Parameterizing Currency Risk in the EMS: The Irish Pound and Spanish Peseta against the German Mark*

G. C. Lim[†] and Paul D. McNelis[‡]

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Abstract

This paper compares alternative estimates of systemic time-varying excess returns for the Irish pound and the Spanish peseta, against the German mark, since 1985. We make use of progressively more complex models, going from the GARCH in Mean specification, to the International Capital Asset Pricing model (ICAPM) with a time-varying "beta", to a general equiblirum Constant Relative Risk Aversion model (CRRA), with trivariate GARCH-M esimation. The results show significant relative risk aversion as well as significant volatility effects on redictable excess returns. The time-varying "beta" has also declined in the past five years for both Ireland and Spain.

1 Introduction

This paper compares alternative estimates of systemic time-varying excess returns for the Irish pound and the Spanish peseta, against the German mark, since 1985,

*Prepared for ESEM98, Berlin.

[†]Department of Economics, University of Melbourne, Parkville, Victoria, Australia 3052. Email: g.lim@ecomfac.unimelb.edu.au

[‡]Department of Economics, Georgetown University, Washington, D.C., USA 20057-1036. Visiting Professor, Spring 1998, Universitat Pompeu Fabra, Barcelona, Spain.Email: McNelisP@gunet.georgetown.edu

a period of financial openness and adjustment to low inflation, but also a period of turbulence, with major swings in the value of the exchange rates during the European currency crises of 1992.

From a policy perspective, it is helpful to know if the underlying or systemic components of excess returns have been increasing or decreasing during the past five years. One of the goals of monetary unification as well as domestic policy reform programs has been the reduction of risk through greater market transparency, lower inflation rates and liberalized capital flows. How have these programs worked?

Casual empiricism suggests that there may be some decline in these excess returns. The interest rates on similar assets, such as the Irish, German, and Spanish call rates are slowly converging (see Figure 1). Certainly, the volatilities of the spot rates of the Irish pound and Spanish peseta relative to the German mark seem less in the late 1990's compared to the mid-1990's and the mid-1980's (see Figure 2).

The question we ask in this paper is straightforward: Is there any quantitative evidence of a decline in systemic currency risk in the sample period examined?

The literature contains many studies of the role of the excess returns or risk premia in foreign exchange markets; for survey see Lewis (1995). Models of the risk premia developed include: models which relate the risk premia directly to spot rate volatility;[1] models which explain risk in terms of the international capital asset-pricing framework;[2] and models which include explicitly a role for the coefficient of relative risk aversion.[3]

There is also the calibration approach. One recent study tries to account for both the predictability and the volatility of risk premia in currency, bond, and equity markets between the United States and Japan.[4]

In this paper we employ the multivariate generalized autoregressive conditional heteroskedastic in mean (M-GARCH-M) framework to estimate progressively more complicated versions of risk premia models. The models include: the spot volatility in mean model (SPOT-M), the international capital asset pricing model (ICAP-M), and the intertemporal model with explicit reference to the coefficient of relative risk aversion parameter in the utility function (CRRA-M).

The paper is structured as follows. Section 2 contains a brief discussion of the theoretical background to the models estimated. It shows that the three models

[1] See Bollerslev (1990), Baillie and Bollerslev (1990), Dukas, Fatemi and Lai (1993).

[2] For examples, see McCurdy and Morgan (1991), Malliaropulos (1997).

[3] For example, see Ayuso and Restoy (1996).

[4] See Baekert, Hodrick, and Marshall (1997).

examined - the model which focuses on the role of exchange rate volatility as an explanator of currency risk; the model which focuses on time-varying betas, and the model which focuses on the role of the risk aversion parameter - can all be viewed as variations of the Euler condition derived from the dynamic general equilibrium intertemporal consumption portfolio model.

Section 3 presents results for all three approaches estimated within the M-GARCH-M framework. While the SPOT-M and ICAP-M have been popularly estimated as univariate and bivariate GARCH systems respectively, the intertemporal model has been usually estimated by generalized methods of moments (GMM). We show how the CRRA-M can also be set up as a trivariate GARCH system. Hence we present a unified framework for estimating all three models. Section 3 applies these methods to the Irish pount/German mark and Spanish peseta/German mark exchange rates. Results are presented for the in-mean variance, the time-varying beta and the risk aversion coefficient approaches to the parameterization of exchange-rate risk. The last section 4 concludes.

2 Theoretical Framework

The general equilibrium approach for explaining risk in currency markets is inspired by the two-country complete markets model of Lucas (1982). In this framework, asset prices are determined from the Euler condition for an intertemporal choice problem of an investor who can trade freely in asset j, and who maximizes the expectation of a time-separable utility function. The Euler condition is:

$$\frac{U'(C_t)}{P_t} = \delta E_t\left[R_t^j \frac{U'(C_{t+1})}{P_{t+1}}\right] \tag{1}$$

where δ is the time preference parameter and C_t is real consumption, $U'(C)$ denotes the marginal utility of consumption, P_t is the price index. R_t^j is the one-period gross nominal return on asset j; $R_t^j = (1+r_t^j)$. This expression is more often presented as:

$$E_t\left[R_t^j Q_{t+1}\right] = 1 \tag{2}$$

where Q_{t+1} is the intertemporal marginal rate of substitution:

$$Q_{t+1} \quad = \quad \delta \frac{U'(C_{t+1})}{U'(C_t)} \frac{P_t}{P_{t+1}} \tag{3}$$

To derive the measure of excess returns, first recognise that the Euler equation for the riskless asset is:

$$R_t^f \quad = \quad \frac{1}{E_t\left[Q_{t+1}\right]} \tag{4}$$

and the equivalent first-order condition for asset j is:

$$E_t\left[Q_{t+1}, R_t^j\right] \quad = \quad 1 \tag{5}$$

From equation (4) and the definition of covariance applied to (5) we obtain the standard excess returns result:

$$E_t\left[R_t^j - R_t^f\right] \quad = \quad -R_t^f Cov_t\left[Q_{t+1}, R_t^j\right] \tag{6}$$

When applying the model to international asset pricing, we define the the risk-free rate as the return to a domestic asset, while the return to asset j includes the currency risk:

$$R_t^j \quad = \quad (1+r_t^*)\frac{S_t}{S_{t+1}}$$

where S_t is the spot rate, defined as the units of foreign currency per domestic currency. Hence equation (6) shows that the conditionally expected excess return associated with an uncovered position in the foreign currency is proportional to the conditional covariance of the spot price with the intertemporal marginal rate of substitution of domestic currency.

Since Q is not observable, additional assumptions are needed to obtain a testable version. A typical assumption is to re-express equation (6) in terms of a benchmark portfolio on the conditional mean-variance frontier. The benchmark portfolio has gross return R^m, which can be written as a linear combination of the minimum variance portfolio nominal return (which is perfectly correlated with Q) and the risk-free return, R^f. The equilibrium return on asset j can then be expressed as the conditional beta CAPM model examined by, for example, McCurdy and Morgan (1991):

$$E_t(R_t^j - R_t^f) = \frac{Cov_t\left[R_t^j, R_t^m\right]}{Var_t\left[R_t^m\right]} E_t(R_t^m - R_t^f) \tag{7}$$

Another version of the first order condition is based on the assumption that $q_{t+1} = \log(Q_{t+1})$ and $r_t^j = \log(R_t^j)$ are conditional joint lognormally distributed.[5] Hence an alternative expression for excess returns is:

$$E_t\left[r_t^j - r_t^f\right] = -\frac{Var_t(r_t^j)}{2} - Cov_t(r_t^j, q_{t+1}) \tag{8}$$

where $Var_t(r_t^j)$ is the conditional variance of r_t^j, and $Cov_t(r_t^j, q_{t+1})$ is the covariance between r_t^j and q_{t+1}. If the covariances are assumed to be negligible, we have the spot volatility in mean model studied by for example, Baillie and Bollerslev (1990):

[5] See Campbell, Lo, and MacKinlay (1997), various sections, for a discussion of the following substitutions.

$$E_t\left[r_t^j - r_t^f\right] \quad = \quad -\frac{Var_t(s_{t+1})}{2}$$

To render (8) empirically tractable, it is common to assume a time-separable power utility function:

$$U(C_t) \quad = \quad \frac{C_t^{1-\gamma} - 1}{1-\gamma}$$

where γ is the coefficient of relative risk aversion.[6]

This implies a first-order condition of form:

$$E_t\left[\delta R_t^j \left(\frac{C_{t+1}}{C_t}\right)^{-\gamma}\left(\frac{P_t}{P_{t+1}}\right)\right] \quad = \quad 1 \tag{9}$$

which gives the general volatility-in-mean expression:

$$E_t\left[r_t^j - r^f\right] \quad = \quad -\frac{Var_t(r_t^j)}{2} - Cov_t(r_t^j, \pi_{t+1}) + \gamma Cov_t(r_t^j, c_{t+1}) \tag{10}$$

where $\pi_{t+1} = \log(P_{t+1}/P_t)$, $c_{t+1} = \log(C_{t+1}/C_t)$ and $Cov_t(r_t^j, \pi_{t+1})$, $Cov_t(r_t^j, c_{t+1})$ are the conditional covariances. An estimate of γ can be obtained if consumption data is available.

However, high frequency data on consumption are generally unavailable. Ayuso and Restoy (1996), suggest approximating nominal consumption growth with the return on the equilibrium portfolio. We thus have:

[6]In this setting, risk premia critically depend on the specification of the underlying utility function. Mark (1985) has found that the parameter of risk aversion in a constant relative risk aversion specification of the utility function has to be quite large (in the range 12 to 20) to explain the variability of excess returns. Cumby (1988) suggested that the non-separability over time of the utility function in t may account for the failure of the general equilibrium models to explain speculative returns.

$$E_t \left[R_t^j \, (R_t^m)^{-\gamma} \left(\frac{P_t}{P_{t+1}} \right)^{1-\gamma} \right] \;=\; 1 \tag{11}$$

Again assuming joint log normality, the expression for excess returns becomes a function of second moments of asset returns:

$$E_t \left[r_t^j - r_t^f \right] \;=\; -\frac{Var_t(r_t^j)}{2} + (1-\gamma) Cov_t(r_t^j, \pi_{t+1}) + \gamma Cov_t(r_t^j, r_t^m) \tag{12}$$

where $Cov_t(r_t^j, r_t^m)$ is the conditional covariance of the return on asset j with the return on the market portfolio.

The advantage of equation (12) is that it allows direct estimation of the CRRA parameter γ. It is apealing as a model of risk premium because it includes the three main explanators of currency risk: spot volatility, co-variability of the spot rate with inflation and co-variability of the spot rate with the world return. The major weakness is that it is derived from a specific type of utility function.

3 Empirical Analysis

3.1 Data

Figure 3 shows the evolution of the excess returns ($\log(R^j/R^f)_t$) from investing in a foreign asset, in Ireland or Spain, for a German investor. The frequency is monthly covering the period 1985:1 to 1997:04. The interest rates are monthly returns on comparable assets - the three-month bill rates for the three countries.

From Figure 3, it appears that the two series are very similar, with the exception of the large jump in the Irish series between 1992 and 1993. Table I presents some descriptive statistics. The mean excess return is non-zero and highly volatile for both countries. The series are clearly non-normal, but stationary. Ireland satisfies the Engle and Ng (1993) test for symmetry in the volatility, but Spain does not.

The aim of the paper is to extract information from the two series about systemic risk. Did the non-random components of these series decline as the economy adjusted to an era of lower inflation and increased globalisation of financial markets?

3.2 Estimating the M-GARCH-M Framework

The ARCH model proposed by Engle (1982), and generalised by Bollerslev (1986), GARCH, have been used extensively to model the behaviour of volatility over time.[7] In particular, the GARCH-M model of Engle, Lilien and Robins (1987) explicitly links the conditional variance to the conditional mean of the returns and hence is the ideal framework to study the relationship between measures of currency risk and volatility. This technique has been used extensively in this literature, to estimate the SPOTM and the ICAPM analysis of risk premia. In this paper, the framework is also applied to the CRRAM. All models were estimated for the GARCH (1,1) case. Alternative orders of the GARCH process will be examined at a later stage.

All data are demeaned, and deseasonalized. We estimate all three non-linear systems by maximum likelihood methods. Following Dorsey and Mayer (1995), we initialized the parameter search with a genetic algorithm, and then used a gradient-descent optimization algorithm to reach the reported estiamtes.

Normally, one would report heteroscedastic-consistent estimates of the standard error based on the Hessian matrices. . Bollerslev and Wooldridge (1988), for example, have shown that asymptotically valid inference may be based on a quasi maximum likelihood procedure, when a robust covariance matrix for the parameters is calculated from $H^{-1}(GG')H^{-1}$, where H is the Hessian, and G is the outer product of the gradients.

However, the high degree of non-linearity in the multivariate GARCH systems made inversion of the Hessian matrices impossible. We thus made use of the boostrapping technique for obtaining the standard errors and the corresponding t-statistics. [8][9]

[7] For a review of the numerous applications of the GARCH framework for estimating volatility, see Bollerslev, Chou and Kroner (1992).

[8] We are indebted to Andreas Weigand for suggesting the use of bootstrapping methods for calculating the standard errors.

[9] For an exposition of boostrapping techniques, see Mooney and Duval (1993).

3.3 Spot Rate Volatility

Baillie and Bollerslev (1990) argue that the covariances in equation (12) are negligible. So the simplest version of the currency risk model relates the excess returns to the square root of the conditional variance of the spot exchange rate, and may be set up as a univariate GARCH-M model as follows:[10]

$$
\begin{aligned}
y_t &= \alpha y_{t-1} + \sqrt{h_t} + \varepsilon_t \\
& \varepsilon_t | I_{t-1} \tilde{} N(0, h_t) \\
h_t &= c + a\varepsilon_{t-1}^2 + gh_{t-1} + \zeta_t
\end{aligned}
$$

where y_t is either $(f_{t-1} - s_t)$ or $(\log(R^j/R^f)_t)$. With these models, the conditional mean and volatility of the series are assumed to be predictable using past available information on returns and volatility measures.[11]

Table II presents the results of the GARCH-in-Mean model for the two countries. The results show that there are significant GARCH processes, and that volatility in the underlying spot exchange rates has significant effects on the excess returns, for mean and volatility. The diagnostics indicate consistency under the Pagan-Sabau tests, but also show evidence of autocorrelation and lack of symmetry.

3.4 The ICAP-M Method

In the partial equilibrium models of asset pricing, Adler and Dumas (1983) were the first to show that the "market return" in the international CAPM model should generalize across many countries. The international capital asset pricing model evaluates the risk and return of an asset j relative to a benchmark return and risk;

[10] In a related model by Dukas, Fatemi, and Lai (1993), the variable s_t is modeled as a random walk process and the currency risk is hypothesied to be related to the conditional variance of the exchange rate, h_t^s which follows the GARCH process.

[11] See McCurdy and Stengos (1992) for a comparison of parametric versus non-parametric conditional mean estimators. Their results show that a parametric specification of the GARCH process avoids the problem of over-fiting.

specifically the ICAPM postulates that the equilibrium excess return on any asset j, is related to the excess returns from a benchmark portfolio as follows:

$$\begin{aligned}
r_t^m - r_t^f &= \delta[r_{t-1}^m - r_{t-1}^f] + \varepsilon_{1t} \\
y_t &= \frac{h_t^{12}}{h_t^{22}} E_{t-1}[r_t^m - r_t^f] + \varepsilon_{2t} \\
\varepsilon_t' &= [\varepsilon_{1t}, \varepsilon_{2t}];\ \varepsilon_t' | I_{t-1} \tilde{} N(0, H_t) \\
H_t &= C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}' A + G' H_{t-1} G
\end{aligned}$$

$$\begin{aligned}
H &= \begin{bmatrix} h^{11} & h^{12} \\ h^{12} & h^{22} \end{bmatrix}; C = \begin{bmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{bmatrix}; \\
A &= \begin{bmatrix} a_{11} & a_{12} \\ a_{12} & a_{22} \end{bmatrix};\ G = \begin{bmatrix} g_{11} & g_{12} \\ g_{12} & g_{22} \end{bmatrix}
\end{aligned}$$

where h_t^{22} is the conditional variance of the benchmark portfolio and h_t^{12} is the conditional covariance between the excess return of the foreign asset and the benchmark portfolio. Following McCurdy and Morgan (1991), we have used the Morgan Stanley Capital International world equity index as the appropriate benchmark portfolio to compute the market return, R_t^m.[12] In this model, beta is not a constant but is conditional on the covariance between the asset and market returns relative to the variance of the market return.

The ICAP-M time-varying beta model makes use of GARCH-in-mean estimation, and the vector of errors ε_t' is assumed to have a conditional bivariate normal distribution with zero mean and conditional covariance matrix defined by the Engle and Kroner (1993) BEKK form, where C, is an upper triangular matrix and A and G are symmetric matrices of parameters.[13]

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[12]For the benchmark world portfolio, McCurdy and Morgan (1991) included a moving average component, to reflect the effects of non-synchronized trades of the components of the world index. Since this study is based on monthly data, non-synchronicity is not an issue.

[13]For an alternative parametrization, see Malliaropulos (1997) application of Bollerslev (1990)

The results from estimating the time-varying beta for the excess returns model appear in Table III.

The first point is that few of the coefficient estimates are significant. The second point, based on the Pagan-Sabau tests for error consistency, is that the error structure for the excess returns formulation is better captured by the GARCH-M specification than by the ICAP-M one. The error diagnostic for the systemic risk premia suggests the need for a more complex error structure.

Concentrating on the excess returns, Figure 4 shows that systemic time-varying beta, given by $\frac{h_t^{12}}{h_t^{22}}$ has become relatively more stable in the 1990's for both countries.

But as can be seen from Table III, there is clearly room for improvement, possibly due to an omission of shocks associated with consumption.

3.5 CRRA Approach

The generalized method of moments (GMM) has been used to estimate the "deep parameters" such as the coefficient of risk aversion in the representative agent's utility function, which ultimately determine excess returns under efficient markets.[14] An alternative procedure is to estimate the CRRAM embodied in equation (12) as a trivariate GARCH-M system:[15]

$$\begin{aligned}
r_t^m &= \alpha_1 r_{t-1}^m + \varepsilon_{1t} \\
\pi_t &= \alpha_2 \pi_{t-1} + \varepsilon_{2t} \\
y_t &= -\frac{1}{2} h_t^{33} + (1-\gamma) h_t^{32} + \gamma h_t^{31} + \varepsilon_{3t} \\
\varepsilon_t' &= [\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}];\ \varepsilon_t' | I_{t-1} \tilde{} N(0, H_t)
\end{aligned}$$

model which assumes a constant conditional correlation while allowing the conditional variances and covariances to vary over time.

[14]The GMM method is due to Hansen (1982). For applictions in this area see Bodurtha and Mark (1991), Ayuso and Restoy (1996).

[15]For an earlier work on a tri-variate CAPM model, see Bollerslev, Engle and Wooldridge (1988), their work also suggest ptential role for consumption shocks. See Bekaert (1995) for a combined VAR-GARCH model.

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + G'H_{t-1}G$$

$$H = \begin{bmatrix} h^{11}h^{12}h^{13} \\ h^{12}h^{22}h^{23} \\ h^{13}h^{23}h^{33} \end{bmatrix}; C = \begin{bmatrix} c^{11}0 & 0 \\ c^{21}c^{22} & 0 \\ c^{31}c^{32} & c^{33} \end{bmatrix};$$

$$A = \begin{bmatrix} a^{11}a^{12}a^{13} \\ a^{12}a^{22}a^{23} \\ a^{13}a^{23}a^{33} \end{bmatrix}; G = \begin{bmatrix} g^{11}g^{12}g^{13} \\ g^{12}g^{22}g^{23} \\ g^{13}g^{23}g^{33} \end{bmatrix}$$

This framework has the same structure as previous models and has the advantage of allowing for a time-varying risk premia.[16]

Results are presented in Table IV. The main point is that the coefficient of relative risk aversion is significant for Ireland, there are strong and significant persistence effects in the trivariate GARCH processes for both countries, and the errors appear to be adequately parametrized by the CRRA framework for Ireland, somewhat less so for Spain. There is evidence of autocorrelation in the residuals for the excess returns for both countries.

4 Conclusion

Understanding the determinants of excess returns is important for appropriate policy responses. The results show that the excess returns cannot be attributable solely to spot exchange rate volatility, nor can they be explained by the risk aversion behaviour embodied in the time separable power utility function. But, results from the ICAPM framework shows that beta has declined in volatility, which in turn suggest a decline in foreign currency risk against the German mark, for both Ireland and Spain.

Although the coefficient of relative risk aversion was not significant for Spain, it must be recalled that the linear form of the intertemporal asset pricing condition estimated was based on the power utility function. In recent years, more complex

[16] In many other empirical studies, such as those of Lewis (1988) and Engel and Rodriguez (1989), the relative risk aversion coefficient is not significantly different from zero. A larger class of dynamic asset pricing models has recently been studied by Bakshi and Naka (1997). They note that stochastic discount factors that incorporate habit forming behaviour are better at explaining the empirically observed asset prices.

utility functions allowing for habit persistence behaviour are being developed. Future research incorporating more complex risk behaviour in the utility function into the M-GARCH-M modeling framework, with its emphasis on the second moments of asset returns, could potentially lead to better models of currency risk.

Comparing the last two models, the CRRA model is more complex in terms of parameter space. The ICAP-M model, on the other hand, is more complex insofar as its functional form is highly nonlinear in parameters. In this model, a time-varying conditional covariance is divided by a time-varying conditional variance. Given the insignificant coefficient estimates and significant tests for consistency produced by the ICAP-M,our estimation results show that the ”curse of dimensionality” may not be as severe as the ”curse of complexity”.

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