of prices, the greater the central bank's concern for the stability of the level of output, the greater the dependence of the credibility of the exchange commitment on the exchange rate's position in the band, and the greater the relevance of the existence of the aforementioned economic policy dilemma.

The paper's findings, briefly summarised in the preceding paragraphs, have several interesting implications for economic policy. First, one conclusion of the paper is that a system of fixed but also adjustable exchange rates, like the ERM, can contribute notably to reducing exchange risk. This stabilising effect, however, is not automatically derived from membership of the exchange rate agreement. For this to occur, economic agents must perceive ERM membership as sustainable. Thus, the minimisation of exchange risk requires a certain equilibrium between the degree of rigidity of the commitment (measured in terms of the width of the fluctuation bands) and the effects of this rigidity on the agreement's credibility. In this respect, relatively wide bands could be preferable in a framework in which additional limits on exchange rate movements are not perceived as credible by economic agents. In any event, according to the paper's findings, the optimum width of the fluctuation band would appear to differ greatly from the band width that would correspond to a free float system.

Second, the paper's results also show that the reduction in exchange risk through a formal commitment to exchange rate stability exacts a price in terms of greater interest rate risk only for those economies whose performance is very dependent on the shocks that asymmetrically affect the anchor country (or countries) of the exchange rate agreement. For economies in which external interest rate shocks and (real) domestic demand shocks play a less unequal role, there is leeway for reducing both types of risk simultaneously via the replacement of a free float exchange rate system by membership of an exchange agreement such as the ERM. This leeway will be all the greater, the more relevant the role played by domestic shocks and also the greater the degree of credibility assigned by agents to the maintenance of the exchange rate commitment in the future.

APPENDIX 1

The matrices of the central bank's optimisation problem take the following form:

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ & & & - & - & A_y & - & - & & & \\ & & & - & - & A_p & - & - & & & \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ & & & - & - & A_i & - & - & & & \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ & & & - & - & A_x & - & - & & & \end{bmatrix}$$

where

$$A_y = [\Omega, \Omega\frac{\eta}{\alpha}, -\Omega(\delta+\frac{\eta}{\alpha}), 0, \Omega\delta, 0, -\Omega(\delta+\frac{\eta}{\alpha}), 0, 0, \Omega\frac{\eta}{\alpha}, -\Omega\delta]$$

$$A_p = \phi A_y + [0,0,1,0,0,0,1,0,0,0,0]$$

$$A_x = \frac{(k+\phi)(1-\gamma_2)}{\alpha}A_y + [0, \frac{\gamma_2-1}{\alpha}, \frac{1-\gamma_2}{\alpha}, -1, 0, 0, \frac{1-\gamma_2}{\alpha}, 0, 0, \frac{\gamma_2-1}{\alpha}, 1-\gamma_1]$$

$$A_i = \frac{1}{1-\gamma_2}A_y + [0,0,0,\frac{1}{1-\gamma_2},0,0,0,0,0,0,\gamma_1-1]$$

$$\Omega = \Gamma\frac{1}{1+\delta\phi}, \quad \Gamma = [1+\frac{\eta(k+\phi)}{(1+\delta\phi)\alpha}]^{-1}$$

$$B' = [0,0,0,0,0,B_y,B_p,0,B_i,1,B_x]$$

$$B_y = \Omega\frac{\eta}{\alpha}$$

$$B_p = \phi B_y$$

$$B_x = \frac{(k+\phi)(1-\gamma_2)}{\alpha}B_y - \frac{1-\gamma_2}{\alpha}$$

$$B_i = \frac{1}{1-\gamma_2}Bx$$

- o -

$$Q = q_y A_y' A_y + q_p A_p' A_p + q_i A_i' A_i + q_x A_x' A_x$$

- o -

$$U = q_y A_y' B_y + q_p A_p' B_p + q_i A_i' B_i$$

- o -

$$R = q_y B_y' B_y + q_p B_p' B_p + q_i B_i' B_i$$

- o -

and, lastly,

$$\omega_t' = [\omega_t^{\nu}, \omega_t^{\theta}, \omega_t^{\epsilon}, \omega_t^{*}, 0,0,0,0,0,0]$$

- o -

APPENDIX 2[13]

The maximisation of (9) subject to the set of linear restrictions in (1) to (8) provides the optimum sequence of interventions by the central bank $\{u_t\}_{t=1,2..}$. However, the optimality of this sequence is subject to a classic problem of time consistency: after announcing the rule at time t, the monetary authority has, at time t+1, a clear incentive to deviate from the same by reoptimising and announcing a new rule. In these conditions, if there is no mechanism that guarantees the commitment by the central bank, the variables, which, at t, are forward-looking, will depend exclusively on the variables predetermined at the same instant t. I.e., in assuming discretion in the exercise of monetary policy, a new linear restriction must be added, which takes the form:

$$x_t = CX_t$$

where C is an endogenously determined vector.

Oudiz and Sachs (1985) and Backus and Driffill (1986) prove that the stationary solution to the above optimisation programme is

$$\begin{aligned} u_t &= -F^*X_t \\ X_t &= (A^*-B^*F^*)X_{t-1} + \omega_t \\ x_t &= CX_t \end{aligned}$$

where A^*, B^*, F^*, C and V^* (defined below) are the respective limits of the sequences A_t, B_t, F_t, C_t and V_t when $t \to -\infty$. These sequences are constructed as follows.

Let us assume that we know C_{t+1} and V^*_{t+1} . C_t and V^*_t are obtained in the following way. First, the matrices A, B, Q and U are decomposed in consonance with the breakdown of Z_t in terms of X_t and x_t:

$$A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, \quad Q = \begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix}, \quad B = \begin{bmatrix} B_1 \\ B_1 \end{bmatrix}, \quad U = \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$$

[13] This appendix very closely follows Appendix 1 in Svensson (1994).

The matrices D_t and G_t are then constructed:

$$D_t = (A_{22} - C_{t+1}A_{12})^{-1}(C_{t+1}A_{11} - A_{21})$$

$$G_t = (A_{22} - C_{t+1}A_{12})^{-1}(C_{t+1}B_1 - B_2)$$

On the basis of D_t and G_t, it follows that

$$A_t^* = A_{11} + A_{12}D_t$$

$$B_t^* = A_{12}G_t + B_1$$

$$Q_t^* = Q_{11} + Q_{12}G_t + D_t'Q_{21} + D_t'Q_{22}D_t$$

$$U_t^* = Q_{12}G_t + D_t'Q_{22}G_t + U_1 + D_t'U_2$$

and

$$R_t^* = R + G_t'Q_{22}G_t + U_2'G_t + G_t'U_2$$

The above equations allow a new optimisation programme to be defined in terms of the variables with asterisks, where the problem of time consistency disappears. The matrices F_t^* and V_t^* are obtained from the solution of this new programme, i.e.:

$$F_t^* = (\beta B_t^{*\prime}V_{t+1}^*B_t^* + R_t^*)^{-1}(\beta B_t^{*\prime}V_{t+1}^*A_t^* + U_t^{*\prime})$$

$$V_t^* = \beta(A_t^* - B_t^*F_t^*)'V_{t+1}^*(A_t^* - B_t^*F_t^*) + Q_t^* - U_t^*F_t^* - F_t^{*\prime}U_t^{*\prime} + F_t^{*\prime}R_t^*F_t^*$$

Lastly, vector C_t is updated:

$$C_t = D_t - G_tF_t^*$$

Although the algorithm is quite complex and, in principle, it is not easy to identify the theoretical conditions that guarantee its convergence no problem arose in carrying out any of the exercises. From the random matrices V and C and by establishing as the convergence criterion that the (absolute) maximum difference between the elements of the matrices corresponding to two successive iterations is less than 10^{-10}, the convergence occurred after an average of 1,800 iterations[14]. The solution of the different programmes was maintained amid alterations in the algorithm's initial matrices.

The optimum risk combinations are calculated as follows. First, it is easy to check that the solution of the programme can be written in the following way

$$Z_t = M^* Z_{t-1} + \omega_{zt}$$

where

$$M^* = \begin{bmatrix} A^* - B^* F^* & 0 \\ C(A^* - B^* F^*) & 0 \end{bmatrix}$$

$$\omega_{zt} = \begin{bmatrix} I \\ C \end{bmatrix} \omega_t$$

Therefore, the matrix of variances and covariances of the variables will be the matrix $\bar{\Sigma}_{zz}$ that solves the following equation:

$$\bar{\Sigma}_{zz} = M \bar{\Sigma}_{zz} M' + \Sigma_{zz}$$

where Σ_{zz} is the matrix of variances and covariances of the innovations ω_{zt}.

[14] In addition to satisfying the convergence criterion, the maximum difference between elements proved to be always monotonously decreasing with the iteration number.

Chart 1. Trade -off in the base scenario

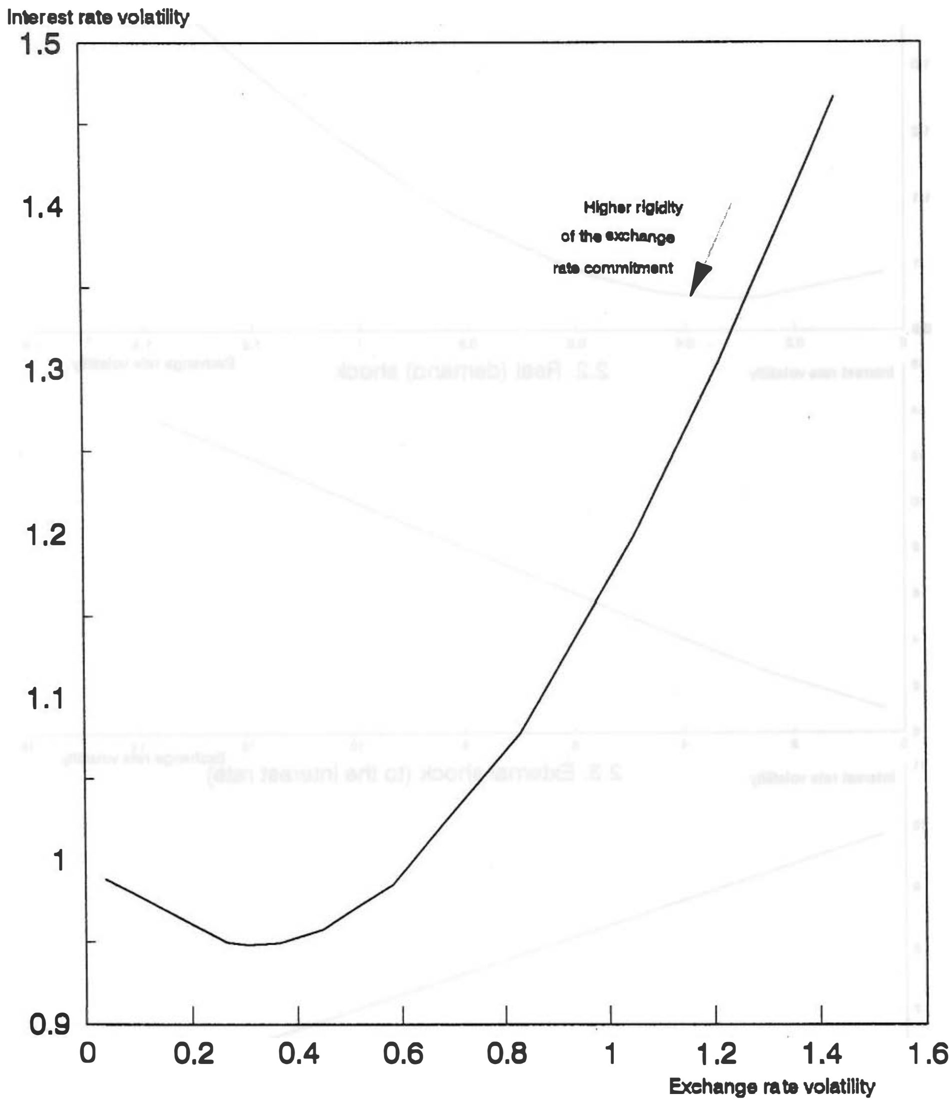


Chart 2.Trade-off and relative importance of shocks.

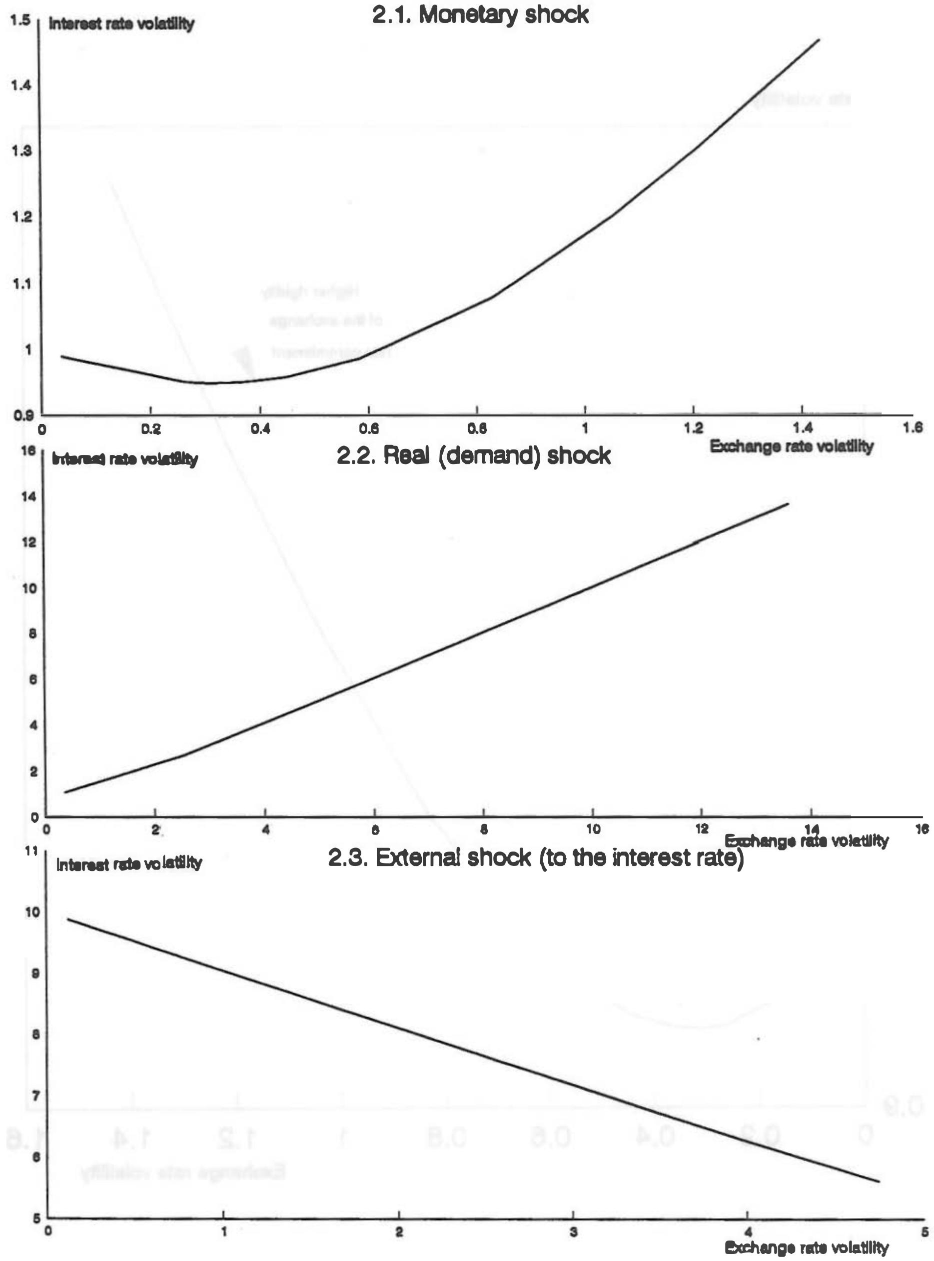
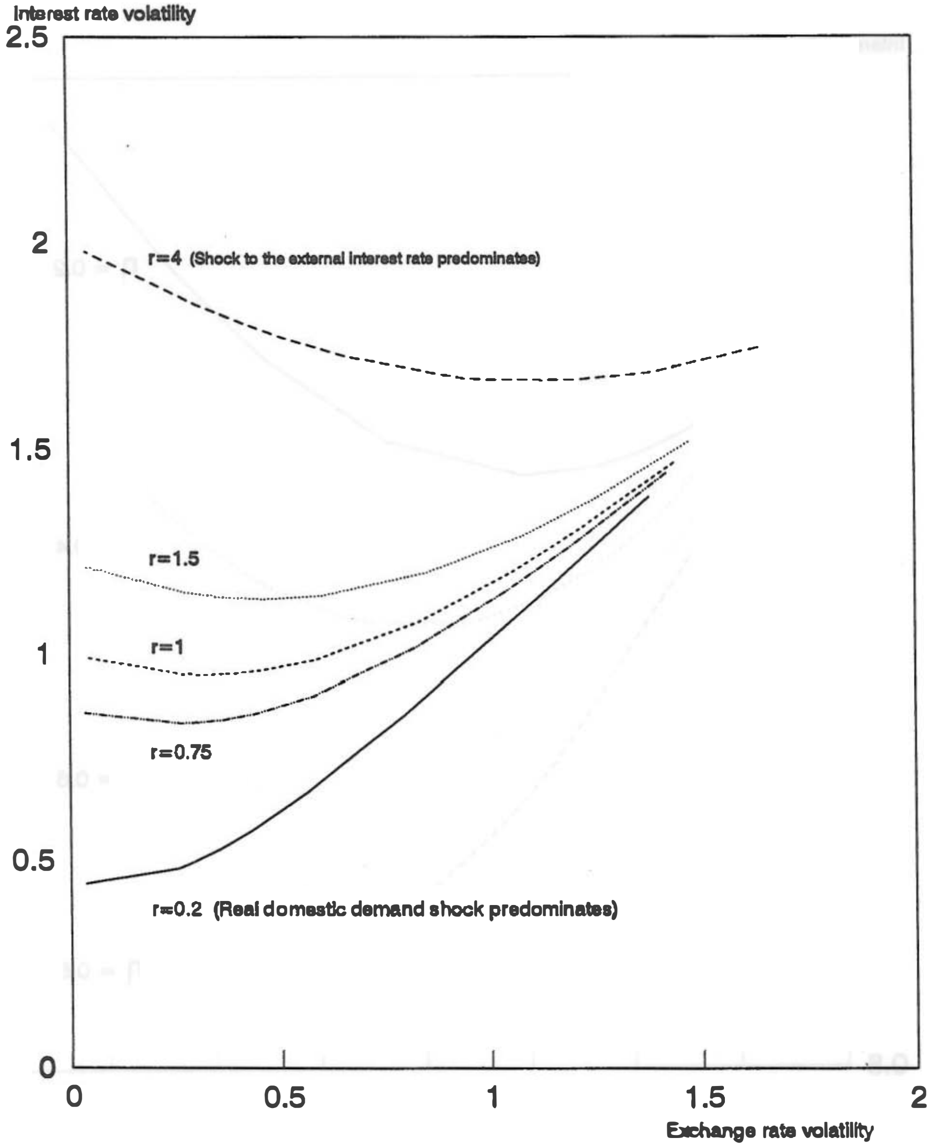


Chart 3 Trade-off and the relative importance of the external shock.



NOTE: r is the quotient between the variances of the shock to the external interest rate and the real domestic demand shock

Chart 4. Changes in the sensitivity of IS to the interest rate.

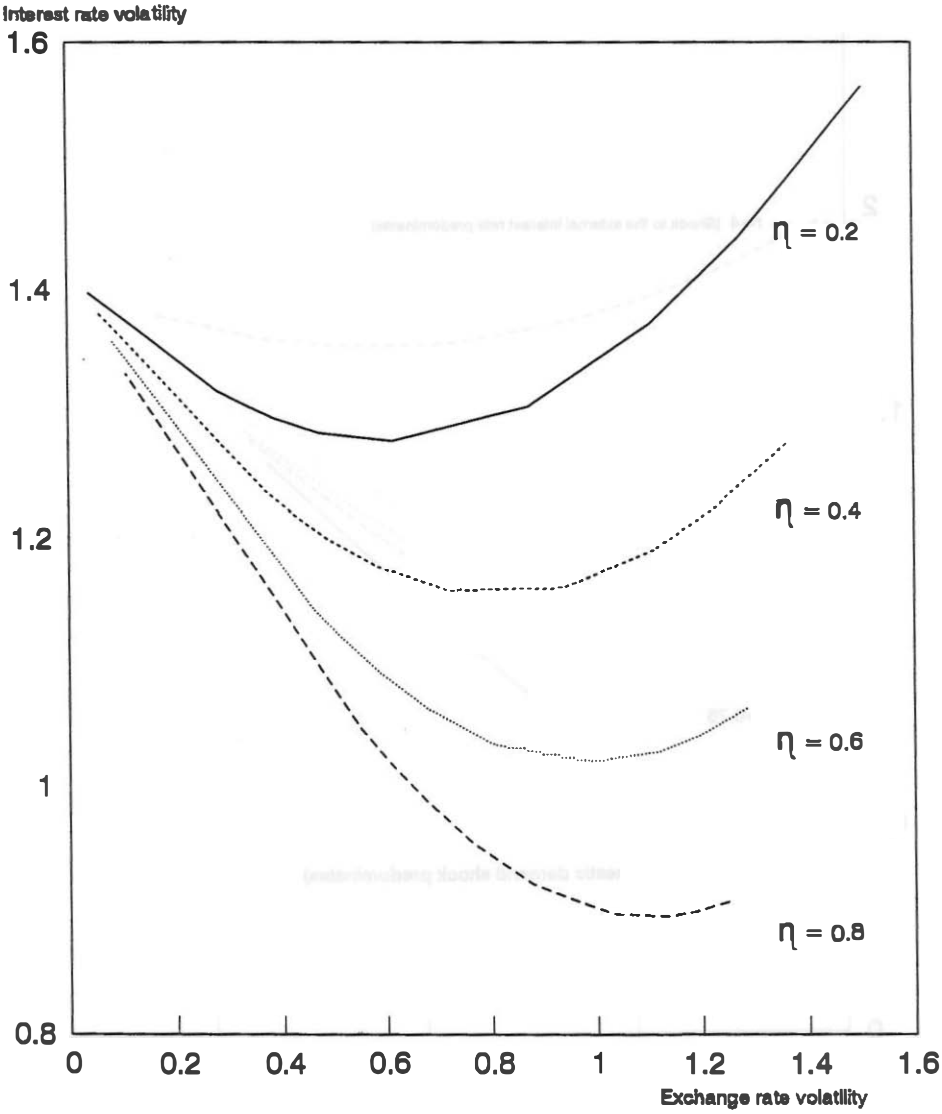


Chart 5. Changes in the sensitivity of IS to the exchange rate.

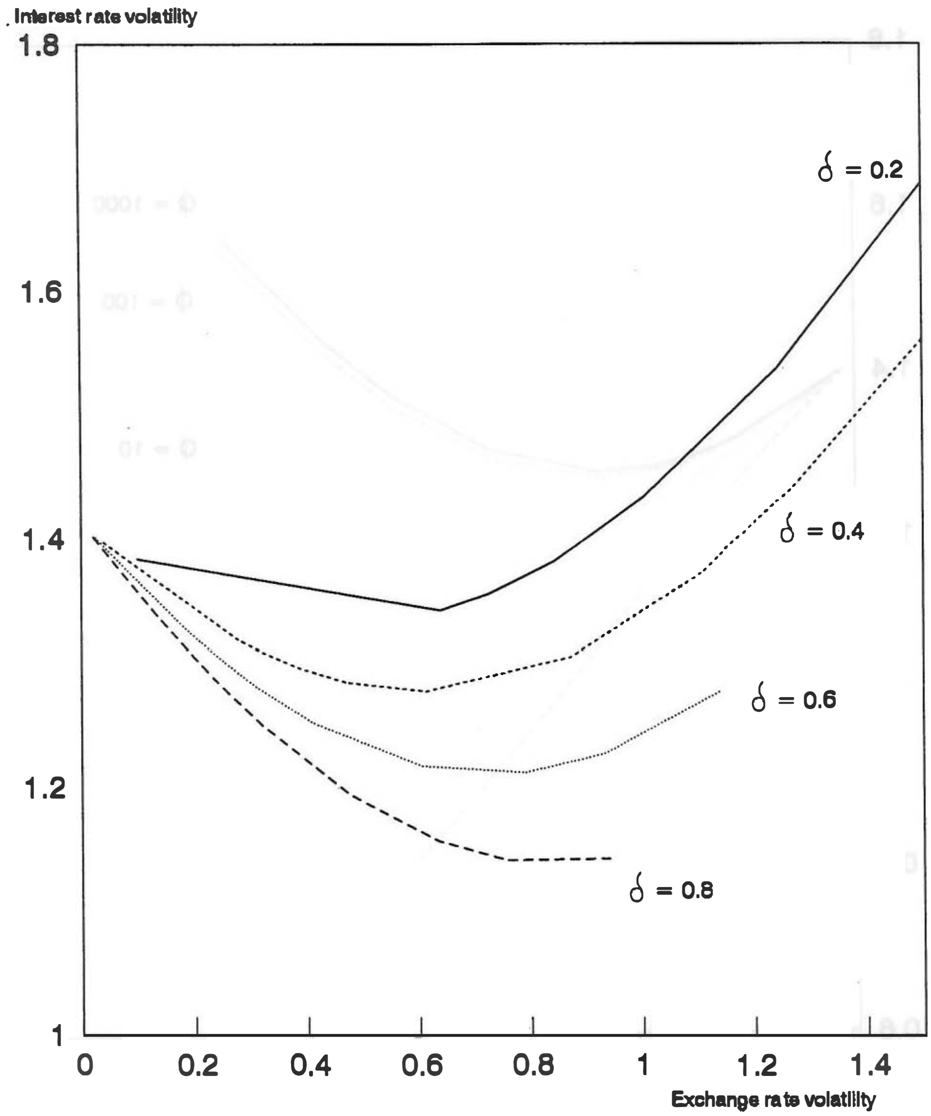


Chart 6. Changes in the level of price flexibility.

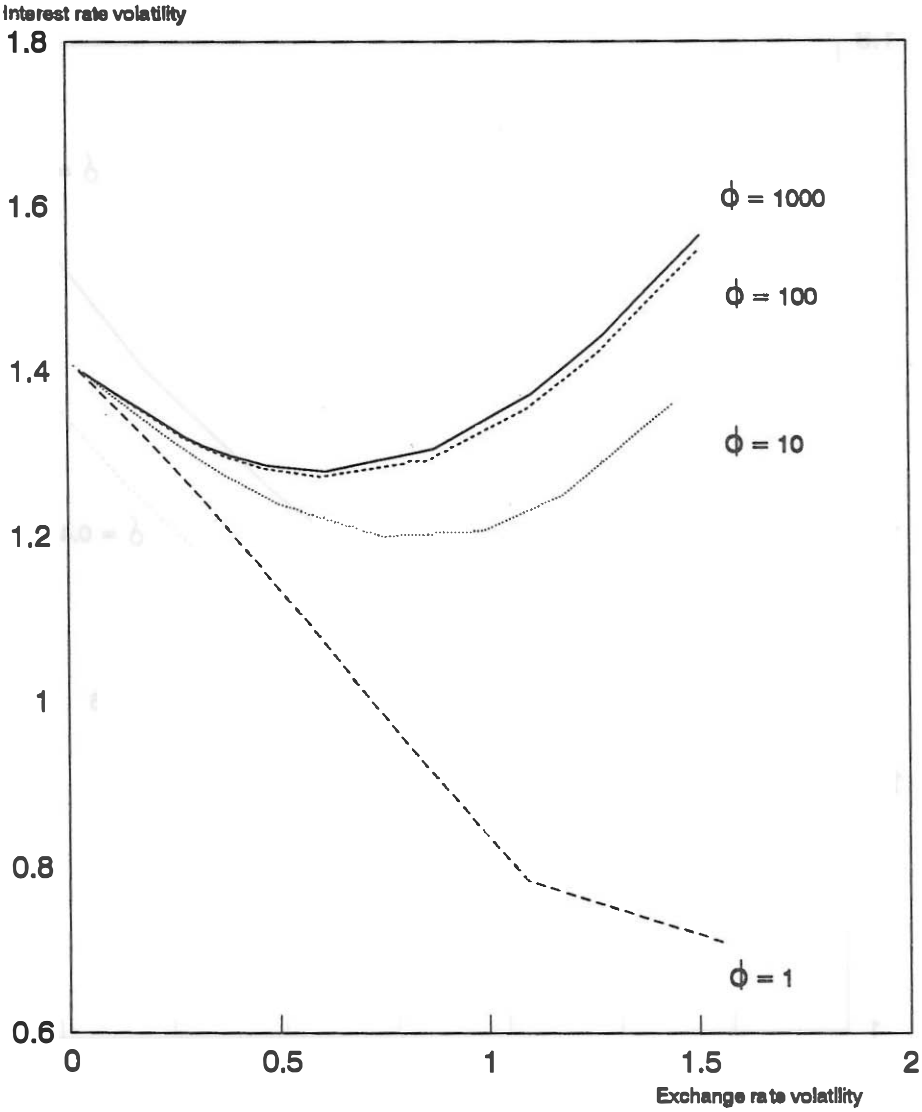
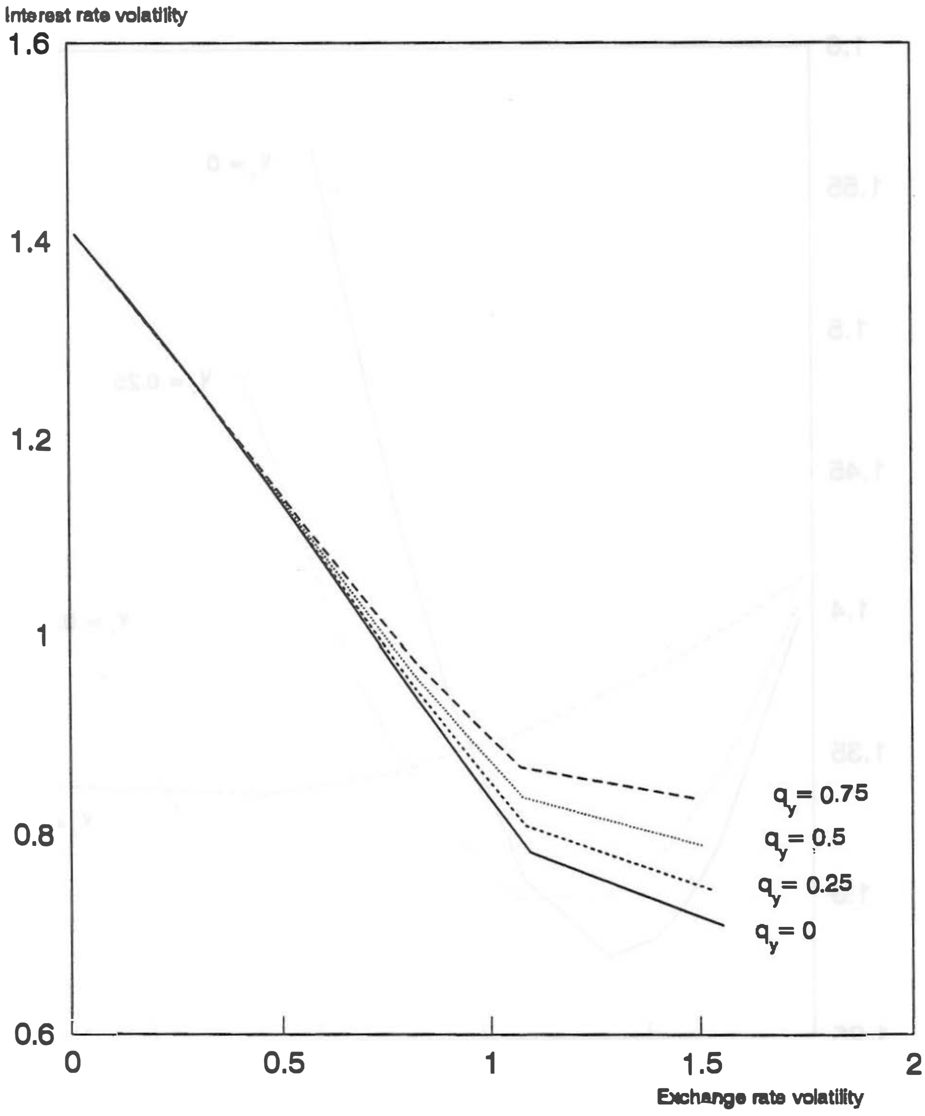


Chart 7. Effects of the lesser independence of the central bank.



NOTE: Rigid prices (ϕ = 1)

Chart 8. Effects of the imperfect credibility.

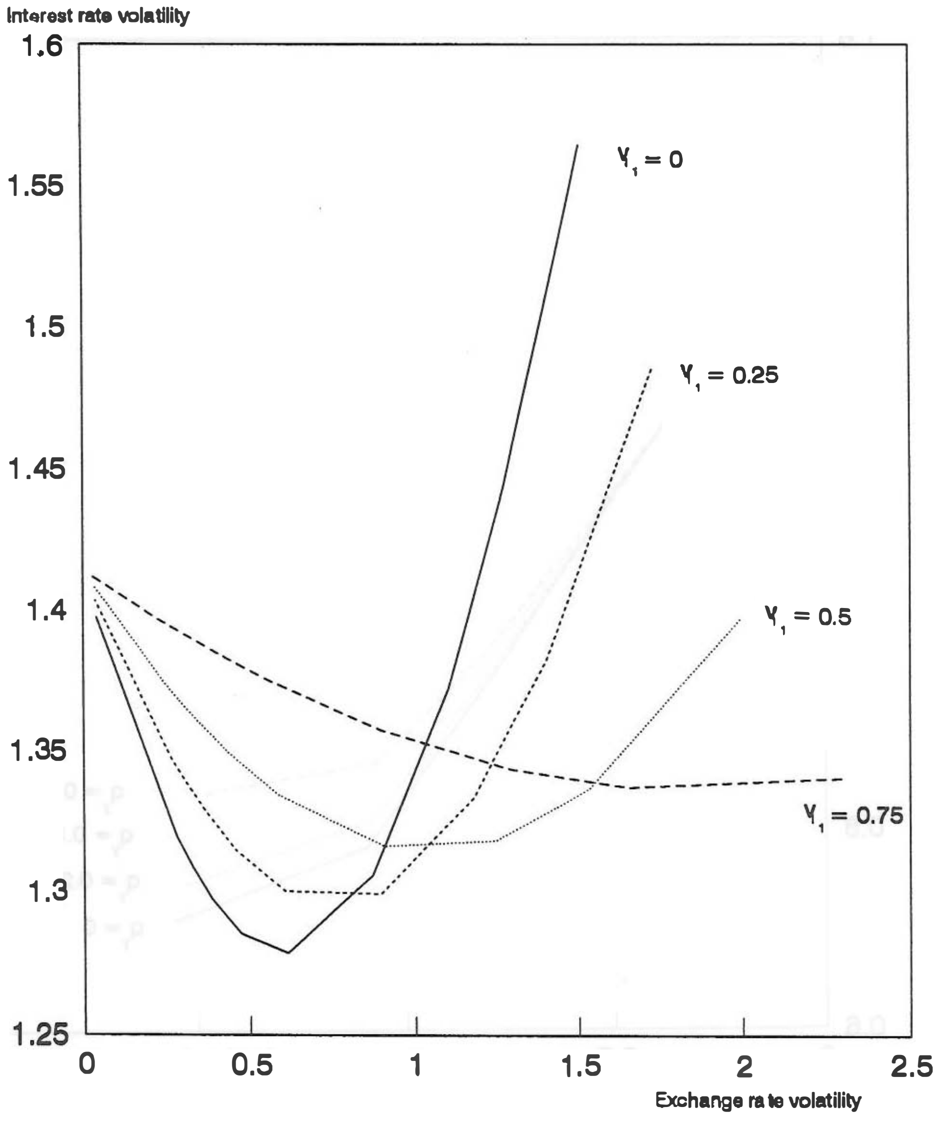


Chart 9. Effects of the existence of a dilemma.

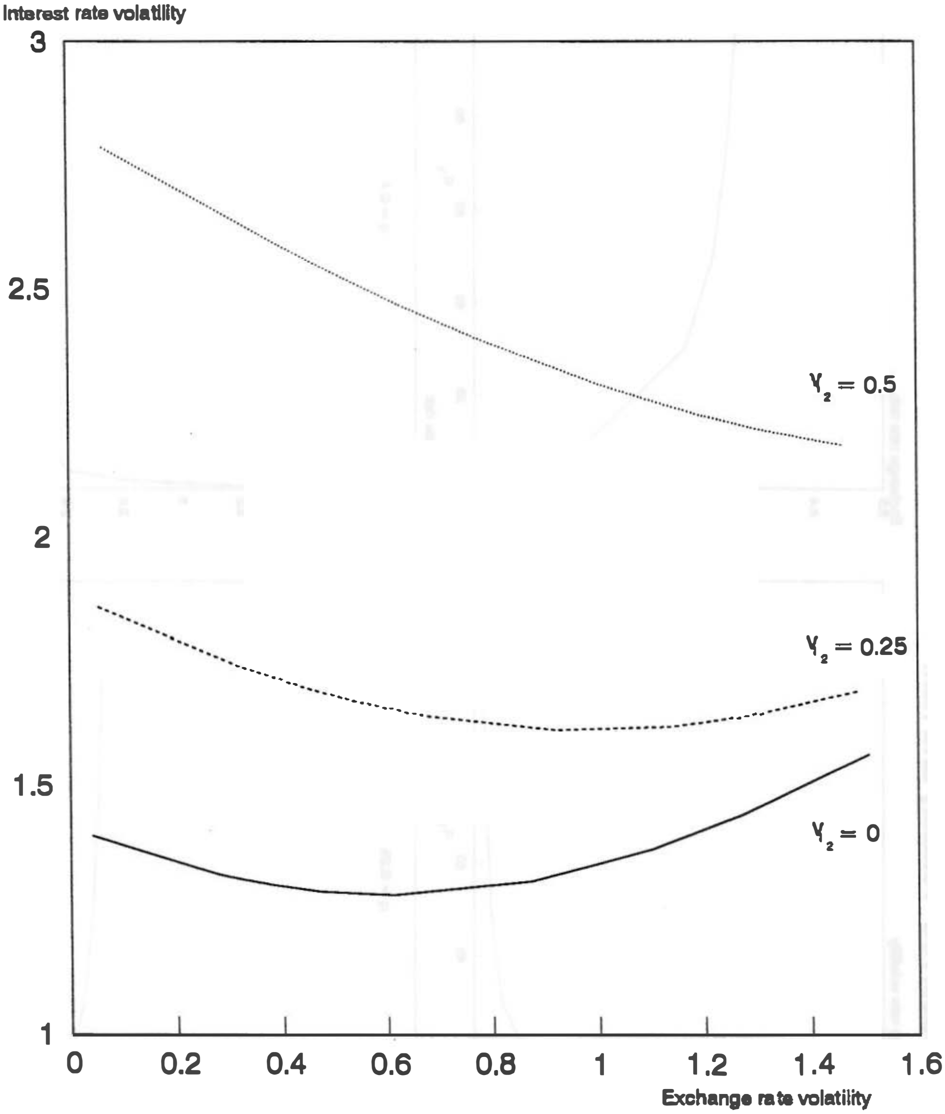
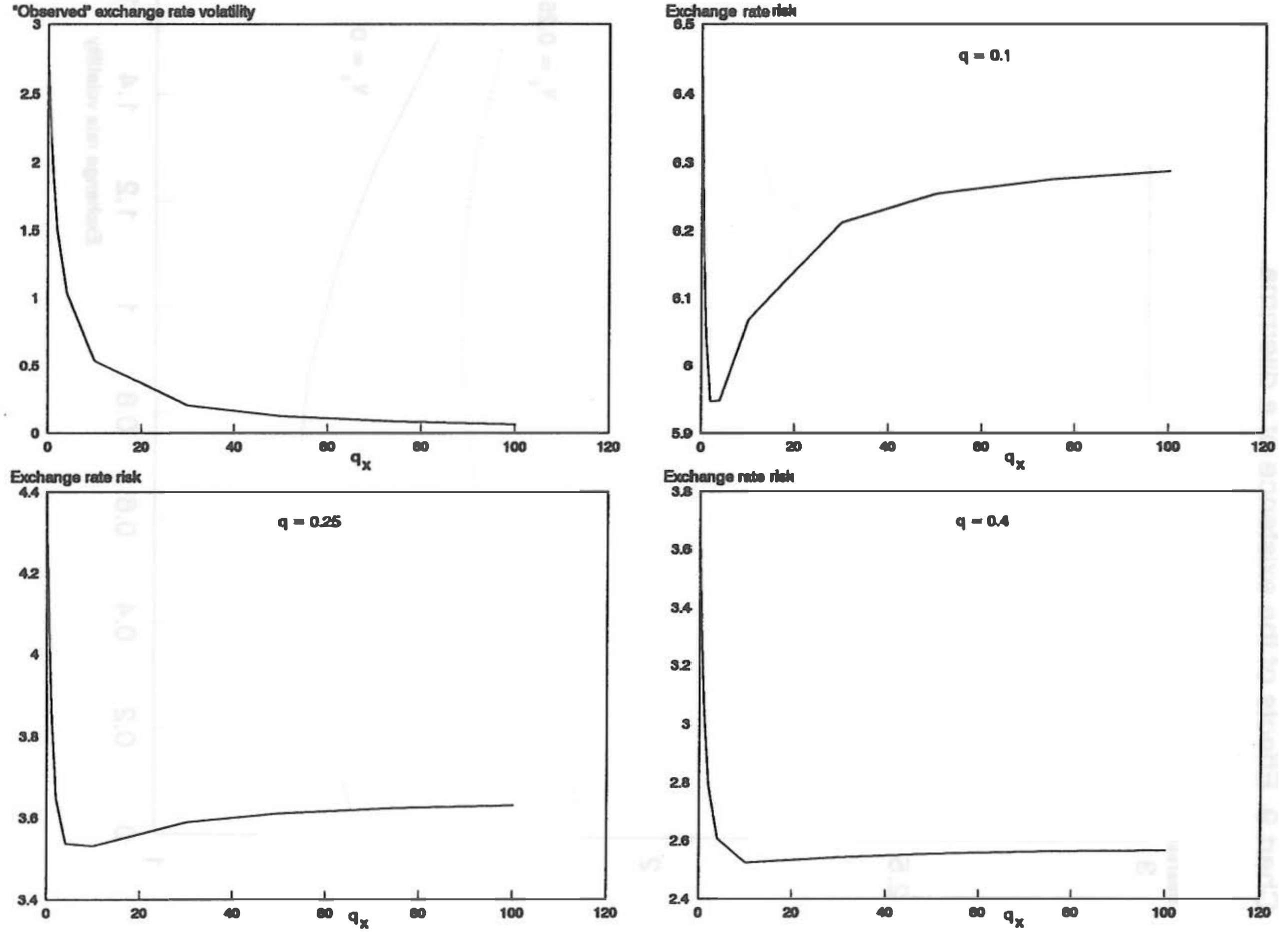


Chart 10. "Observed" volatility and risk.



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