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PARAMETRIC AND NONPARAMETRIC ANALYSIS OF INTEREST RATE EXPOSURE OF SPANISH BANKS

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ABSTRACT

Interest rates represent a major source of uncertainty for the value of companies because interest rate changes influence both the expected future cash flows and the discount rate employed to value them. The high interest rate volatility and the important level of financial leverage constitute additional factors contributed the increasing relevance of the corporate exposure.

The main contribution of this paper is to conduct an analysis of bank interest rate exposure using linear, non linear, asymmetric and non parametric models. Also, it investigates whether the introduction of the Euro as a common currency has affected banks' interest rate sensitivity.

Keywords: interest rate risk, banking firms, stocks.

J.E.L. Classification: G12, G21, C52

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1. INTRODUCTION

Interest rate risk (IRR, hereafter) is broadly acknowledged as one of the most important financial risks faced by companies. This is due to the fact that changes in interest rates affect both the firm's expected future cash flows and the discount rates used to value these cash flows. Moreover, the high volatility in interest rates and financial market conditions in recent years along with the significant degree of financial leverage for most of the companies have also contributed to the growing importance of interest rate exposure.

The bulk of the research on corporate exposure to IRR has been concentrated on financial institutions because of the particularly interest rate sensitive nature of the banking business. Specifically, financial assets and liabilities represent a substantial portion of the total assets of financial firms and it is generally admitted that there exists a maturity mismatch between banks' assets and liabilities. The most common approach consists of measuring interest rate exposure as the sensitivity of bank stock returns to movements in interest rates using traditional linear regression models (e.g., Flannery and James, 1984; Madura and Zarruk, 1995; Faff and Howard, 1999; Fraser et al., 2002; or Au Yong and Faff, 2008).

There are, however, several reasons to suspect that the relationship between interest rates and market value of banks may be of nonlinear nature. On the one hand, since bank stock prices depend on interest rates through the discount factor and through the impact of interest rate changes on expected cash flows, it seems reasonable to assume that the link between interest rates and bank equity values may not be strictly linear. On the other hand, the risk management policy followed by banks may also play a major role in explaining the presence of nonlinearity in interest rate exposure. In addition, the response of bank stock returns to interest rate shocks may depend upon the sign or the magnitude of the shock, thus generating an asymmetric exposure to IRR. Specifically, interest rate rises and falls may affect bank value differently (*sign asymmetry*). Similarly, larger interest rate fluctuations may have a differential effect on bank value than smaller interest rate changes (*size or magnitude asymmetry*). Lastly, it is also possible that the relationship between interest rates and stock prices does not follow a time invariant functional form. Obviously, should these cases exist the conventional linear model would not be appropriate for estimating interest rate exposure of banks.

This study aims to provide a comprehensive analysis of the interest rate exposure of the Spanish banking industry both at the portfolio and firm level. To this end, the degree of interest rate exposure is assessed not only by employing the standard linear model used in most studies, but examining the possible existence of nonlinear exposure through alternative nonlinear parametric and nonparametric approaches as well. The primary contribution of the paper lies in the fact that it represents, to the best of our knowledge, the first attempt to estimate interest rate exposure using nonparametric regression methods. This new perspective helps to improve the understanding of the effect of IRR on banking firms and how it can be measured, which is an essential prerequisite for effective hedging decisions.

Nonparametric estimation techniques provide a flexible approach to model the relationship between interest rates and stock prices. Unlike parametric regression analysis, this method allows estimating a different functional form for each firm and also permits this function to vary over time. The comparison of the results of the alternative empirical techniques allows us to assess the extent to which the assumptions regarding the functional relationship between interest rates and bank stock prices may influence the conclusions over the level of interest rate exposure.

The Spanish banking sector provides an excellent context to investigate whether the introduction of the euro as a common currency in January 1999, with its implications in terms of greater financial stability and deepening and broadening of capital markets, has significantly affected the nature and magnitude of interest rate exposure of Spanish banks.

The empirical evidence in this study reveals some interesting points. In general, the Spanish banking system is characterized by a remarkable exposure to IRR during the sample period. It must be noted, however, that the extent of IRR faced by Spanish banks has noticeably decreased after the adoption of the euro. Furthermore, a distinctive feature of the Spanish case is that a pattern of positive interest rate exposure seems to emerge during the post-euro period, reflecting a sharp change in the nature of the impact of IRR on bank stocks. A significant nonlinear component is also detected in the link between interest rates and bank stock prices, confirming the importance of nonlinearity. This implies that using only the conventional linear model to measure interest rate exposure may underestimate the true degree of exposure.

The evidence of a lower exposure to interest rate changes in the more stable environment associated to the European Monetary Union can be relevant results for other countries which are currently involved in a process of rapid development and deep transformations just like the one occurred in Spain over the past two decades. This is the case, for example, of the Central and Eastern European countries which have joined the European Union and have adopted the Euro recently or are expected to do so in the following years.

The knowledge of the impact of interest rate fluctuations on the value of banking firms is essential not only for purposes of IRR management, but also for other areas of finance such as asset allocation, portfolio management, implementation of monetary policy, and banking regulation.

The rest of the paper is organized as follows. Section 2 offers a brief survey of previous literature regarding banks' exposure to interest rate risk. Section 3 describes the data used. Section 4 discusses the model specifications employed in the analysis. Section 5 reports the major empirical results. Finally, Section 6 provides some concluding remarks.

2. LITERATURE REVIEW

A large number of empirical studies have examined the impact of IRR on the value of firms since the early 1980s. Most of this research has adopted a stock market approach within the framework of the two-index linear regression model developed by Stone (1974), which includes an interest rate change factor in addition to the traditional market index for explaining stock returns of firms. This literature is primarily focused on financial institutions because of the special nature of the business of financial intermediation (e.g., Flannery and James, 1984; Elyasiani and Mansur, 1998; Fraser et al., 2002; or Czaja et al, 2009 and 2010).[1] Further, prior studies investigating the exposure of banks to IRR have limited to a few developed countries, principally the US, and only more recently Japan, the UK, Germany, or Australia. Three main results emerge from this line of work. First, a significant negative effect of movements in interest rates on the stock returns of financial firms is generally documented, which has commonly been attributed to the maturity mismatch between banks' assets and liabilities. Since banks tend to borrow short and lend long, the average maturity of the assets is usually longer than the average maturity of the liabilities. Thus, a rise in interest rates not only adversely affects a bank's net worth (the value of its assets falls more than the value of its liabilities), but also bank profits are reduced (the cost of its liabilities increases more rapidly than the yield on its assets). Second, bank stock returns typically exhibit more sensitivity to changes in long-term interest rates than to changes in short-term rates (e.g., Akella and Chen, 1990; Faff and Howard, 1999; Bartram, 2002; Saporoschenko, 2002; or Czaja et al., 2009). Third, as pointed out by Faff and Howard (1999), Benink and Wolff (2000), Ryan and Worthington (2004), and Joseph and Vezos (2006), among others, the interest rate sensitivity of stock returns of financial institutions has declined over time, possibly as a result of the increasing availability of more advanced tools and techniques for measuring and managing IRR.

Moreover, it is worth mentioning that the implicit assumption underlying almost all the literature on corporate exposure to IRR is that interest rate exposure is linear. Much less attention has been paid, however, to other possible interest rate risk profiles. In fact, the vast majority of studies of exposure to macroeconomic risks (such as exchange rate, interest rate, or inflation risk) that investigate the presence of nonlinear or asymmetric exposure components focus on exchange rate risk (e.g., Di Iorio and Faff, 2000; Koutmos and Martin, 2003; Bartram, 2004; Tai, 2005; and Priestley and Odegaard; 2007).

One critical reason why the standard approach based on a linear exposure pattern has been subject to persistent criticism is that using the same functional form for all the firms can be too restrictive, leading to understate the level of interest rate exposure. In this regard, it is widely accepted that the degree of exposure depends on firm and

[1] For a survey of the literature on bank interest rate exposure see Staikouras (2003 and 2006).

industry characteristics such as leverage, profitability, size, liquidity or risk management strategy. These characteristics not only determine the degree of exposure, but also have important implications for the functional relationship between changes in interest rates and the value of the firm. In addition, the relationship between interest rates and stock prices does not have to follow a time invariant functional form. Interest rate exposure may vary over time as firm and industry characteristics, and market conditions change. Hence, the assumption of a time invariant function implicit in the traditional approach to measuring the impact of IRR can lead to the erroneous conclusion that exposure is insignificant.

There exist, however, a few empirical papers that explore the possibility of a profile of exposure to IRR more complex than the linear one. The seminal work in this field was done by Chen and Chan (1989), who investigate for potential asymmetry of interest rate sensitivity of U.S. financial institutions around different interest rate cycles. Their results reveal a significant interest rate asymmetry during up and down cycles of interest rates, suggesting that the sensitivities of bank stock returns are highly sample-dependent. Similarly, Hallerbach (1994) shows that the sensitivity of the Dutch stock market to changes in interest rates is not constant over time and finds a clear pattern of asymmetry to interest rate fluctuations of different sign. He argues that the specification of a nonlinear model could partly explain the asymmetry between sensitivities for interest rate rises and falls.

In a very influential paper, Bartram (2002) investigates the impact of IRR on a large sample of German nonfinancial corporations at the industry level. Bartram presents empirical evidence for the existence of significant linear and nonlinear exposures with regard to various interest rate factors. In another empirical study, Verma and Jackson (2008) use a multivariate EGARCH (exponential generalized autoregressive conditional heteroskedastic) model to examine the presence of spillover effects and asymmetries between short- and long-term interest rates and portfolios of US banks. Their results provide evidence of response asymmetries for the portfolios of money center and other large banks, indicating that these banks are more sensitive to negative than positive interest rate changes.

In a more recent paper, Ferrer et al. (2010) conduct a comprehensive study of the influence of IRR on Spanish companies at the industry level. It is reported that interest rate exposure differs largely across sectors. In particular, highly leveraged, regulated, and banking are the most interest rate sensitive industries, although the introduction of the euro seems to have weakened the degree of interest rate exposure. It is also documented that the standard linear exposure profile is economically more important than the nonlinear or asymmetric exposure patterns.

Nevertheless, it should be noted that, to our best knowledge, the estimation of interest rate exposure using nonparametric regression techniques has not been addressed until now. As a matter of fact, the only two studies that have employed a nonparametric approach in the context of corporate exposure to risk have focused on exchange rate exposure (e.g., Guo and Wu, 1998; and Aysun and Guldi, 2009).

3. DATA

The sample consists of all Spanish commercial banks listed on the Spanish Stock Exchange during the period of study (a total number of 23 banking firms). Thus, the sample size varies over time because the number of publicly traded banks changes over time. The rationale for this sample selection procedure is to use all the firms' data available in each period, hence minimizing the survivor bias, and to maximize the membership in the sample in order to improve estimator efficiency. The sample period runs from January 1993 to December 2008, covering a time interval in which interest rates have varied considerably within a framework of clear downward trend.

The period of study allows us to investigate whether the introduction of the Euro in January 1999 has caused a significant change in the magnitude and pattern of interest rate exposure of Spanish commercial banks. To this end, the total sample period is split into two sub-samples, namely January 1993 to December 1998 (pre-Euro period), and January 1999 to December 2007 (post-Euro period).

The adoption of the euro as a common European currency is a major historical event in international financial markets with a potentially significant impact on the degree of IRR. The euro may affect bank interest rate exposure through two principal channels. First, since the launch of the euro, Eurozone interest rates are set by the European Central Bank (ECB) at the expense of national central banks. The ECB is responsible for monetary policy within the Eurozone, so its decisions are taken from a euro area-wide perspective, without any national bias. Therefore, the greater financial stability and transparency induced by the single monetary policy should have theoretically led to a reduction in the degree of IRR faced by European financial institutions. Second, the broadening and deepening of European financial markets since the introduction of the euro may have also contributed to improved interest rate risk management by banks.

Weekly stock prices and interest rate data are used in the empirical analysis. Weekly stock returns are computed using Wednesday closing prices of bank stocks. All stock prices have been adjusted for dividends, splits and capital gains.

With the aim of checking whether there exists a relationship between the size of banking institutions and the level of interest rate exposure, the analysis is conducted using bank stock portfolios constructed according to size (amount of total assets). This procedure is consistent with earlier studies on bank IRR (e.g., Song, 1994; Elyasiani and Mansur, 1998; Faff et al., 2005; Joseph and Vezos, 2006; or Verma and Jackson, 2008). Thus, Spanish commercial banks are categorized into three portfolios: large banks portfolio, medium banks portfolio, and small banks portfolio. Table 1 lists the individual banks included in the sample and their allocation among the three bank portfolios, along with the corresponding stock ticker symbol, number of observations, and average amount of total assets during the sample period. Summary descriptive statistics for each individual bank and portfolio are also reported. The portfolio returns employed are market value-weighted figures.[2]

In particular, the large banks portfolio (portfolio *L*, hereafter) consists of those banks with total assets exceeding €60 billion, leading to the inclusion therein of the two Spanish banking conglomerates (Banco Santander and BBVA). The medium banks portfolio (portfolio *M*) is composed of those entities whose total assets range from €7 billion to €60 billion. A total of seven banking firms, representative of the traditional Spanish mid-size banks, comprise this category. Lastly, the small banks portfolio

[2] The composition of the three bank stock portfolios remains fixed for the whole sample period.

(portfolio *S*) consists of the twelve smallest banks of the sample (amount of total assets below €7 billion).

The summary statistics suggest that the series of individual bank and portfolio returns are skewed and leptokurtic relative to the normal distribution. Consequently, the null hypothesis of normality of returns is clearly rejected at conventional levels of significance in all cases.

The series of weekly returns on each portfolio are calculated as the weighted arithmetic average of weekly returns on individual stocks included in each portfolio. The factor weight for each individual bank stock in the portfolio is the ratio of its stock market capitalization at the end of fiscal year over the market capitalization of the whole portfolio.

The proxy used for the market portfolio is the *Indice General de la Bolsa de Madrid*, the widest Spanish value-weighted market index. Equity market data are obtained from the Bolsa de Madrid Spanish Stock Exchange database. The average yield on 10-year Spanish Government bonds and the one-year and three-month average rates of the Spanish interbank market are employed as proxies for market interest rates. Weekly interest rate data are collected from the Bank of Spain historical database.

Table 2 presents the descriptive statistics of the levels and first differences of the interest rate series used in the study. As expected, for both the whole sample period and the two sub-periods the mean value of the series of 10-year government bond yields in levels is higher than that series of 1-year and 3-month interbank rates in levels, which in turn have similar mean value and very high correlation (0.98). For the series in first differences, the mean is almost zero in all the cases. With regard to the standard deviation, the 3-month rate series appears as the one with higher variability, followed by 1-year and 10-year rate series, with the exception of the post-euro period. Graph 1 displays the time evolution of the returns of large-, medium- and small-bank portfolios and the return on the market portfolio. The time evolution of the levels of the series of interest rates is also shown. It can be seen how comparatively the large and medium bank portfolios have much higher correlation with the market portfolio return (0.69 and 0.53, respectively) than the small banks portfolio (0.26). In turn, the series of interest rates exhibit a decreasing trend over the sample period.

4. METHODOLOGY

In this section, we briefly describe the different models used to estimate interest rate exposure both at the portfolio and individual bank level. We begin with the linear model traditionally employed in the exposure literature. Parametric nonlinear, asymmetric and nonparametric models are then discussed.

4.1. Parametric models

4.1.1. Linear Model

Following the standard practice in the literature, the classical two-index linear regression model postulated by Stone (1974) is used as the starting point to quantify interest rate exposure. This model has the following form:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \varepsilon_{it} \qquad (1)$$

where R_{it} denotes the return on bank *i*'s stock in period *t*, R_{mt} the return on the market portfolio in period *t*, ΔI_t the change in the interest rate used as reference in period *t*, and ε_{jt} is an error term for period *t*.

The coefficient on the return of the market portfolio β_i reflects the sensitivity of the return on *i*th bank stock or portfolio to general market fluctuations. The inclusion of a market index permits to control for general macroeconomic effects and reduces omitted variable bias. In turn, the coefficient on the interest rate term δ_i measures the sensitivity of *i*th bank stock or portfolio returns to movements in interest rates controlling for changes in the return on the market. Hence, it can be interpreted as a measure of the average linear interest rate exposure of *i*th bank over the estimation period. Note that a negative interest rate exposure coefficient corresponds to the traditional view of banks as borrowing short-term and lending long-term.

This model is estimated for each bank stock and portfolio return in the sample using OLS. To avoid possible multicolinearity problems, the market portfolio return is orthogonalized with respect to the interest rate change variable. Thus, the original market portfolio return series in Eq. (1) is replaced by the residuals from a regression of the market return variable on a constant and the interest rate change variable. This orthogonalization procedure has been used by, among others, Lynge and Zumwalt (1980), Hirtle (1997), Fraser et al. (2002) and Czaja et al. (2009). After orthogonalization, the coefficient β_i captures the pure sensitivity to general market movements. In turn, the coefficient δ_i represents a total measure of interest rate exposure as it reflects both the direct effect of interest rate changes on bank equity returns and the indirect effect through changes in the return on the market. It should be noted that the same orthogonalization approach is followed in all the other models described below.

4.1.2. Nonlinear Model

Early empirical studies of corporate exposure to IRR have focused almost exclusively on linear exposure. Nevertheless, as Bartram (2002) states, the value of a firm, defined as the present value of all its expected future cash flows, could depend in a very complex way on movements in interest rates. Since changes in interest rates affect both expectations about future cash flows and discount rates, it may occur that the relationship between firm value and interest rates is not strictly linear. Furthermore, companies primarily use instruments with linear payoff profiles (e.g., forward rate agreements, futures or swaps) to reduce their linear IRR. In contrast, nonlinear exposures are taken into account by firms to a much lesser extent when designing their hedging strategies with derivatives.[3] Hence, it is possible to empirically find a significant nonlinear exposure in certain cases, which could be hedged using instruments with nonlinear payoff structures such as interest rate options.

Nonetheless, it could be very restrictive to impose *a priori* a particular functional form to be used for measuring nonlinear interest rate exposure since the shape of the exposure may not be uniform across firms. Specifically, the exact form of nonlinearity may be a complex function of several firm characteristics such as financial leverage ratio, profitability, size, liquidity or risk management strategy. Given that this study can

[3] See Stultz (2005).

be viewed as a first attempt for assessing nonlinear interest rate exposure for Spanish banks (basis of comparison), a simple approach is taken assuming that some standard nonlinear functions may be sufficient to capture the possible nonlinearities. Thus, a regression equation with a generic nonlinear component is written as:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i f(\Delta I_t) + \varepsilon_{it} \tag{2}$$

where $f(\cdot)$ denotes a nonlinear function of the changes in interest rates and the parameter δ_i measures the effect of nonlinear movements in interest rates on the stock returns of bank *i*.

Various types of nonlinear functions may be appropriate for our purposes. One of the simplest ways to capture nonlinearity is by using a polynomial function of the third degree specified as $f(x) = a + b \cdot x + c \cdot x^2 + d \cdot x^3$, where the quadratic and cubic terms allow this function to take different shapes depending on the sign and magnitude of the parameters *c* and *d*. Another possible choice could be using the hyperbolic sine and inverse hyperbolic sine functions. The hyperbolic sine function, $f(x) = \sinh(x) = \left(e^x - e^{-x}\right)/2$, is characterized by a positive slope in the origin. Further, it is a convex function for positive values of the variable *x*, whereas it is a concave function for negative values of *x*. This feature can help to reflect a comparatively more aggressive response of bank stock returns to larger interest rate fluctuations. In turn, the inverse hyperbolic sine function, defined as $f(x) = inv\sinh(x) = \ln(x + \sqrt{x^2 + 1})$, has the opposite behaviour.

Therefore, the polynomial and the hyperbolic sine functions can be suitable to capture a nonlinear relationship between interest rate fluctuations and stock returns. Specifically, they accommodate the idea of inefficiencies in capital markets in the sense that whereas small interest rate movements are possibly dominated by other price relevant information and, thus, are less reflected in returns or even neglected, large interest rate fluctuations may have a greater impact on banks' stocks returns. Further, they allow distinguishing the effects of interest rate rises from the effects of interest rate falls.

Unfortunately, the last two specifications have proven not to be suitable for our purposes since the values of the independent variable (the series of interest rate changes) are not large enough to generate significant differences in the values of both nonlinear functions. Thus, the image set of the function is practically the same as the original series of changes in interest rates. Therefore, a third degree polynomial function is applied in the empirical analysis.

4.1.3. Asymmetric Sign and Size Model

An alternative way of detecting a nonlinear exposure is to examine the existence of an asymmetric response of bank stock returns to changes in interest rates of different sign and/or size. Note that bank stock returns may react differently to interest rate rises and falls (*sign asymmetry*). Besides, stock returns can be affected differently by large and small interest rate changes (*size or magnitude asymmetry*). In order to allow for these asymmetries, the basic model in Eq. (1) has been extended.

In particular, the sign asymmetry can be tested using the following equation:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \gamma_i D_t^{sign} + \eta_i D_t^{sign} \Delta I_t + \varepsilon_{it} \tag{3}$$

where a dummy variable, D_t^{sign}, is included to capture the potential sign asymmetry. In particular, $D_t^{sign} = 1$ if $\Delta I_t > 0$, and zero otherwise. Thus, for a given value of the market portfolio return, the response of bank stock returns to interest rate changes $\left(\frac{\partial R_{it}}{\partial \Delta I_t}\right)$ will be equal to δ_i when $\Delta I_t < 0$, and it will be $\delta_i + \eta_i$ for $\Delta I_t > 0$.

Analogously, the size or magnitude asymmetry can be analyzed through the following equation:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \gamma_i D_t^{mag} + \eta_i D_t^{mag} \Delta I_t + \varepsilon_{it} \tag{4}$$

In this case, the dummy variable, D_t^{mag}, reflects the potential size asymmetry. Thus, $D_t^{mag} = 1$ if $\Delta I_t \geq \mathrm{z_U}$ or $\Delta I_t < \mathrm{z_L}$ where $\mathrm{z_U}$ and $\mathrm{z_L}$ indicate the upper and lower threshold levels, respectively, that discriminate between small and large interest rate changes, and $D_t^{mag} = 0$ otherwise. The threshold values $\mathrm{z_U}$ and $\mathrm{z_L}$ are calculated as $\overline{\Delta I_t} + 2\sigma_{\Delta I_t}$ and $\overline{\Delta I_t} - 2\sigma_{\Delta I_t}$, respectively.[4] As in the previous case, the response of bank stock returns to interest rate changes $\left(\frac{\partial R_{it}}{\partial \Delta I_t}\right)$ will be equal to $\delta_i + \eta_i$ when $\Delta I_t \geq \mathrm{z_U}$ or $\Delta I_t < \mathrm{z_L}$, and δ_i in the remaining cases.

Additionally, notice that for the models (3) and (4) the value of the standard error associated with the sum of the estimated coefficients δ_i and η_i to be used in calculating their statistical significance, is calculated as follows:

$$\hat{\sigma}_{\frac{\partial R_{it}}{\partial \Delta I_t}} = \sqrt{Var(\hat{\delta}_i) + D_t^2 Var(\hat{\eta}_i) + 2D_t Cov(\hat{\delta}_i, \hat{\eta}_i)} \quad (5)$$

4.2. Nonparametric Model

All four model specifications presented above (linear, nonlinear, sign asymmetry and size asymmetry) require a specific functional form and assume that this functional form does not change during the period of study. Moreover, these methodologies rule out the possibility of different functions for different firms. In order to tackle these issues, we also estimate the relationship between movements in interest rates and bank stock returns without adhering to any specific parametric functional form using a non-parametric regression method. In particular, the local linear regression method developed by Stone (1977) is employed in order to avoid the typical specification problems inherent to traditional parametric approaches. This approach is chosen because it has a higher asymptotic efficiency and allows for faster convergence at boundary points compared to other nonparametric methods.[5]

[4] Thus, if the series of interest rate changes follow a Gaussian distribution, the dummy variable will take the value 1 only in the 5% of the cases.

[5] See Fan and Gijbels (1992) and Pagan and Ullah (1999) for a more detailed discussion of these properties.

As a first step the following linear regression is estimated for each individual bank stock and portfolio:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{6}$$

where R_{mt} is the orthogonalized market portfolio return.

From (6) the parameter $\hat{\beta}_i$ is obtained for each bank stock and portfolio. Then, the excess return on bank *i*'s stock, $\hat{R}^e_{it}$, is calculated as follows:

$$\hat{R}^e_{it} = R_{it} - \hat{\beta}_i R_{mt} \tag{7}$$

Finally, for each bank stock and portfolio return the following expression is estimated:

$$\hat{R}^e_{it} = f(\Delta I_t) + \varepsilon_{it} \tag{8}$$

Although the exact form for $f(\Delta I_t)$ is not known, the local linear estimation methodology approximates the relationship between ΔI_t and $\hat{R}^e_{it}$ by making use of the Taylor's series expansion around each observation of interest rate changes such that

$$f(\Delta I_t) \approx f(\Delta I_j) + f'(\Delta I_j)(\Delta I_t - \Delta I_j) = a_j + b_j(\Delta I_t - \Delta I_j) \quad \forall j \tag{9}$$

Next, it fits a line for each observation of ΔI_j by minimizing the following expression:

$$Min \sum_{t=1}^{N} \left\{ \hat{R}^e_{it} - \left[a_j + b_j(\Delta I_t - \Delta I_j) \right] \right\}^2 / K_j \tag{10}$$

where $K_j = \dfrac{K(\Delta I_t - \Delta I_j)}{h}$ is a function that weights the distance or gap between each ΔI_t with ΔI_j and depends on a normal kernel and *h* denotes the regression smoother bandwidth. Following the standard practice, we set *h* equal to $h = \sigma_{\Delta I_t} / N^5$, where $\sigma_{\Delta I_t}$ is the standard error of the interest rate change series and *N* the number of observations. Notice that only observations close to ΔI_j are included in the minimization problem so that the coefficients *a* and *b* are functions of ΔI_j .

After estimating b_j for every point in the sample, the mean of the estimator is calculated as:

$$\bar{\hat{b}}_i = \sum_{j=1}^{N} \hat{b}_j / N \qquad (11)$$

to quantify the relationship between the interest rate and the bank's excess stock return. Similarly, the variance of b_i is measured as

$$\sigma^2(b_i) = \sum_{j=1}^{N} (\hat{b}_j - \bar{\hat{b}}_i)^2 / N - 1 \qquad (12)$$

Rilstone (1991) shows that this estimator is consistent and asymptotically normal. Furthermore, its standard errors are comparable to those obtained from a conventional parametric estimation.

5. EMPIRICAL RESULTS

Table 3 summarizes the results of the estimation of the interest rate exposure coefficients at the portfolio level for the three proxies of market interest rates under consideration. Columns (1) to (4) correspond to the different parametric models used, whereas column (5) presents the results of the nonparametric estimation. Panel A reports the exposure estimates for the entire sample period, and Panels B and C refer to the pre-euro and post-euro sub-periods, respectively.

Linear interest rate exposure

Regarding the linear effect of interest rate movements on bank portfolio returns, the exposure coefficients obtained from estimating the two-index model of Stone (1974) outlined in Eq. (1) are always negative for the entire sample period, although they are only statistically significant at conventional levels for the three portfolios when 10-year and 3-month interest rate changes are used. This implies that Spanish bank stock returns are, on average, adversely impacted by rises in interest rates. This negative relationship between movements in interest rates and bank stock returns is consistent with the typical bank balance sheet maturity structure, where long-term assets are funded with short-term liabilities (positive duration gap). The negative link also agrees with most of the empirical literature on interest rate exposure of the banking industry (e.g., Flannery and James, 1984; Madura and Zarruk, 1995; Elyasiani and Mansur, 1998; and Czaja et al., 2009 and 2010).

However, the different series of interest rate changes have not a homogeneous effect on the three bank portfolios. Thus, whereas changes in 10-year government bond yields have greater impact on the medium banks and small banks portfolios, fluctuations in 3-month interbank rates primarily affect to the large banks portfolio. In contrast, changes in 1-year interbank rates appear by far as those that exert a lower linear influence on bank portfolio returns. Additionally, the small banks portfolio seems to be the less vulnerable one to linear IRR (in absolute terms) during the total sample period regardless of the proxy of interest rates used.

Nonlinear interest rate exposure

As shown in column (2) of Table 3, the cubic function of changes in interest rates permits to identify a level of nonlinear exposure to IRR during the entire sample period even higher than that found for the linear specification. In particular, all the estimated nonlinear exposure coefficients are statistically significant at the 1% level regardless of the bank portfolio and proxy of market interest rates used. The sign of the nonlinear coefficients is always negative, indicating that, on average, Spanish banks take advantage of decreases in interest rates from a nonlinear perspective, thus supporting the widespread view that banks tend to maintain a positive mismatch between the maturity of their assets and liabilities. Similarly to the linear approach, the estimated exposure coefficients are larger (in absolute terms) when changes in 10-year government bond yields are used, and the large banks portfolio appears as the one with higher nonlinear exposure irrespective of the proxy of interest rates considered.

Since the independent variables in the linear and nonlinear specifications are different, in order to compare the economic importance of both kinds of exposure the product of the exposure coefficient with one standard deviation of the proxy for market interest rates is computed for all bank portfolios exhibiting both significant linear and nonlinear exposure. As Bartram (2002) notes, this procedure makes the coefficients comparable as it standardizes the variables across regression specifications.

As shown in Table 4, for almost all the portfolios regardless of the proxy for interest rates and the sample period considered, the absolute values obtained for the nonlinear exposure coefficients are larger than those corresponding to the linear exposure. This result means that, in general, the nonlinear interest rate exposure of Spanish banking firms is economically more important than the linear exposure.

Analysis of asymmetries

The asymmetric sign model, consistently with the linear model, shows negative coefficients on the interest rate changes, but in this case the independent variables are statistically significant only in 50% of the cases (see Table 3). Bank stock returns are especially sensitive to 10-year and 3-month rate changes. Again, the larger the banks included in the portfolio, the greater the interest rate exposure.

Accordingly with the above result, when interest rates decrease, bank stock returns increase; this relationship is shown to be particularly important for the larger banks, regardless of the interest rate proxy considered. However, for interest rate rises, there seems not to be such a clearly negative effect on the bank stock returns, especially for larger banks, since none of the interest rate proxies is statistically significant in that case.

However, this idea of asymmetries in the in the sensitivity of bank stock returns to interest rate positive and negative variations which could be suggested by the above results is not supported by the Wald test carried out to identify them. As it can be seen in Table 5, the parameter η_i is not statistically different from zero in most of the cases, so no asymmetric sign effect is detected for the bank interest rate exposure.

With respect to the size or magnitude asymmetry, it should be pointed out that firstly it has been necessary to set both the upper and lower threshold in order to separate small from large interest rate fluctuations. For each proxy of interest rate changes, the upper threshold is computed as its sample mean plus two standard deviations whereas that the lower threshold is calculated as the sample mean of the interest rate change series minus two standard deviations.

Analogously to the sign asymmetry, the results of Table 3 could suggest that the size asymmetry is basically manifested when short-term (3-month) interest rates are used. In that case portfolios *L* and *M* show a negative relationship with the interest rate changes. These interest rate changes are significant if they are large enough to exceed the thresholds but they are not otherwise. Additionally, the coefficients are larger when the 3-month interest rate changes are outside the bounds. For the case of the other two interest rate proxies, consistently with the results for the symmetric linear model, the 1-year interest rate changes do not seem to exert any influence on the bank stock returns, regardless the magnitude of the changes and independent of the size of the portfolio considered; in turn, the 10-year interest rate changes are always significant.

The above statements, however, should be reconsidered according to the results obtained with the Wald test, which are shown in Table 5. As it can be seen, for the entire sample period there are no size asymmetries detected at 5% level for any bank portfolio.

Non Parametric model

Analogously to the previous models, regardless the portfolio and the interest rate proxy considered, all the estimated durations show negative sign when estimated through the non parametric model.

As expected, the estimated exposure coefficients are very close to the values obtained in the linear parametric model. However, the standard deviations of the estimators are much lower when using the nonparametric specification. This helps to provide greater reliability relative to the statistic significance of the estimated coefficients. The idea of the stability of the parameter can be observed in Graph 2, where it can be seen that the range of values for the estimated coefficient $\hat{b}$ is really small, even though the scale of the graph could suggest just the opposite.

Sub-period analysis

The sub-period analysis reveals a substantial reduction of the degree of interest rate exposure for all the specifications considered. This seems to indicate that the importance of interest rate risk in explaining bank stock return variability has declined following the introduction of the euro. A possible explanation for this finding is related to the greater stability and lower levels of interest rates, and the development of better interest rate risk management tools in recent years. In this regard, financial institutions may have taken advantage of the increased depth and completeness of corporate bond markets with the advent of the euro to implement a more effective management of interest rate risk.

In the pre-euro period (1993-1998) all the significant exposure coefficients have negative sign for the different specifications employed regardless of the bank portfolio and proxy of interest rates under consideration. There may be also a size effect, so larger banks exhibit a higher interest rate exposure. In turn, long-term interest rates seem to be the ones that exert a greater influence (in absolute value) on bank portfolio returns. Additionally, the absolute values of the exposure coefficients are always greater than those obtained for the entire sample period.

The post-euro period (1999-2008), however, shows a completely different pattern of results. The number of significant interest rate exposure coefficients is considerably lower than that obtained in the pre-euro period regardless of the bank portfolio, proxy of interest rates, and model specification used. Moreover, a large part of the significant exposure coefficients take positive values. This implies that Spanish banks benefit from rising interest rates during the post-euro era, which is opposite to the evidence obtained for the entire sample and pre-euro periods. This finding is also in conflict with the significant negative relationship between bank stock returns and interest rate fluctuations typically documented in the literature (e.g., Flannery and

James, 1984; Madura and Zarruk, 1995; Elyasiani and Mansur, 1998; or Czaja et al., 2009).

Two major reasons may help to explain the positive exposure of Spanish banking firms to interest rate risk. First, the dramatic reduction of the traditional maturity mismatch (borrowing short and lending long) in recent years due to the combined effect of several new trends in banking. On the one hand, the massive use of adjustable-rate banking products tied to short-term interbank rates since the mid-1990s. Specifically, interbank market rates have become the usual reference in the price setting of bank retail operations, mainly in the mortgage segment. On the other hand, the unprecedented growth of asset securitization transactions in Spain, mostly remarkable in the residential mortgages area, along with the increased use of interest rate derivatives may also have played an outstanding role in this context.[6] Second, the positive impact of interest rate risk may reflect the serious difficulties of banks to maintain their margins at reasonable levels in a falling interest rate scenario. Thus, when interest rates are very low banking firms face to a narrowing of the lending-deposit rate spread since a positive interest on their deposit accounts is required. This argument is consistent with the evidence of gradual compression in bank margins within an environment of pronounced decline of interest rates and intense competitiveness as the occurred in the Spanish banking industry over the last decade.

It should be pointed out that the values of the standard deviations of the estimators obtained for this sub-period in the parametric models are substantially higher than the ones corresponding to the pre-euro and the entire sample period. Therefore, a more caution in the interpretation of the findings obtained in the post-euro period is required. In fact, the results for this period do not show a clear pattern for the different portfolios or interest proxies used. This finding is especially evident in the case of the non-parametric model, which shows results that diverge from the corresponding to the parametric models. This result can be suggesting that, whereas for the pre-euro period the parametric and nonparametric models capture adequately the interest rate exposure for the portfolios and the individual stocks, the post-euro period requires a different

[6] According to the European Securitisation Forum Data Report 2008:Q2, since 2006 Spain constitutes the second largest country, only behind the U.K., in terms of issuance volumes in the European securitised debt markets.

functional form for each bank that can vary along the time, which is the main feature of the nonparametric specification. Thus, for the post-euro period the parametric models, which show estimators with greater standard deviations in comparison to the nonparametric model, may not be appropriate to adequately capture a common interest rate exposure for the banks included in the same portfolio.

The idea of that the results are less consistent in the post-euro period is supported by the results shown in the Table 6, corresponding to the measures of fit obtained with each model for the different portfolios, interest proxies, and sample periods used in the analysis. It can be seen that the adjusted R^2 statistic shows systematically higher values for the pre-euro period, so indicating better model fit. This result is valid for any model specification and interest proxy used, regardless of the portfolio considered.

With regard to the existence of sign or size asymmetries in any of the two sub-periods of study, whereas the Wald test does not permit to detect evidence of sign asymmetries, some size asymmetries are detected (see Table 5). Specifically, the returns of the *L* portfolio show different sensitivity to small and large interest variations during the pre-euro period, regardless of the interest rate proxy considered. This result obeys to the fact that both the level and variability of the interest rates is much higher during the pre-euro period (see Table 2). Thus, it is more likely that there exists an asymmetric behaviour in the sensitivity of bank stock returns. In contrast, during the post-euro period, due to the convergence process of interest rates, their range is much smaller so it is the chance to find size asymmetries.

The analysis carried out at the portfolio level is complemented with an analysis of the banks working on an individual basis. The results obtained in this complementary study are shown in Table 7. Specifically, this table shows the percentages of banking firms with significant interest rate exposure for the different models and interest proxies used. As usual, Panels A, B and C show the results for the entire sample period, pre- and post-euro sub-periods, respectively.

The findings support the idea that the negative empirical durations obtained for the whole sample period are due to the results corresponding to the pre-euro sub-period. Thus, taking the standard symmetric linear model as the reference, in the entire period all the empirical duration coefficients are negative for the statistically significant 1-year and 3-month interest rate changes, and only 2 out of 23 firms show a positive empirical duration coefficient when the proxy considered is the long-term interest rate changes. The results for the remaining models are in the same line.

In the pre-euro period this negative relationship between stock returns and interest rate changes is accentuated. No positive empirical durations are detected in the symmetric linear model regardless the interest rate proxy used, and only one banking firm shows a positive coefficient when the nonlinear model is used to capture the interest rate risk.

The results, however, are drastically different in the post-euro period, especially when the 1-year interest rate changes are used in the context of a symmetric linear model. Now the prior negative empirical durations turn into positive values in most cases, indicating that banks benefit from rising interest rates. This finding is in conflict with the significant and negative relationship between bank stock returns and interest rate fluctuations typically documented in the literature (see e.g. Flannery and James, 1984; Madura and Zarruk, 1995; Elyasiani and Mansur, 1998; or Czaja et al., 2009). However, it should be pointed out the existence of some differences among the results corresponding to the 1-year interest rate and the results obtained for the other two interest rate proxies, which could suggest a different pattern of exposure depending on the interest rate considered as relevant for the banking firms during the post-euro period.

Residual Analysis

In addition to using a measure of overall adjustment amongst the models, to properly compare them it is necessary to analyze the series of each model's residuals. The idea is to observe the adjustment with each particular observation, in the sense that it could be possible that global adjustment measures were very similar, as it actually happens in the case of portfolios, without implying that the different models perform the data equally. With illustrative purposes, Graph 3 shows the actual and fitted portfolio series and residuals for all the estimated models for the whole period.

Tables 8 and 9 show the descriptive statistics of residuals series obtained in parametric models and the correlation matrix between these residuals and the dependent variable, respectively.[7] The results in both tables correspond to the analysis at the portfolio level and, as usual, they are disaggregated for the three portfolios, interest rate proxies and sample periods. Those results will be jointly commented on below.

With regard to the descriptive statistics, for all portfolios the series of residuals obtained with the different models are quite similar. Thus, there are no significant differences in mean, standard deviation, maximum, and minimum values. This idea is supported by the fact that the correlation coefficients amongst the residuals of the different models for the entire sample period are greater than 0.99. The null hypothesis of normality is clearly rejected for each residuals series, due basically to the excess of kurtosis of those series.

In the comparison among different models, notice that the lower the standard deviation of the residuals and the correlation of those residuals with the dependent variable, the greater the model explanatory power. According to this criterion, the model with greater explanatory power is the asymmetric size model in most cases regardless the portfolio and the interest rate proxy considered.

Regarding the correlation between the residuals and the bank portfolios returns should be noted that in all cases portfolio *L* exhibits the lowest value in all sample periods, so confirming that usually models have a better adjustment for the portfolio of large banks.

Analyzing the differences between sample periods, it can be seen that regardless of the model considered, the standard deviation of its residuals and the correlation between those residuals and the portfolio returns are higher in post-euro period. These results confirm that the fit of the model is better in the pre-euro sample period.

To complement the above results, the Wilcoxon signed-rank test for residuals[8] has been carried out (see Table 10). It constitutes a non-parametric statistical hypothesis test for the case of two related samples or repeated measurements on a single sample

[7] Notice that the nonparametric estimation has no residuals.

[8] Wilcoxon (1945).

and it can be used as an alternative to the paired Student's t-test when the population cannot be assumed to be normally distributed, as it happens in our case. Its null hypothesis is that the median difference between pairs of observations is zero.[9]

It can be seen that most of *p*-values in Table 10 are less than 0.05, so indicating that according to this test, the series of residuals of the parametric models considered are different. This result suggests that even though the correlation coefficients amongst the series of residuals are exceptionally high, the explanatory variables considered in the four parametric models have not the same information content about the variability of bank portfolio returns.

6. CONCLUSIONS

This paper provides a comprehensive analysis of the impact of interest rate risk on the Spanish banking sector using both parametric and non-parametric models. In particular, the traditional linear interest rate exposure approach is extended to allow for the possibility of a nonlinear component as well as the presence of asymmetric behaviour in the exposure pattern. The main contribution of this study is to use for the first time a non-parametric regression method that avoids the assumption of a specific functional form to measure the degree of bank interest rate exposure.

The study shows some interesting results. In general, the Spanish banking industry presents a remarkable exposure to interest rate risk during the sample period. It must be noted, however, that the extent of interest rate risk borne by Spanish banks has noticeably decreased after the adoption of the euro. This lower interest rate sensitivity is possibly due to the higher monetary stability, the low levels of interest rates derived from the European convergence process, and the increasing availability of better tools for managing interest rate risk in recent years. Furthermore, a pattern of positive interest rate exposure seems to emerge during the post-euro period, reflecting a sharp change in the nature of the impact of interest rate risk on bank stocks. This distinctive feature of

[9] Note that this hypothesis is different from the null hypothesis of the paired t-test, which is that the mean difference between pairs is zero, or the null hypothesis of the sign test, which is that the number of differences in each direction is equal.

the Spanish banking system can be attributed to two main reasons. First, the substantial reduction of the maturity mismatch due to the conjunction of various recent trends in the Spanish banking industry such as the prevalence of adjustable rate products, the spectacular growth of asset securitization or the widespread use of financial derivatives. Second, the positive exposure may also reflect the strong pressure on bank margins in a scenario of strong downward trend in interest rates and intense competition in force over the last years.

It is also documented that the nonlinear exposure profile is economically more important than the linear one, whereas very scant evidence of sign and size asymmetries is found. The key role played by nonlinear interest rate exposure has important practical implications in terms of interest rate risk management. Thus, the standard linear models should be augmented to capture the nonlinear component of risk in order to gain a better insight into the effect of interest rate risk on banking firms.

With respect to asymmetric models is tested that no asymmetric sign and size effect are detected for the bank interest rate exposure for the entire sample period. In the two sub-periods of study some size asymmetries are detected, specifically, the returns of the *L* portfolio show different sensitivity to small and large interest variations during the pre-euro period, regardless of the interest rate proxy considered. This result obeys to the fact that both the level and variability of the interest rates is much higher during the pre-euro period. Thus, it is more likely that there exists an asymmetric behaviour in the sensitivity of bank stock returns. In contrast, during the post-euro period, due to the convergence process of interest rates, their range is much smaller so it is the chance to find size asymmetries.

Using the nonparametric specification the estimated exposure coefficients are very close to the values obtained in the linear parametric model, however, the standard deviations of the estimators are much lower. This helps to provide greater reliability relative to the statistic significance of the estimated coefficients.

Comparing the series of residuals obtained in the parametric models, the model with greater explanatory power is the asymmetric size model in most cases regardless the portfolio and the interest rate proxy considered.

Analyzing the differences between sample periods, it can be seen that regardless of the model considered, the standard deviation of its residuals and the correlation between those residuals and the portfolio returns are higher in post-euro period. These results confirm that the fit of the model is better in the pre-euro sample period.

Analyzing the residuals series obtained in the parametric models, the result is that this series are different. This result suggests that even though the correlation coefficients amongst the series of residuals are exceptionally high, the explanatory variables considered in the four parametric models have not the same information content about the variability of bank portfolio returns.

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ANNEX: TABLES AND GRAPHS

Table 1
List of Banks, Composition of Bank Portfolios and Descriptive Statistics of Bank and Market Weekly Returns

Bank	Ticker	Obs.	Asset Volume (€ x 10^3)	Mean	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis (excess)	JB
Portfolio *L*		**811**		**0.0017**	**0.0413**	**-0.2024**	**0.1881**	**-0.3945*****	**4.0181*****	**566.6283*****
Banco Santander Central Hispano	BSCH	493	527.699.133	-0.0004	0.0440	-0.2139	0.2083	-0.4093***	3.4977***	265.0774***
Banco Bilbao Vizcaya Argentaria	BBVA	453	346.037.438	0.0003	0.0469	-0.1856	0.2340	0.2726**	4.0452***	314.4888***
Banco Bilbao Vizcaya	BBV	358	178.232.614	0.0052	0.0434	-0.2340	0.1780	-0.7377***	6.0490***	578.2846***
Banco Santander	SAN	318	138.205.050	0.0041	0.0476	-0.2550	0.1947	-0.8727***	5.6107***	457.4783***
Banco Central Hispano	BCH	318	71.668.583	0.0041	0.0413	-0.1769	0.1989	0.4152***	3.6253***	183.8544***
Argentaria	ARG	341	71.360.857	0.0032	0.0390	-0.1606	0.1515	-0.0740	1.4619***	30.6810***
Portfolio *M*		**811**		**0.0010**	**0.0270**	**-0.1468**	**0.1403**	**0.0065**	**4.1839*****	**591.5475*****
Banesto	BTO	811	54.805.640	0.0006	0.0395	-0.2477	0.2856	-0.0111***	10.8877***	4005.7982***
Banco Popular Español	POP	811	43.308.947	0.0017	0.0374	-0.1651	0.2009	0.2947***	3.6503***	462.0225***
Banco Exterior	EXT	217	34.941.640	-0.0014	0.0172	-0.0583	0.1310	2.3881***	17.9776***	3128.5090***
Banco Sabadell	SAB	391	28.529.393	-0.0001	0.0311	-0.1711	0.1029	-1.1476***	5.8192***	637.5175***
Bankinter	BKT	811	22.133.367	0.0019	0.0432	-0.1442	0.3048	0.7053***	5.4133***	1057.5052***
Banco Pastor	PAS	811	12.177.073	0.0020	0.0315	-0.1078	0.1901	0.6390***	4.0906***	620.6553***
Banco Atlántico	ATL	581	7.807.936	0.0024	0.0263	-0.1625	0.3412	4.6393***	60.9188***	91923.92***
Portfolio *S*		**811**		**0.0013**	**0.0166**	**-0.0798**	**0.1294**	**0.6883*****	**9.1546*****	**2896.067*****
Banco Valencia	BVA	811	6.713.193	0.0033	0.0305	-0.1397	0.2353	1.0020***	7.5072***	2040.2043***
Banco Guipuzcoano	GUI	811	5.123.700	0.0017	0.0278	-0.1143	0.1814	1.1666***	7.9904***	2341.4559***
Banco Andalucía	AND	811	5.097.787	0.0009	0.0282	-0.1695	0.3001	1.4331***	20.0062***	13802.69***
Banco Zaragozano	ZRG	553	4.713.960	0.0043	0.0332	-0.0971	0.2366	1.8118***	9.5679***	2411.8961***
Banco Herrero	HRR	404	2.944.989	0.0000	0.0376	-0.2513	0.2809	0.5917***	18.2621***	5637.5732***

Banco de Castilla	CAS	811	2.709.587	0.0004	0.0282	-0.1842	0.2580	1.3998***	17.7088***	10862.05***
Banco Galicia	GAL	811	2.233.393	0.0014	0.0308	-0.1890	0.2979	2.2172***	25.5837***	22782.03***
Banco de Vasconia	VAS	811	1.846.067	0.0003	0.0319	-0.2231	0.3036	0.8099***	17.3193***	10224.78***
Banco de Vitoria	VIT	271	1.271.736	-0.0003	0.0391	-0.2000	0.2727	1.9468***	17.5775***	3659.9822***
Banco Crédito Balear	CBL	811	1.098.787	0.0014	0.0348	-0.2000	0.2518	1.8374***	13.2345***	6375.03***
Banco Alicante	ALI	271	872.386	-0.0015	0.0153	-0.0622	0.1473	3.4386***	35.7005***	14925.64***
Banco Simeón	SIM	284	836.763	-0.0026	0.0455	-0.3263	0.2792	-1.4332***	19.0991***	4413.7671***
Market Portfolio (IGBM)		811		0.0022	0.0275	-0.1138	0.1261	-0.3145***	1.7203***	113.3831***

This table displays the list of Spanish commercial banks considered and their distribution in portfolios according to size criteria (portfolios *L*, *M* and *S*). JB is the Jarque-Bera test for normality of returns. This statistic is distributed as chi-squared with two degrees of freedom. ***, ** and * represent significance at the 1%, 5% and 10%, respectively.

Table 2
Descriptive Statistics of Level and First Differences of Interest Rates

	Mean	Std. Deviation	Minimum	Maximum
Entire sample period (1993-2008)				
TIR10	0.0597	0.0255	0.0305	0.1244
ΔTIR10	-0.0001	0.0013	-0.0062	0.0070
TIR1	0.0506	0.0268	0.0195	0.1426
ΔTIR1	-0.0001	0.0014	-0.0228	0.0089
TIR3	0.0499	0.0276	0.0198	0.1542
ΔTIR3	-0.0001	0.0020	-0.0362	0.0209
$Corr(TIR10, TIR1) = 0.94$ $Corr(TIR10, TIR3) = 0.91$ $Corr(TIR1, TIR3) = 0.98$				
Pre-euro period (1993-1998)				
TIR10	0.0855	0.0245	0.0399	0.1244
ΔTIR10	-0.0003	0.0019	-0.0062	0.0070
TIR1	0.0763	0.0262	0.0317	0.1426
ΔTIR1	-0.0004	0.0021	-0.0229	0.0090
TIR3	0.0768	0.0264	0.0328	0.1542
ΔTIR3	-0.0004	0.0032	-0.0362	0.0209
Post-euro period (1999-2008)				
TIR10	0.0444	0.0068	0.0305	0.0586
ΔTIR10	0.0000	0.0009	-0.0029	0.0036
TIR1	0.0352	0.0102	0.0196	0.0551
ΔTIR1	0.0000	0.0008	-0.0035	0.0031
TIR3	0.0334	0.0100	0.0198	0.0540
ΔTIR3	0.0000	0.0008	-0.0054	0.0051

Table 3
Exposure of Bank Portfolios to Interest Rate

	Linear Model (1)	Nonlinear Model (2)	Asymmetric Sign Model (3)		Asymmetric Size Model (4)		Nonparametric Model (10)
	δ_i	δ_i	δ_i	$(\delta_i+\eta_i)$	δ_i	$(\delta_i+\eta_i)$	$\bar{\hat{b}}_i$
Panel A: Entire sample period (1993-2008)							
10-year interest rate							
Portfolio *L*	-2.3047**	-102670.30***	-3.7050**	-1.9823	-1.7887	-2.8417***	-2.3061***
	(0.9054)	*(31031.77)*	*(1.7064)*	*(1.4188)*	*(1.3568)*	*(0.9349)*	*(0.0032)*
Portfolio *M*	-3.0899***	-97596.83***	-2.7278**	-3.0427**	-3.5093***	-2.6565***	-3.0908***
	(0.6284)	*(22497.26)*	*(1.1077)*	*(1.0938)*	*(0.9123)*	*(0.7177)*	*(0.0024)*
Portfolio *S*	-1.6396***	-62855.17***	-0.7382	-2.3058***	-1.4478**	-1.8099***	-1.6410***
	(0.4052)	*(14172.32)*	*(0.8134)*	*(0.7484)*	*(0.6122)*	*(0.4928)*	*(0.0028)*
1-year interest rate							
Portfolio *L*	-0.2708	-2495.47***	-1.1377	-0.8771	2.4059	-1.5139	-0.2710***
	(0.8026)	*(316.951)*	*(1.0110)*	*(1.1699)*	*(1.6674)*	*(0.9751)*	*(0.0008)*
Portfolio *M*	-0.6906	-682.83***	-0.7960	-1.2041	0.2241	-0.9891	-0.6915***
	(0.4911)	*(253.59)*	*(0.7257)*	*(0.8548)*	*(1.0082)*	*(0.7868)*	*(0.0013)*
Portfolio *S*	-0.2739	-804.96***	-0.1734	-1.7216*	0.6566	-0.7216*	-0.2743***
	(0.3059)	*(128.70)*	*(0.4291)*	*(0.6779)*	*(0.6866)*	*(0.3763)*	*(0.0008)*
3-month interest rate							
Portfolio *L*	-1.5899***	-1285.64***	-1.8446***	-1.3156	0.4036	-1.7494***	-1.5905***
	(0.4879)	*(141.48)*	*(0.6748)*	*(0.4602)*	*(1.7259)*	*(0.4096)*	*(0.0017)*
Portfolio *M*	-1.0733***	-514.66***	-1.1784**	-0.4482	-0.5321	-0.9633**	-1.0752***
	(0.3766)	*(124.10)*	*(0.5825)*	*(0.2761)*	*(1.0498)*	*(0.4026)*	*(0.0026)*
Portfolio *S*	-0.4122**	-358.04***	-0.4585*	-0.2741	0.3950	-0.5020	-0.4132***
	(0.2047)	*(110.26)*	*(0.2649)*	*(0.4018)*	*(0.7542)*	*(0.2125)*	*(0.0009)*
Panel B: Pre Euro period (1993-1998)							
10-year interest rate							
Portfolio *L*	-6.0372***	-231892.29***	-7.4335***	-7.9702***	-5.2875***	-7.1679***	-6.0390***
	(0.5402)	*(30679.40)*	*(1.1255)*	*(1.02483)*	*(0.8130)*	*(0.5894)*	*(0.0057)*
Portfolio *M*	-4.9635***	-155293.58***	-5.8355***	-3.7873***	-5.1632***	-4.8898***	-4.9662***
	(0.5085)	*(24062.26)*	*(1.0330)*	*(1.1286)*	*(0.6975)*	*(0.6585)*	*(0.0061)*
Portfolio *S*	-1.9041***	-73900.75***	-1.6036*	-2.3527**	-1.5765***	-2.3896***	-1.9059***
	(0.3297)	*(12159.82)*	*(0.8885)*	*(0.6837)*	*(0.4867)*	*(0.4408)*	*(0.0031)*
1-year interest rate							
Portfolio *L*	-2.4275***	-7227.11***	-3.2923***	-2.7008*	-0.7203	-3.3556***	-2.4283***
	(0.6249)	*(309.21)*	*(0.5263)*	*(0.9637)*	*(0.7252)*	*(0.1530)*	*(0.0013)*
Portfolio *M*	-2.0932***	-3568.56***	-2.2046***	-1.4219	-2.1110***	-1.8986***	-2.0943***
	(0.3542)	*(267.16)*	*(0.52952)*	*(1.0440)*	*(0.6084)*	*(0.3824)*	*(0.0016)*
Portfolio *S*	-0.7191***	-1737.38***	-0.9190***	-1.6833	-1.7775	-2.6324*	-0.7199***
	(0.2189)	*(123.97)*	*(0.2751)*	*(0.7983)*	*(0.4337)*	*(0.2559)*	*(0.0016)*
3-month interest rate							
Portfolio *L*	-1.6473***	-1730.74***	-1.9515***	-1.9520***	0.5164	-2.0458***	-1.6492***
	(0.2682)	*(192.01)*	*(0.2595)*	*(0.2340)*	*(1.0543)*	*(0.1107)*	*(0.0021)*
Portfolio *M*	-1.2503***	-857.64***	-1.1700***	-0.6551	-0.4878	-1.3328***	-1.2519***
	(0.2511)	*(172.16)*	*(0.3522)*	*(0.3011)*	*(0.7412)*	*(0.3741)*	*(0.0020)*
Portfolio *S*	-0.5483***	-474.05***	-0.6733***	-0.5038	-0.1160	-0.6059*	-0.5497***
	(0.1499)	*(131.46)*	*(0.2004)*	*(0.4077)*	*(0.5398)*	*(0.2034)*	*(0.0013)*
Panel C: Post Euro period (1999-2008)							

10-year interest rate							
Portfolio *L*	7.0858**	1039059.19	1.3094	11.0115***	8.6238***	3.3521	1.0000
	(2.8734)	*(909703.63)*	*(7.8710)*	*(4.6589)*	*(2.1637)*	*(7.7489)*	*(0.0009)*
Portfolio *M*	1.6552	16315.34	3.3275	-0.9299	2.9724**	-0.5684	-0.7062
	(1.8276)	*(573103.60)*	*(4.6523)*	*(3.2989)*	*(1.4842)*	*(4.9926)*	*(0.0019)*
Portfolio *S*	-0.9497	-459916.06	0.6197	-3.1730*	0.0450	-2.3570*	1.0000
	(1.1322)	*(343701.65)*	*(3.0016)*	*(2.2884)*	*(0.8374)*	*(2.9074)*	*(0.0009)*
1-year interest rate							
Portfolio *L*	9.0641**	187006.33	6.4021	7.1958*	9.5608***	8.3099***	2.7048
	(3.6070)	*(1711796.8)*	*(9.5915)*	*(4.2429)*	*(2.5080)*	*(6.7621)*	*(0.0030)*
Portfolio *M*	5.4656***	232532.54	6.6603	3.3442	6.1921***	3.5063*	1.0000
	(1.9520)	*(932149.54)*	*(5.3414)*	*(2.1279)*	*(1.7163)*	*(3.5242)*	*(0.0008)*
Portfolio *S*	1.7239	55083.41	4.4846	-1.9054	1.3561	1.0503	1.0000
	(1.3217)	*(493051.61)*	*(3.5321)*	*(1.5176)*	*(1.1567)*	*(2.2343)*	*(0.0008)*
3-month interest rate							
Portfolio *L*	-1.4429	-450821.42	-4.5516	1.1340	1.1977	-3.5346	6.4294
	(4.8956)	*(492240.63)*	*(7.8907)*	*(6.5157)*	*(4.3447)*	*(6.5964)*	*(0.0158)*
Portfolio *M*	0.8345	-191386.31	0.0021	0.9088	3.1917	-1.0028	5.8632
	(2.7061)	*(263543.46)*	*(4.5842)*	*(1.8300)*	*(2.8810)*	*(3.3890)*	*(0.0038)*
Portfolio *S*	1.0558	-13032.67	2.1306	0.1295	-1.4456	1.7622	4.0778
	(1.7621)	*(161982.82)*	*(3.1889)*	*(2.0120)*	*(2.0916)*	*(2.3048)*	*(0.0023)*

This table reports the coefficients of the interest rate exposure for the five estimated models with the three different interest rate proxies and the three portfolios for the entire sample, pre-euro and post-euro period. OLS is used to estimate equation (1) to (4). Cubic function is used in the non linear model. Nonparametric model (5) is estimated with local linear regression method developed by Stone (1977). Estimated standard deviations in parenthesis. ***, ** and * represent significance at 1%, 5% and 10% level, respectively.

(1) $R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \varepsilon_{it}$	**(3)** $R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \gamma_i D_t^{sign} + \eta_i D_t^{sign} \Delta I_t + \varepsilon_{it}$ $D_t^{sign} = 1; \Delta I_t > 0; D_t^{sign} = 0; \Delta I_t < 0$
(2) $R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i f(\Delta I_t) + \varepsilon_{it}$	**(4)** $R_{it} = \alpha_i + \beta_i R_{mt} + \delta_i \Delta I_t + \gamma_i D_t^{mag} + \eta_i D_t^{mag} \Delta I_t + \varepsilon_{it}$ $D_t^{mag} = 1;\ \Delta I_t \geq z_U$ and $\Delta I_t < z_L\ ; D_t^{mag} = 0\ \ otherwise$

$$\textbf{(10)}\ Min \sum_{t=1}^{N} \left\{ \hat{R}_{it}^{e} - \left[a_j + b_j (\Delta I_t - \Delta I_j) \right] \right\}^2 / K_j \ ;\ K_j = \frac{K(\Delta I_t - \Delta I_j)}{h} \ ;\ h = \sigma_{\Delta I_t} / N^5$$

Table 4
Economic significance of linear and nonlinear exposures

	Linear Model (1)			Nonlinear Model (2)		
	10-year interest rate	**1-year interest rate**	**3-month interest rate**	**10-year interest rate**	**1-year interest rate**	**3-month interest rate**
Panel A: Entire sample period (1993-2008)						
Portfolio *L*	-0.0028	-0.0011	-0.0022	-0.0032	-0.0004	-0.0033
Portfolio *M*	-0.0026	-0.0003	-0.0009	-0.0043	-0.0010	-0.0022
Portfolio *S*	-0.0017	-0.0003	-0.0006	-0.0023	-0.0004	-0.0009
Panel B: Pre-euro period (1993-1998)						
Portfolio *L*	-0.0102	-0.0050	-0.0048	-0.0115	-0.0050	-0.0053
Portfolio *M*	-0.0068	-0.0025	-0.0024	-0.0095	-0.0043	-0.0041
Portfolio *S*	-0.0032	-0.0012	-0.0013	-0.0036	-0.0015	-0.0018
Panel C: Post-euro period (1999-2008)						
Portfolio *L*	0.0042	0.0007	-0.0053	0.0066	0.0071	-0.0011
Portfolio *M*	0.0001	0.0008	-0.0023	0.0016	0.0043	0.0006
Portfolio *S*	-0.0018	0.0002	-0.0002	-0.0009	0.0013	0.0008

Table 5
Asymmetry in Interest Rate Exposure

	Asymmetric Sign Model			Asymmetric Size Model		
Panel A: Entire sample period (1993-2008)						
	10-year interest rate	**1-year interest rate**	**3-month interest rate**	**10-year interest rate**	**1-year interest rate**	**3-month interest rate**
Portfolio *L*	1.7227	0.2606	0.5290	-1.0530	-3.9198*	-2.1530
	(2.0520)	*(1.4137)*	*(0.8262)*	*(1.4917)*	*(2.2299)*	*(1.8489)*
Portfolio *M*	-0.3149	-0.4081	0.7302	0.8528	-1.2132	-0.4312
	(1.4332)	*(1.0714)*	*(0.6289)*	*(1.0788)*	*(1.4075)*	*(1.1476)*
Portfolio *S*	-1.5676	-1.5482*	0.1844	-0.3621	-1.3782*	-0.8970
	(1.0538)	*(0.7988)*	*(0.4896)*	*(0.7627)*	*(0.8246)*	*(0.7904)*
Panel B: Pre-euro period (1993-1998)						
Portfolio *L*	-0.2367	0.5915	-0.0005	-1.8804*	-2.6353***	-2.5622**
	(1.5959)	*(0.9099)*	*(0.3219)*	*(0.9954)*	*(0.7429)*	*(1.0878)*
Portfolio *M*	2.0482	0.7827	0.5149	0.2734	0.2124	-0.8450
	(1.5489)	*(0.9623)*	*(0.4364)*	*(0.9497)*	*(0.7029)*	*(0.8439)*
Portfolio *S*	-0.7491	-0.7643	0.1695	-0.8131	-0.8548*	-0.4899
	(1.1848)	*(0.8862)*	*(0.4526)*	*(0.6550)*	*(0.5081)*	*(0.5926)*
Panel C: Post-euro period (1999-2008)						
Portfolio *L*	9.7021	0.7937	5.6856	-5.2717	-1.2509	-4.7323
	(8.7141)	*(10.3602)*	*(9.8519)*	*(7.9781)*	*(7.1661)*	*(7.5855)*
Portfolio *M*	-4.2574	-3.3161	0.9067	-3.5408	-2.6858	-4.1945
	(5.2197)	*(5.6627)*	*(4.8001)*	*(5.2753)*	*(3.9849)*	*(4.3822)*
Portfolio *S*	-3.7927	-6.3900*	-2.0011	-2.4420	-0.3058	3.2078
	(3.6083)	*(3.7992)*	*(3.7961)*	*(2.9494)*	*(2.4931)*	*(3.2576)*

This table shows the estimated coefficient η_i and their respective standard deviation (in parenthesis) testing the null hypothesis that both estimated coefficient of interest rate exposure in asymmetric models (3) and (4) are the same.

Table 6

Adjustment Measures: Adjusted R^2 and Sum of Squared Residuals

	Linear Model (1)		**Nonlinear Model (2)**		**Asymmetric Sign Model (3)**		**Asymmetric Size Model (4)**	
	R^2 **Adj.**	**SSR**	R^2 **Adj.**	**SSR**	R^2 **Adj.**	**SSR**	R^2 **Adj.**	**SSR**
Panel A: Entire sample period (1993-2008)								
10-year interest rate								
Portfolio *L*	47.66	0.7214	47.51	0.7235	47.61	0.7203	47.56	0.7210
Portfolio *M*	28.03	0.4257	26.46	0.4350	27.86	0.4256	27.90	0.4254
Portfolio *S*	7.60	0.2076	6.77	0.2095	7.60	0.2071	7.86	0.2065
1-year interest rate								
Portfolio *L*	47.77	0.7199	47.83	0.7191	47.81	0.7176	48.41	0.7094
Portfolio *M*	27.23	0.4305	27.11	0.4312	27.08	0.4303	27.60	0.4272
Portfolio *S*	6.55	0.2100	6.54	0.2100	6.67	0.2092	6.83	0.2088
3-month interest rate								
Portfolio *L*	47.64	0.7217	47.28	0.7267	47.54	0.7214	48.11	0.7135
Portfolio *M*	27.28	0.4301	26.70	0.4336	27.21	0.4295	27.73	0.4265
Portfolio *S*	6.66	0.2099	6.47	0.2102	6.38	0.2099	6.82	0.2089
Panel B: Pre-euro period (1993-1998)								
10-year interest rate								
Portfolio *L*	72.19	0.1069	69.91	0.1156	72.59	0.1046	72.26	0.1059
Portfolio *M*	56.73	0.1070	51.46	0.1200	56.67	0.1064	56.78	0.1062
Portfolio *S*	17.51	0.0751	16.63	0.0759	17.04	0.0750	17.15	0.0749
1-year interest rate								
Portfolio *L*	74.58	0.1073	72.07	0.1073	72.33	0.1056	72.82	0.1038
Portfolio *M*	58.83	0.1066	55.38	0.1103	56.65	0.1065	56.84	0.1060
Portfolio *S*	6.01	0.0750	17.37	0.0752	17.59	0.0745	17.41	0.0747
3-month interest rate								
Portfolio *L*	74.17	0.1095	71.09	0.1111	71.69	0.1081	72.14	0.1064
Portfolio *M*	58.33	0.1069	55.44	0.1108	56.87	0.1059	57.25	0.1050
Portfolio *S*	5.88	0.0751	17.04	0.0755	17.07	0.0750	17.38	0.0747
Panel C: Post-euro period (1999-2008)								
10-year interest rate								
Portfolio *L*	38.46	0.5841	37.03	0.5976	38.66	0.5799	38.79	0.5786
Portfolio *M*	14.14	0.2880	13.78	0.2892	14.05	0.2872	14.28	0.2864
Portfolio *S*	2.98	0.1276	3.98	0.1273	3.10	0.1270	3.72	0.1262
1-year interest rate								
Portfolio *L*	38.49	0.5837	35.87	0.6086	38.41	0.5822	38.26	0.5836
Portfolio *M*	14.64	0.2863	12.02	0.2951	14.42	0.2859	14.83	0.2846
Portfolio *S*	2.26	0.1286	1.59	0.1295	3.00	0.1271	3.18	0.1269
3-month interest rate								
Portfolio *L*	39.28	0.5763	40.72	0.5626	39.33	0.5735	39.44	0.5724
Portfolio *M*	14.03	0.2884	14.73	0.2860	13.76	0.2881	14.56	0.2855
Portfolio *S*	2.15	0.1287	1.91	0.1290	2.01	0.1284	2.38	0.1279

Table 7
Percentage of individual banks with significant interest rate exposure (*)

	Linear Model (1)	Nonlinear Model (2)	Asymmetric Sign Model (3)		Asymmetric Size Model (4)		Nonparametric Model (10)
	δ_i	δ_i	δ_i	$(\delta_i + \eta_i)$	δ_i	$(\delta_i + \eta_i)$	$\bar{\hat{b}}_i$
Panel A: Entire sample period (1993-2008)							
10-year interest rate							
Positive	13.04%	17.39%	26.09%	13.04%	30.43%	17.39%	13.04%
% significant	66.67%	25.00%	16.67%	0.00%	14.29%	25.00%	100.00%
Negative	86.96%	82.61%	73.91%	86.96%	69.57%	82.61%	86.96%
% significant	65.00%	52.63%	41.18%	45.00%	50.00%	63.16%	100.00%
1-year interest rate							
Positive	43.48%	26.09%	21.74%	21.74%	65.22%	30.43%	43.48%
% significant	0.00%	66.67%	0.00%	0.00%	13.33%	0.00%	100.00%
Negative	56.52%	73.91%	78.26%	78.26%	34.78%	69.57%	56.52%
% significant	100.00%	82.35%	16.67%	16.67%	0.00%	25.00%	100.00%
3-month interest rate							
Positive	13.04%	13.04%	13.04%	30.43%	56.52%	13.04%	13.04%
% significant	0.00%	33.33%	66.67%	28.57%	7.69%	0.00%	100.00%
Negative	86.96%	86.96%	86.96%	69.57%	43.48%	86.96%	86.96%
% significant	45.00%	90.00%	50.00%	50.00%	0.00%	45.00%	100.00%
Panel B: Pre-euro period (1993-1998)							
10-year interest rate							
Positive	8.70%	4.35%	13.04%	13.04%	17.39%	4.35%	8.70%
% significant	0.00%	0.00%	0.00%	0.00%	25.00%	100.00%	100.00%
Negative	86.96%	91.30%	82.61%	82.61%	78.26%	91.30%	86.96%
% significant	85.00%	80.95%	52.63%	63.16%	83.33%	85.71%	100.00%
1-year interest rate							
Positive	13.04%	8.70%	4.35%	21.74%	26.09%	8.70%	13.04%
% significant	0.00%	50.00%	0.00%	40.00%	0.00%	0.00%	100.00%
Negative	82.61%	86.96%	91.30%	73.91%	69.57%	86.96%	82.61%
% significant	50.00%	90.00%	61.90%	70.59%	31.25%	75.00%	100.00%
3-month interest rate							
Positive	8.70%	13.04%	8.70%	13.04%	34.78%	8.70%	8.70%
% significant	0.00%	0.00%	50.00%	33.33%	0.00%	0.00%	100.00%
Negative	86.96%	82.61%	86.96%	82.61%	60.87%	86.96%	86.96%
% significant	70.00%	94.74%	75.00%	78.95%	21.43%	75.00%	100.00%
Panel C: Post-euro period (1999-2008)							
10-year interest rate							
Positive	56.52%	39.13%	56.52%	34.78%	60.87%	39.13%	39.13%
% significant	23.08%	0.00%	23.08%	25.00%	50.00%	11.11%	100.00%
Negative	26.09%	43.48%	26.09%	47.83%	21.74%	43.48%	43.48%
% significant	16.67%	10.00%	0.00%	27.27%	0.00%	30.00%	100.00%
1-year interest rate							
Positive	73.91%	60.87%	73.91%	43.48%	69.57%	60.87%	73.91%
% significant	70.59%	28.57%	35.29%	10.00%	50.00%	57.14%	100.00%
Negative	8.70%	21.74%	8.70%	39.13%	13.04%	21.74%	8.70%
% significant	0.00%	0.00%	0.00%	33.33%	0.00%	20.00%	100.00%
3-month interest rate							
Positive	52.17%	39.13%	52.17%	47.83%	34.78%	56.52%	73.91%
% significant	25.00%	22.22%	41.67%	36.36%	12.50%	15.38%	100.00%
Negative	30.43%	43.48%	30.43%	34.78%	47.83%	26.09%	8.70%
% significant	0.00%	10.00%	0.00%	12.50%	0.00%	16.67%	100.00%

(*) The significance level used to consider a firm as exposed to interest rate risk has been 5%.

Table 8
Descriptive Statistics of Residuals

	Mean	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis (excess)	JB
Panel A: Entire sample period (1993-2008)							
			Portfolio *L*				
10-year interest rate							
R1	0.0000	0.0299	-0.2181	0.2981	-0.1034	22.2705***	16740.73***
R2	0.0000	0.0299	-0.2187	0.3009	-0.0471	22.6131***	17258.45***
R3	0.0000	0.0298	-0.2182	0.2959	-0.1381	22.0242***	16373.60***
R4	0.0000	0.0299	-0.2181	0.2991	-0.0750	22.4317***	16983.17***
1-year interest rate							
R1	0.0000	0.0298	-0.2159	0.3007	-0.04350	22.5931***	17228.01***
R2	0.0000	0.0298	-0.2153	0.3014	-0.0238	22.6983***	17388.65***
R3	0.0000	0.0298	-0.2147	0.2991	-0.0514	22.4108***	16951.12***
R4	0.0000	0.0296	-0.2098	0.2845	-0.1293	20.0873***	13620.41***
3-month interest rate							
R1	0.0000	0.0299	-0.2173	0.2964	-0.1293	21.9197***	16218.06***
R2	0.0000	0.0300	-0.2148	0.3047	0.0160	22.7306***	17438.12**
R3	0.0000	0.0299	-0.2171	0.2956	-0.1330	21.8193***	16070.17***
R4	0.0000	0.0297	-0.2145	0.2802	-0.2811***	19.7238***	13140.39***
			Portfolio *M*				
10-year interest rate							
R1	0.0000	0.0229	-0.1188	0.1577	0.1228	9.3020***	2922.36***
R2	0.0000	0.0232	-0.1251	0.1626	0.1856**	9.5882***	3107.47***
R3	0.0000	0.0229	-0.1188	0.1583	0.1307	9.3232***	2935.97***
R4	0.0000	0.0229	-0.1205	0.1570	0.1003	9.2968***	2918.39***
1-year interest rate							
R1	0.0000	0.0231	-0.1247	0.1635	0.1730**	9.7970***	3243.42***
R2	0.0000	0.0231	-0.1252	0.1658	0.2028**	9.8927***	3308.57***
R3	0.0000	0.0231	-0.1250	0.1633	0.1671*	9.7780***	3230.59***
R4	0.0000	0.0230	-0.1249	0.1536	0.1375	9.2012***	2859.93***
3-month interest rate							
R1	0.0000	0.0231	-0.1245	0.1617	0.1552*	9.6786***	3164.85***
R2	0.0000	0.0232	-0.1249	0.1673	0.2226***	9.9011***	3315.30***
R3	0.0000	0.0230	-0.1236	0.1607	0.1427*	9.5950***	3109.92***
R4	0.0000	0.0230	-0.1245	0.1494	0.0941	9.0540***	2767.85***
			Portfolio *S*				
10-year interest rate							
R1	0.0000	0.0160	-0.0840	0.1260	0.7328***	10.0236***	3109.92***
R2	0.0000	0.0161	-0.0870	0.1259	0.7711***	10.1519***	3558.65***
R3	0.0000	0.0160	-0.0825	0.1250	0.7332***	9.8965***	3378.13***
R4	0.0000	0.0160	-0.0788	0.1257	0.7521***	9.8968***	3382.09***
1-year interest rate							
R1	0.0000	0.0161	-0.0881	0.1257	0.7547***	10.1168***	3558.65***
R2	0.0000	0.0161	-0.0883	0.1258	0.7676***	10.1387***	3448.88***
R3	0.0000	0.0161	-0.0885	0.1262	0.7519***	10.1894***	3580.40***
R4	0.0000	0.0161	-0.0885	0.1261	0.7826***	10.1050***	3529.01***
3-month interest rate							
R1	0.0000	0.0161	-0.0880	0.1255	0.7473***	10.0829***	3448.88***
R2	0.0000	0.0161	-0.0882	0.1261	0.7753***	10.1713***	3572.77***
R3	0.0000	0.0161	-0.0879	0.1254	0.7449***	10.0685***	3496.31***

	Mean	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis (excess)	JB
R4	0.0000	0.0161	-0.0883	0.1268	0.7742***	10.1687***	3570.78***
	Mean	**Std. Deviation**	**Minimum**	**Maximum**	**Skewness**	**Kurtosis (excess)**	**JB**
Panel B: Pre Euro period (1993-1998)							
Portfolio *L*							
10-year interest rate							
R1	0.0000	0.0188	-0.0819	0.0769	-0.4401**	3.3153***	148.55***
R2	0.0000	0.0196	-0.0777	0.0633	-0.3376**	1.8757***	50.17***
R3	0.0000	0.0186	-0.0798	0.0771	-0.3193**	3.0601***	123.37***
R4	0.0000	0.0187	-0.0813	0.0739	-0.4566***	3.1809***	138.27***
1-year interest rate							
R1	0.0000	0.0189	-0.0832	0.0873	-0.3970***	4.0080***	210.77***
R2	0.0000	0.0189	-0.0823	0.0879	-0.3032**	3.5993***	168.20***
R3	0.0000	0.0187	-0.0810	0.0893	-0.3333**	3.9694***	204.53***
R4	0.0000	0.0185	-0.0823	0.0878	-0.3507**	3.9982***	208.02***
3-month interest rate							
R1	0.0000	0.0190	-0.0832	0.0866	-0.4069***	3.9789***	208.24***
R2	0.0000	0.0192	-0.0821	0.0839	-0.2914**	3.3058***	142.26***
R3	0.0000	0.0189	-0.0814	0.0838	-0.3636**	3.5892***	169.32***
R4	0.0000	0.0188	-0.0817	0.0824	-0.3144**	3.4829***	158.14***
Portfolio *M*							
10-year interest rate							
R1	0.0000	0.0188	-0.0899	0.0978	-0.0823	5.5579***	390.33***
R2	0.0000	0.0199	-0.0932	0.0947	-0.1551	4.8149***	293.91***
R3	0.0000	0.0188	-0.0880	0.0990	-0.0288	5.5532***	389.37***
R4	0.0000	0.0188	-0.0888	0.0978	-0.0453	5.5503***	389.02***
1-year interest rate							
R1	0.0000	0.0188	-0.0900	0.0980	-0.0506	5.6415***	401.93***
R2	0.0000	0.0191	-0.0910	0.0968	0.0281	5.3581***	362.50***
R3	0.0000	0.0188	-0.0899	0.0987	-0.0290	5.6518***	403.32***
R4	0.0000	0.0187	-0.0893	0.0980	-0.0491	5.5871***	394.21***
3-month interest rate							
R1	0.0000	0.0188	-0.0908	0.0982	-0.0636	5.5977***	395.80***
R2	0.0000	0.0191	-0.0913	0.0964	-0.0054	5.2630***	349.71***
R3	0.0000	0.0187	-0.0905	0.1005	-0.0550	5.7748***	421.17***
R4	0.0000	0.0187	-0.0901	0.0971	-0.0707	5.6370***	401.42***
Portfolio *S*							
10-year interest rate							
R1	0.0000	0.0158	-0.0502	0.1239	2.6776***	18.0562***	4478.16***
R2	0.0000	0.0159	-0.0490	0.1233	2.6556***	17.7133***	4317.35***
R3	0.0000	0.0158	-0.0502	0.1235	2.6602***	17.9448***	4422.84***
R4	0.0000	0.0158	-0.0499	0.1238	2.6829***	18.1625***	4528.20***
1-year interest rate							
R1	0.0000	0.0158	-0.0502	0.1238	2.6747***	18.0257***	4463.45***
R2	0.0000	0.0158	-0.0499	0.1237	2.6755***	17.9261***	4418.47***
R3	0.0000	0.0157	-0.0493	0.1247	2.7112***	18.4056***	4648.14***
R4	0.0000	0.0157	-0.0500	0.1238	2.7009***	18.2299***	4564.05***
3-month interest rate							
R1	0.0000	0.0158	-0.0501	0.1238	2.6767***	18.0473***	4473.82***
R2	0.0000	0.0158	-0.0501	0.1245	2.6826***	18.0832***	4491.81***

R3	0.0000	0.0158	-0.0497	0.1242	2.6994***	18.2319***	4564.54***
R4	0.0000	0.0157	-0.0501	0.1245	2.7268***	18.5114***	4701.71***
	Mean	**Std. Deviation**	**Minimum**	**Maximum**	**Skewness**	**Kurtosis (excess)**	**JB**
Panel C: Post Euro period (1999-2008)							
			Portfolio *L*				
10-year interest rate							
R1	0.0000	0.0340	-0.2075	0.2870	0.0262	17.3371***	6337.20***
R2	0.0000	0.0344	-0.2024	0.2877	-0.0254	16.2994***	5601.29***
R3	0.0000	0.0339	-0.2082	0.2765	-0.2462**	16.4939***	5740.78***
R4	0.0000	0.0339	-0.2083	0.2663	-0.3724***	15.6229***	5157.62***
1-year interest rate							
R1	0.0000	0.0340	-0.2046	0.2903	0.1126	17.5674***	6507.68***
R2	0.0000	0.0347	-0.2202	0.2665	-0.4237***	14.7283***	4588.58***
R3	0.0000	0.0340	-0.2067	0.2839	-0.0105	17.0494***	6128.57***
R4	0.0000	0.0340	-0.2048	0.2887	0.0931	17.4184***	6397.42***
3-month interest rate							
R1	0.0000	0.0338	-0.2182	0.2611	-0.3881***	15.5703***	5124.03***
R2	0.0000	0.0334	-0.2200	0.1995	-0.9857***	12.2888***	3265.85***
R3	-0.0001	0.0337	-0.2217	0.2473	-0.6480***	15.0222***	4783.74***
R4	0.0000	0.0337	-0.2111	0.2608	-0.2127*	15.1278***	4828.72***
			Portfolio *M*				
10-year interest rate							
R1	0.0000	0.0239	-0.1127	0.1427	0.2052*	8.2692***	1445.23***
R2	0.0000	0.0239	-0.1083	0.1386	0.1227	7.7237***	1259.02***
R3	0.0000	0.0238	-0.1072	0.1459	0.3124***	8.4187***	1502.50***
R4	0.0000	0.0238	-0.1048	0.1391	0.2117*	7.9695***	1342.83***
1-year interest rate							
R1	0.0000	0.0238	-0.1159	0.1520	0.4047***	8.9113***	1688.06***
R2	0.0000	0.0242	-0.1126	0.1428	0.1975*	7.9994***	1352.42***
R3	0.0000	0.0238	-0.1157	0.1554	0.4468***	9.1420***	1778.90***
R4	0.0000	0.0237	-0.1167	0.1526	0.4272***	8.9657***	1710.13***
3-month interest rate							
R1	0.0000	0.0239	-0.1151	0.1420	0.2156*	8.3321***	1467.61***
R2	0.0000	0.0238	-0.1152	0.1311	-0.0811	7.0966***	1062.35***
R3	0.0000	0.0239	-0.1158	0.1384	0.1777	8.2260***	1429.33***
R4	0.0000	0.0238	-0.1161	0.1416	0.3019***	8.4208***	1502.69***
			Portfolio *S*				
10-year interest rate							
R1	0.0000	0.0159	-0.0799	0.0790	-0.4641***	4.7621***	496.29***
R2	0.0000	0.0158	-0.0799	0.0793	-0.4830***	4.4509***	437.34***
R3	0.0000	0.0159	-0.0752	0.0798	-0.3635***	4.5799***	453.38***
R4	0.0000	0.0158	-0.0756	0.0798	-0.3501***	4.3982***	418.17***
1-year interest rate							
R1	0.0000	0.0160	-0.0844	0.0806	-0.3336***	4.9424***	524.40***
R2	0.0000	0.0160	-0.0834	0.0812	-0.4101***	4.9453***	529.80***
R3	0.0000	0.0159	-0.0838	0.0808	-0.2368**	5.1022***	553.59***
R4	0.0000	0.0159	-0.0847	0.0803	-0.2275**	5.1076***	554.38***
3-month interest rate							
R1	0.0000	0.0160	-0.0842	0.0813	-0.3363***	5.0053***	537.74***

R2	0.0000	0.0160	-0.0840	0.0808	-0.4403***	4.9184***	526.36***
R3	0.0000	0.0159	-0.0838	0.0811	-0.2545**	5.0839***	550.39***
R4	0.0000	0.0159	-0.0837	0.0797	-0.2517**	5.0343***	539.69***

R1, R2, R3 and R4 are the residuals of the linear, nonlinear, asymmetric sign and size model, respectively. JB is the Jarque-Bera test for normality of returns. This statistic is distributed as chi-squared with two degrees of freedom. ***, ** and * represent significance at the 1%, 5% and 10% levels, respectively.

Table 9
Correlation matrix between residuals and the dependent variable

Panel A: Entire sample period (1993-2008)												
	Portfolio *L*				**Portfolio *M***				**Portfolio *S***			
10-year interest rate												
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
R2	0.9968				0.9909				0.9948			
R3	0.9992	0.9966			0.9999	0.9904			0.9988	0.9937		
R4	0.9997	0.9977	0.9993		0.9997	0.9891	0.9997		0.9974	0.9935	0.9986	
Portfolio	0.7225	0.7236	0.7220	0.7223	0.8473	0.8565	0.8472	0.8470	0.9600	0.9643	0.9588	0.9575
1-year interest rate												
R2	0.9996				0.9993				0.9998			
R3	0.9984	0.9987			0.9998	0.9992			0.9981	0.9978		
R4	0.9927	0.9939	0.9945		0.9962	0.9959	0.9960		0.9973	0.9977	0.9953	
Portfolio	0.7218	0.7214	0.7206	0.7165	0.8520	0.8527	0.8518	0.8488	0.9655	0.9655	0.9637	0.9629
3-month interest rate												
R2	0.9969				0.9972				0.9993			
R3	0.9997	0.9973			0.9993	0.9965			0.9999	0.9993		
R4	0.9943	0.9929	0.9955		0.9957	0.9933	0.9965		0.9976	0.9975	0.9978	
Portfolio	0.7227	0.7252	0.7225	0.7186	0.8517	0.8550	0.8510	0.8480	0.9652	0.9659	0.9652	0.9629
Panel B: Pre Euro period (1993-1998)												
10-year interest rate												
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
R2	0.9249				0.9526				0.9889			
R3	0.9894	0.9410			0.9974	0.9453			0.9995	0.9898		
R4	0.9955	0.9468	0.9909		0.9961	0.9434	0.9981		0.9988	0.9931	0.9986	
Portfolio	0.5255	0.5466	0.5200	0.5232	0.6556	0.6944	0.6539	0.6530	0.9052	0.9100	0.9047	0.9041
1-year interest rate												
R2	0.9767				0.9856				0.9975			
R3	0.9921	0.9825			0.9995	0.9860			0.9968	0.9954		
R4	0.9833	0.9851	0.9879		0.9974	0.9842	0.9982		0.9979	0.9980	0.9964	
Portfolio	0.5266	0.5267	0.5225	0.5179	0.6543	0.6657	0.6540	0.6526	0.9046	0.9060	0.9017	0.9027
3-month interest rate												
R2	0.9810				0.9891				0.9971			
R3	0.9935	0.9816			0.9953	0.9832			0.9993	0.9975		
R4	0.9856	0.9816	0.9897		0.9909	0.9849	0.9861		0.9975	0.9964	0.9983	
Portfolio	0.5319	0.5359	0.5285	0.5243	0.6554	0.6653	0.6524	0.6495	0.9052	0.9078	0.9046	0.9029
Panel C: Post Euro period (1999-2008)												
10-year interest rate												
	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
R2	0.9913				0.9980				0.9965			
R3	0.9964	0.9886			0.9985	0.9965			0.9974	0.9959		
R4	0.9954	0.9835	0.9954		0.9972	0.9951	0.9977		0.9942	0.9963	0.9965	

Portfolio	0.7829	0.7919	0.7801	0.7793	0.9248	0.9267	0.9234	0.9222	0.9830	0.9780	0.9805	0.9773
1-year interest rate												
R2	0.9818				0.9882				0.9971			
R3	0.9987	0.9802			0.9993	0.9875			0.9943	0.9915		
R4	0.9999	0.9816	0.9989		0.9969	0.9845	0.9980		0.9933	0.9905	0.9963	
Portfolio	0.7827	0.7992	0.7816	0.7826	0.9221	0.9361	0.9214	0.9192	0.9866	0.9900	0.9810	0.9800
3-month interest rate												
R2	0.9908				0.9933				0.9983			
R3	0.9977	0.9918			0.9996	0.9937			0.9987	0.9969		
R4	0.9966	0.9895	0.9926		0.9949	0.9897	0.9944		0.9968	0.9949	0.9982	
Portfolio	0.7777	0.7684	0.7756	0.7751	0.9253	0.9215	0.9249	0.9206	0.9872	0.9884	0.9860	0.9841

R1, R2, R3 and R4 are the residuals of the linear, nonlinear, asymmetric sign and size model respectively.

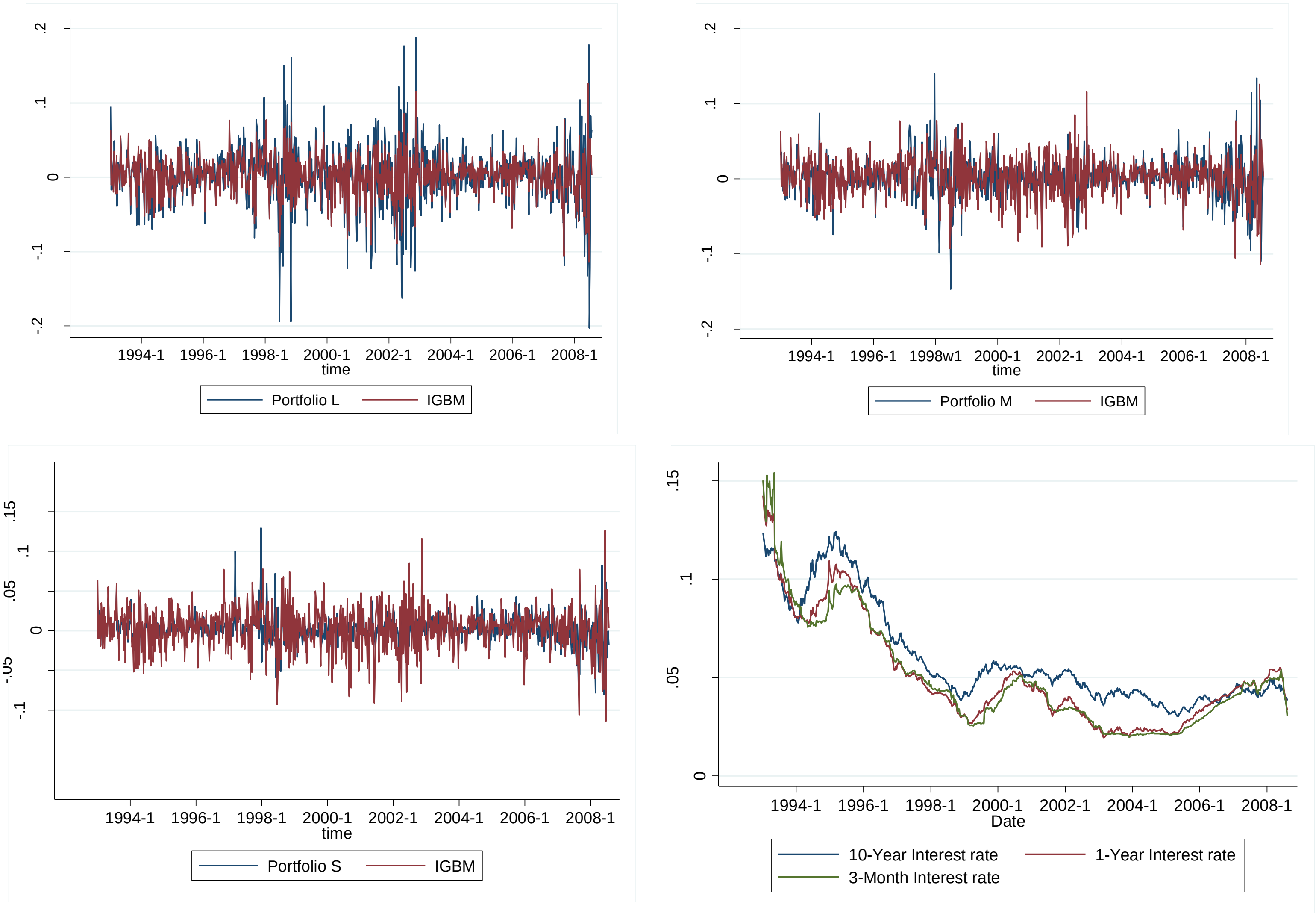
Table 10
Wilcoxon signed-rank test for residuals

WILCOXON SIGNED-RANK TEST									
Panel A: Entire sample period (1993-2008)									
	Portfolio *L*			**Portfolio *M***			**Portfolio *S***		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
10-year interest rate									
R2	0.8376			0.9948			0.9390		
R3	0.3995	0.0000		0.3141	0.7585		0.0000	0.0020	
R4	0.6927	0.7188	0.8060	0.2165	0.9241	0.0000	0.0000	0.0046	0.0213
1-year interest rate									
R2	0.0263			0.0659			0.3137		
R3	0.0703	0.3376		0.0221	0.3946		0.1067	0.2621	
R4	0.0017	0.006	0.0010	0.0000	0.0000	0.0000	0.0197	0.0000	0.0000
3-month interest rate									
R2	0.0000			0.0000			0.0000		
R3	0.0000	0.0000		0.0000	0.0000		0.0156	0.0000	
R4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.3372
Panel B: Pre Euro period (1993-1998)									
	R1	R2	R3	R1	R2	R3	R1	R2	R3
10-year interest rate									
R2	0.9077			0.7701			0.9072		
R3	0.8978	0.9880		0.0093	0.8478		0.0147	0.2051	
R4	0.2696	0.9995	0.9990	0.0000	0.9191	0.7993	0.5208	0.9974	0.0000
1-year interest rate									
R2	0.8509			0.7383			0.8999		
R3	0.0876	0.1568		0.8222	0.2870		0.7782	0.2300	
R4	0.0640	0.0000	0.7274	0.0000	0.0852	0.0000	0.1561	0.0000	0.2817
3-month interest rate									
R2	0.7054			0.3187			0.4162		
R3	0.0016	0.6503		0.0173	0.0471		0.1120	0.0126	
R4	0.6531	0.1644	0.4013	0.0000	0.0000	0.9379	0.0000	0.0000	0.0137
Panel C: Post Euro period (1999-2008)									
	R1	R2	R3	R1	R2	R3	R1	R2	R3
10-year interest rate									
R2	0.8502			0.8066			0.0001		
R3	0.0262	0.2817		0.0330	0.0216		0.0223	0.0091	
R4	0.0000	0.7794	0.0546	0.0004	0.8813	0.0000	0.0000	0.0000	0.0158
1-year interest rate									
R2	0.3657			0.4535			0.4006		
R3	0.6567	0.5706		0.0014	0.0163		0.0003	0.0000	

R4	0.0015	0.3763	0.9299	0.0000	0.1144	0.2838	0.0000	0.0000	0.3419
3-month interest rate									
R2	0.0000			0.0000			0.0009		
R3	0.0029	0.5937		0.0001	0.0008		0.0041	0.0000	
R4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0500	0.0000	0.0004

This table shows the p value obtained in the non-parametric Wilcoxon signed-rank test. Its null hypothesis is that the median difference between pairs of observations is zero. R1, R2, R3 and R4 are the residuals of the linear, nonlinear, asymmetric sign and size model respectively.

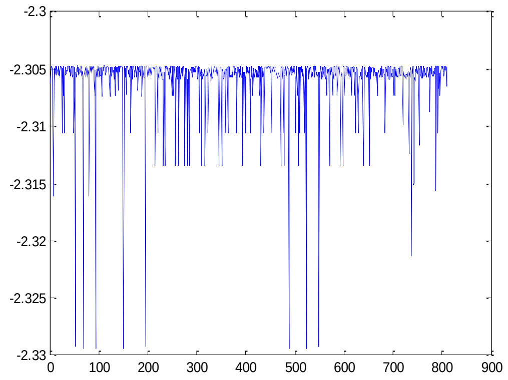
Graph 1
Returns on Bank and Market Portfolios and Level of Interest Rates



Graph 2

Nonparametric Model: Values of the estimated parameter $\hat{b}$

<table>
<tr><td colspan="3">Entire sample period (1993-2008)</td></tr>
<tr><td>10-year interest rate</td><td>1-year interest rate</td><td>3-month interest rate</td></tr>
<tr><td colspan="3">Portfolio L</td></tr>
<tr><td>



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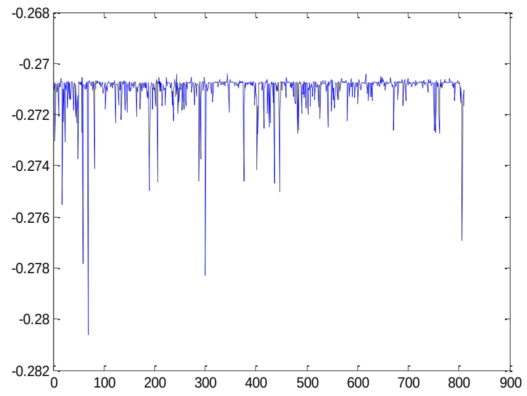

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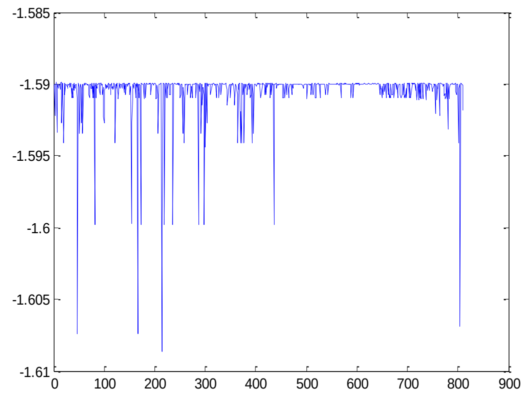

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<tr><td colspan="3">Portfolio M</td></tr>
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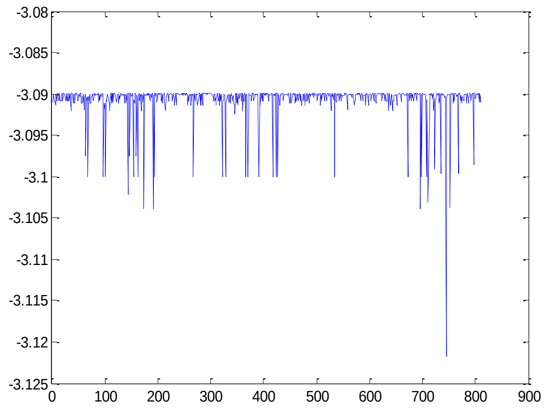

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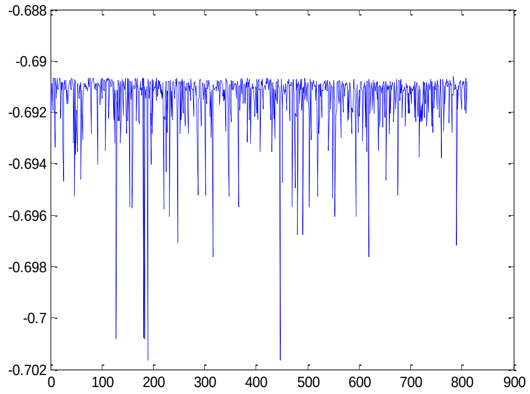

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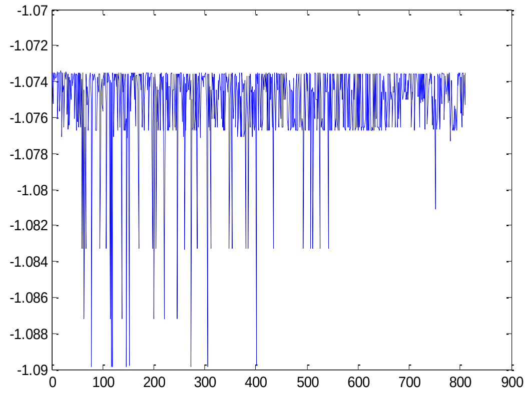

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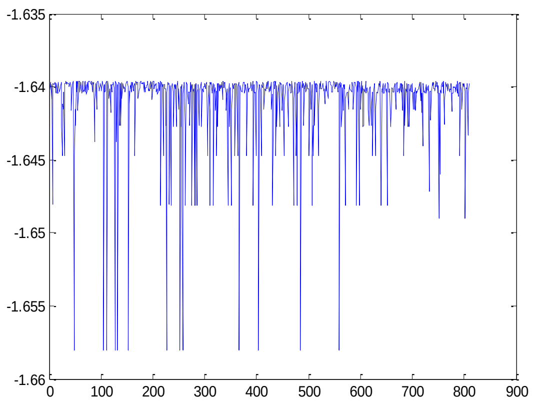
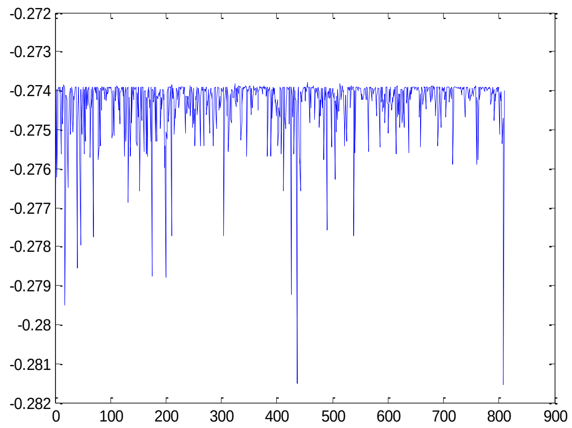
Portfolio *S*


-1.635
-1.64
-1.645
-1.65
-1.655
-1.66
0 100 200 300 400 500 600 700 800 900


-0.272
-0.273
-0.274
-0.275
-0.276
-0.277
-0.278
-0.279
-0.28
-0.281
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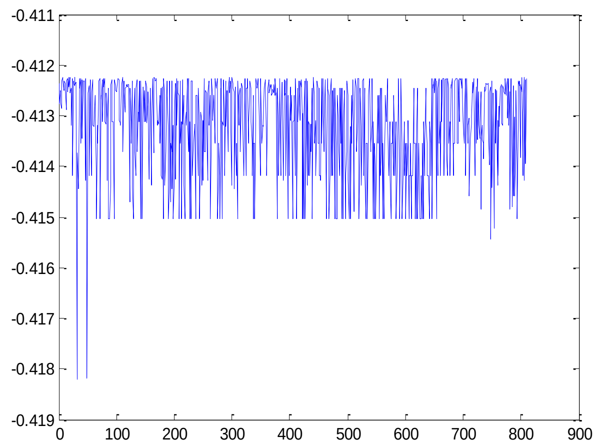
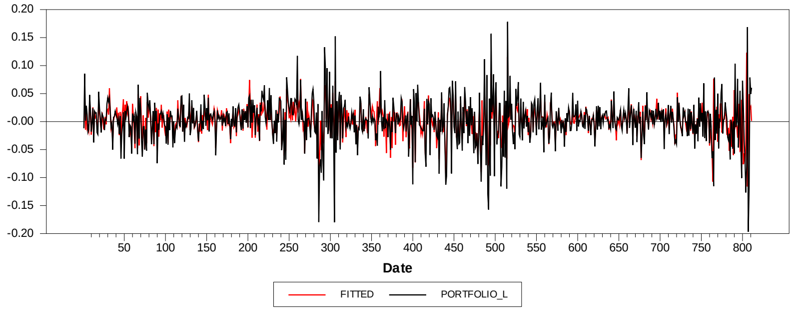
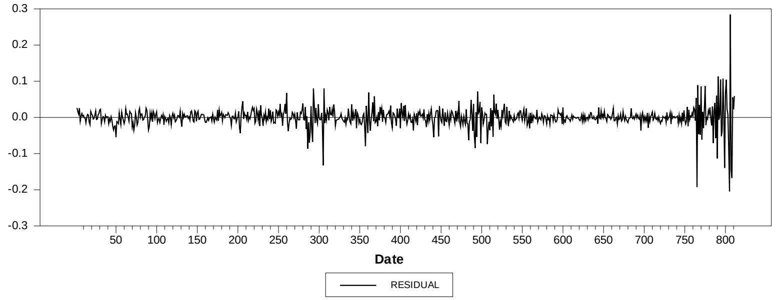
0 100 200 300 400 500 600 700 800 900


-0.411
-0.412
-0.413
-0.414
-0.415
-0.416
-0.417
-0.418
-0.419
0 100 200 300 400 500 600 700 800 900

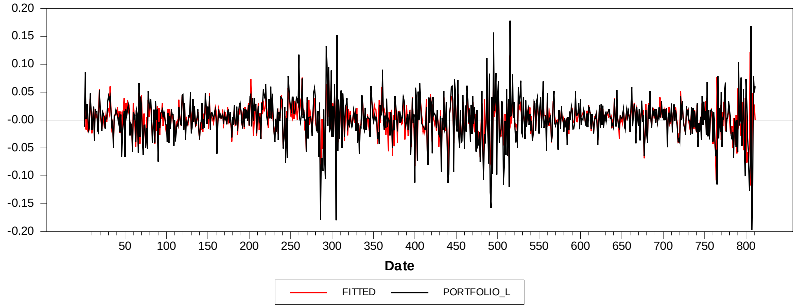
Graph 3
Fitted vs Actual Values and Residuals
Entire sample period (1993-2008)
Portfolio *L* & 1-year interest rate

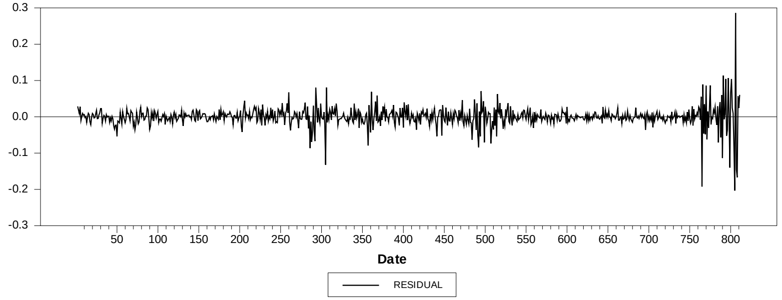
Linear Model



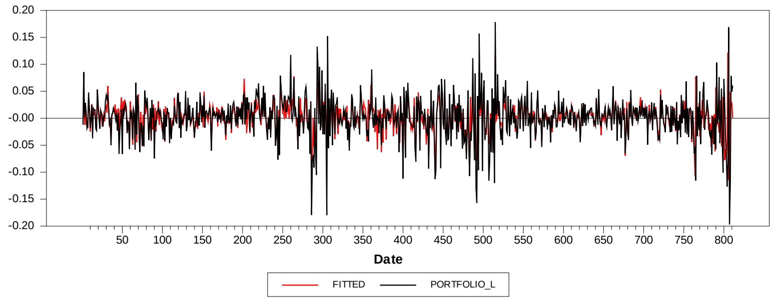


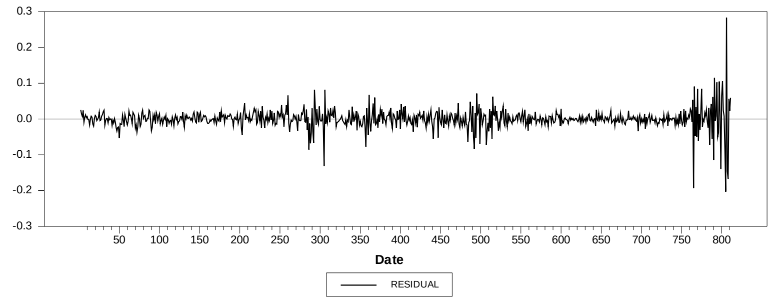
Nonlinear Model



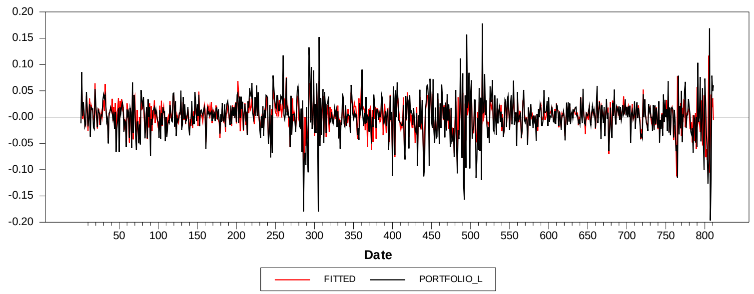


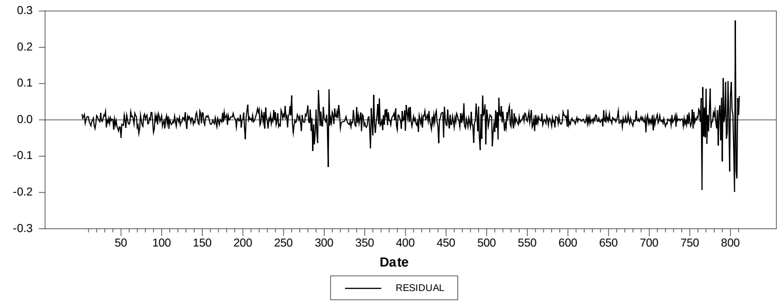
Asymmetric Sign Model





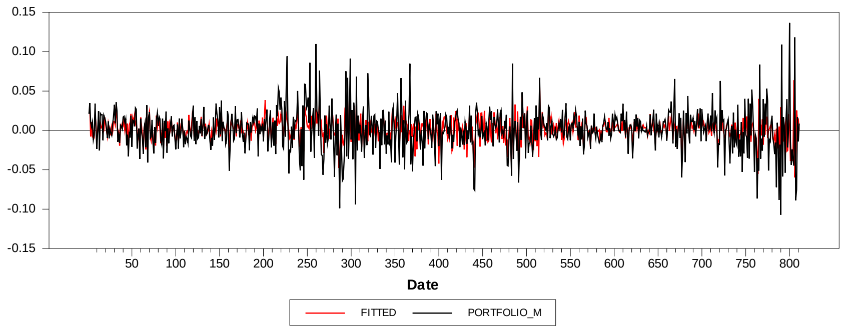
Asymmetric Size Model

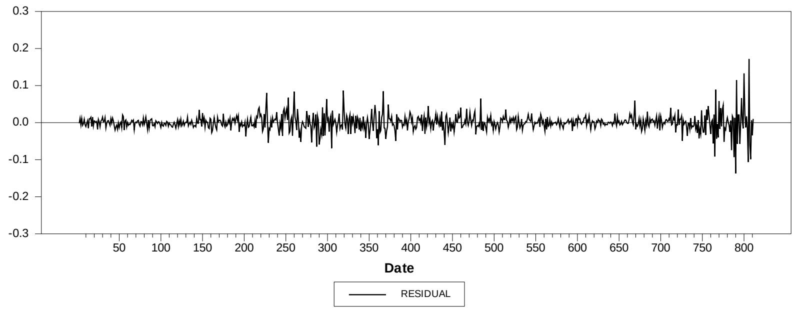




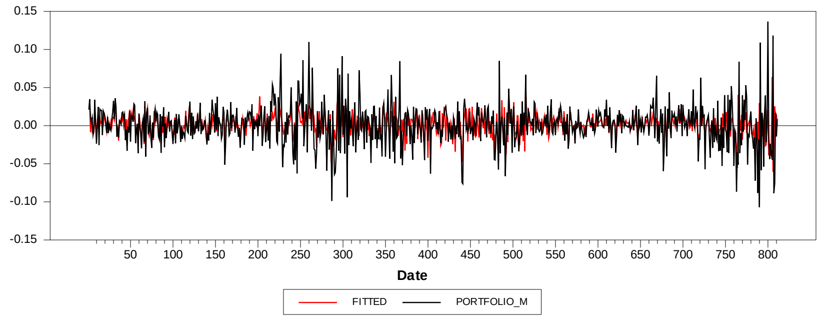
Portfolio *M* & 1-year interest rate

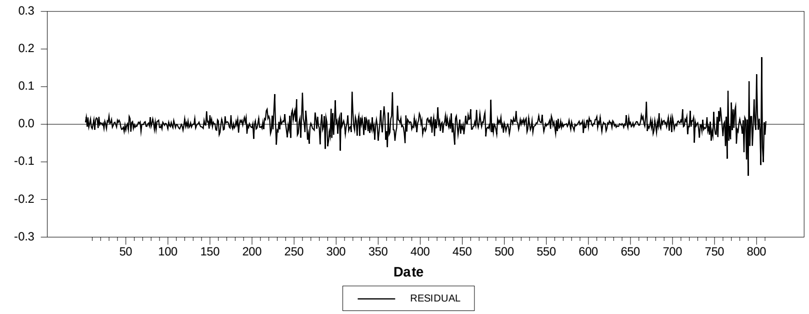
Linear Model



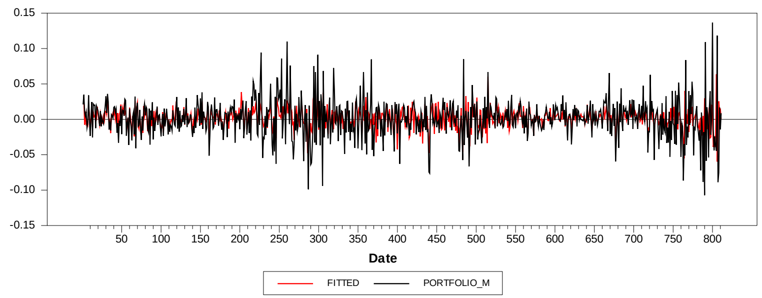


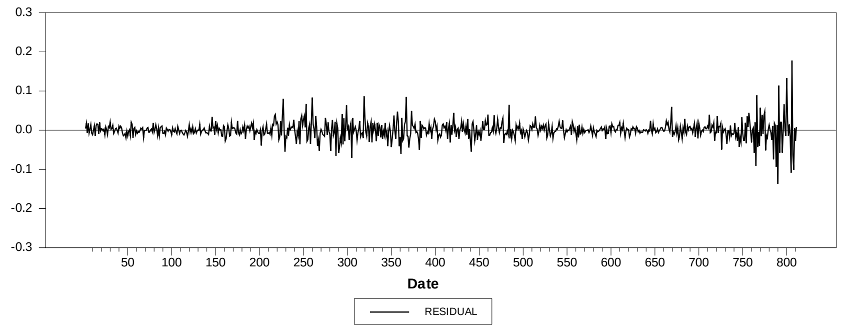
NonLinear Model



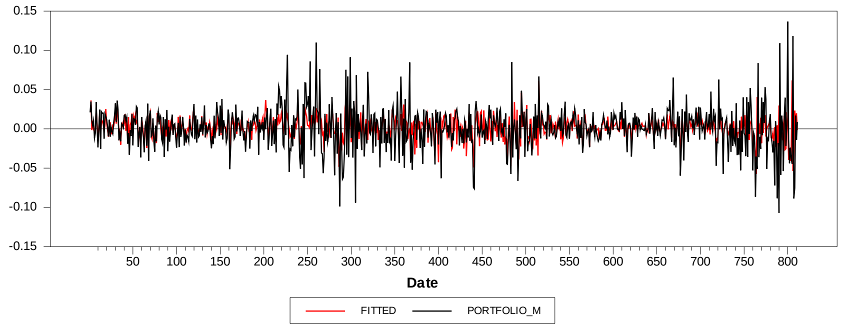


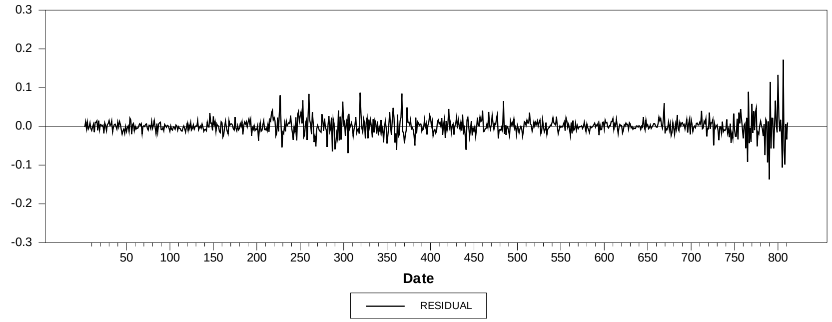
Asymmetric Sign Model





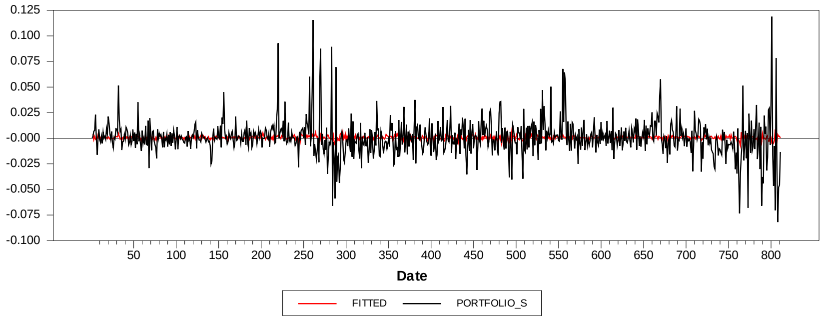
Asymmetric Size Model

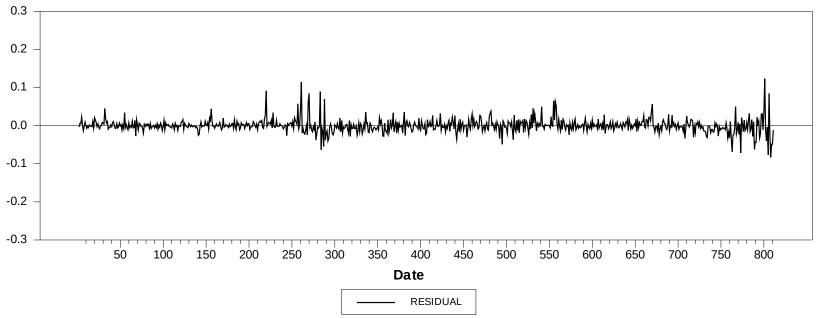




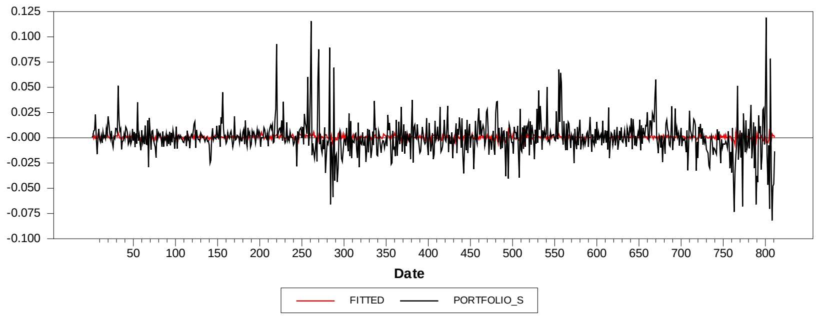
Portfolio *S* & 1-year interest rate

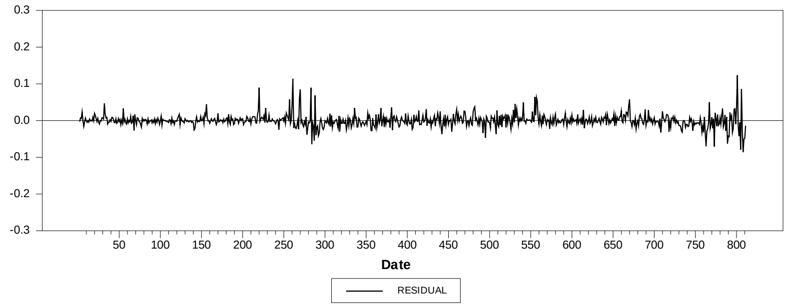
Linear Model





NonLinear Model





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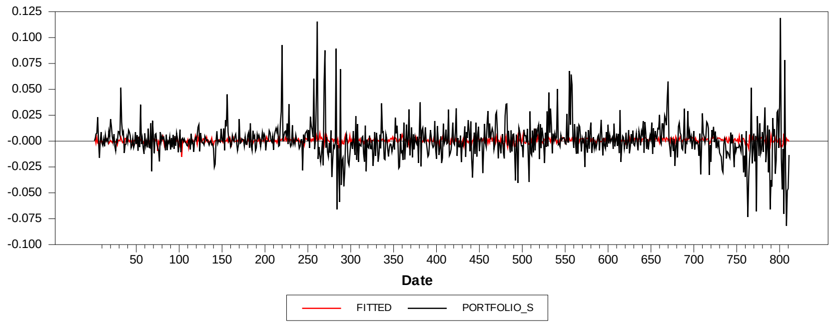

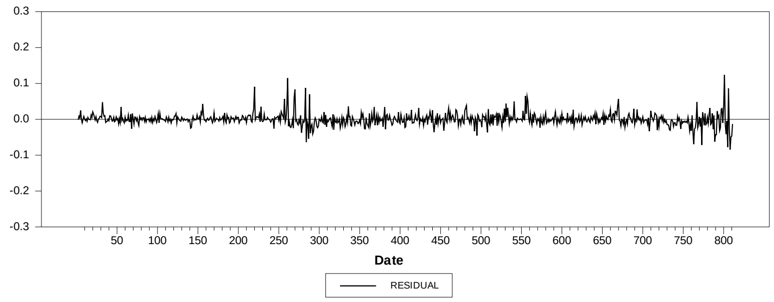

Asymmetric Size Model