Measuring performance in the Portuguese banking industry with a Fourier regression model

Carlos Pestana Barros & Maria Rosa Borges

To cite this article: Carlos Pestana Barros & Maria Rosa Borges (2010) Measuring performance in the Portuguese banking industry with a Fourier regression model, Applied Economics Letters, 18:1, 21-28, DOI: 10.1080/13504850903409755

To link to this article: https://doi.org/10.1080/13504850903409755

Published online: 19 May 2010.

Submit your article to this journal

Article views: 164

View related articles
Measuring performance in the Portuguese banking industry with a Fourier regression model

Carlos Pestana Barros and Maria Rosa Borges*

UECE (Research Unit on Complexity and Economics), ISEG (School of Economics and Management), Technical University of Lisbon, Rua Miguel Lupi, 20, Lisbon, 1249-078, Portugal

This article analyses the determinants of banks’ profitability in the Portuguese banking sector during the period 1990 to 2005. The study extends the established literature on modelling the banks’ performance by applying a Fourier approximation in order to detect for possible nonlinearities between the profitability variables and the explanatory variables. In so doing, we verify that the introduction of the Fourier coefficients in the analysis quite improved the quality of the adjustments, the need to accept the existence of nonlinear relationships among the variables involved in the study thus becoming evident. The results of this article suggest that the best performing banks in the Portuguese banking sector are those which have endeavoured to improve their capital and labour productivity, those which have maintained a high dimension and, finally, those which have been able to reinforce their capital structure.

I. Introduction

The European banking sector at national level is presently confronted with several threats to their traditional profitability, including globalization, competition and the volatile market dynamics (Barros et al., 2007). The question of the determinants of bank performance is, in this context, an important issue. In this article we analyse the profitability of the Portuguese banking sector with a Fourier coefficient model to shed light on the determinants of bank efficiency.

This article departs from the literature on Fourier models in banking, since it does not adopt a frontier model framework, as in Berger and Mester (1997) and Altunbas et al. (2001), but instead adopts the approach of Enders and Sandler (2001), estimating a panel data regression, without the decomposition of the error term. The Fourier model has already been applied by Das and Das (2007) and Huang and Wang (2004). Research of national banking markets includes Agostino et al. (2005) and Shen (2005).

The article is organized as follows: in Section II, we provide a survey of the bank-efficiency literature; in Section III, the methodology is described; in Section IV, the data are presented; in Section V, we set out the results; and finally, in Section VI, we present the conclusions.

II. Literature Survey

There is a growing body of empirical studies devoted to analyse bank performance. The first tradition of studies analysed bank performance with frontier models. For a review of the recent literature related to frontier models, the reader is referred to the survey of Berger and Humphrey (1997), which summarizes all the work done in this area until 1997 and presents a survey on this topic. The second tradition of studies,
which is relevant to this article, analyses the link between market structure and bank performance according to the structure–conduct–performance (SCP) hypothesis (Gilbert, 1984).

According to the SCP hypothesis, market concentration fosters collusion among banks thus exerting a direct influence on competition. The validation of this hypothesis is supported when the market concentration exerts a positive influence on bank performance, regardless of the degree of efficiency of the firm. Early studies, which accepted this hypothesis, including Haggestad and Mingo (1977), Spellman (1981) and Rhoades (1982), have been criticized by Gilbert (1984). An alternative hypothesis has been advanced to explain bank performance, namely, the efficient hypothesis, which maintains that an industry’s structure arises as a result of superior operating efficiency by a particular bank. Gilbert (1984) notes that out of 44 studies listed in a literature survey, 32 support the SCP hypothesis. The efficiency hypothesis is supported by Smirlock (1985) and Evanoff and Fortier (1988). In Europe, Molyneux and Forbes (1995) support the SCP hypothesis, but Maudos (2001) rejects the SCP for the Spanish banking market.

Econometric Fourier models have been applied in banking in a somewhat different context, namely in the context of frontier models, by Berger and Mester (1997) who found that it fits the bank data better than the commonly specified local translog function. Berger and Mester (2003) analysed technological change, deregulation and changes in competition in banking with a Fourier cost function. Altunbas et al. (2001) analysed the efficiency on European banking with a Fourier model. This article departs from this research, not adopting a frontier model, but rather adopting a Fourier panel data regression without decomposition of the errors terms, alongside the approach chosen by Enders and Sandler (2001).

III. Methodology

In this empirical test, we attempt to explain banks’ profitability with respect to a set of explanatory variables, all of them corresponding to endogenous factors under the control of banks’ management. Explanatory variables of productivity, size, capitalization and portfolio composition of the banks are employed. The relationship we wish to estimate can therefore be represented by the following generic equation:

\[ \text{Profitability}_t = f(\text{Prodl}_t, \text{Prodc}_t, \text{Size}_t, \text{Solv}_t, \text{Base}_t) \]  

where \( \text{Prodl} \) is labour productivity, \( \text{Prodc} \) is capital productivity, \( \text{Size} \) is the size variable (a proxy for market share), \( \text{Solv} \) is bank capitalization and \( \text{Base} \) is the bank portfolio composition. The main contribution of this study relatively to the established literature on modelling banks’ profitability resides in its attempt to detect the existence of nonlinear relationships among the involved variables, which is accomplished through a Fourier approximation.

Fourier approximations have been used in other types of studies on banking sector. Examples of these are Altunbas et al. (2001), Mitchell and Onvural (1996) and Berger et al. (1997), who use the Fourier flexible functional form to examine the specification of the cost structure in the banking sector. These studies have stated that the Fourier flexible form is the global approximation, which can be shown to dominate the conventional translog form, normally used in that kind of study. The methodology used in these studies was first proposed by Gallant (1981, 1982).

An alternative way to capture any potential nonlinearities in the data with a Fourier approximation is to use the methodology of Ludlow and Enders (2000), as we choose to do in our study. As stated by Enders and Sandler (2001), the Fourier approximation suggested by Ludlow and Enders (2000) is something quite different from the standard spectral analysis, in which instead of simply using the most significant frequencies in order to approximate the time-varying coefficients associated with the explanatory variables, all possible integer frequencies are used in the interval \( k = [1, T/2] \), where \( T \) corresponds to the number of observations.

We now expose the type of nonlinear methodology suggested by Ludlow and Enders (2000). Consider the simple model

\[ y_t = x_t \cdot \varepsilon_t + \varepsilon_t \]  

where \( x_t \) is a stationary random variable and \( \varepsilon_t \) is a white-noise disturbance such that \( E_{t-1} \varepsilon_t = 0 \) and \( E_{t-1} \varepsilon_t^2 = \sigma^2 \) for every time period \( t \). A simple modification of Equation 3 is to allow the coefficient \( x(t) \) to be a time-dependent function denoted by \( x(t) \), thus resulting in a model that is linear in variables, but nonlinear in parameters (i.e. with a time-varying coefficient),

\[ y_t = x(t) \cdot x_t + \varepsilon_t \]  

As referred by Ludlow and Enders (2000), although we allow the coefficient \( x(t) \) to be a deterministic, but unknown, function of time, if \( x(t) \) is an absolutely
integrable function, for any desired level of accuracy, the behaviour of \( x(t) \) can be represented precisely by a sufficiently long Fourier series of the form:

\[
x_t = A_0 + \sum_{i=1}^{n} [A_i \sin \frac{2\pi ki}{T} \cdot t + B_i \cos \frac{2\pi ki}{T} \cdot t]
\]

where \( k \) is an integer in the interval 1 to \( T/2 \) and \( n \) refers to the number of frequencies contained in the process generating \( x(t) \).

The key point in using Equation 4 is that the behaviour of any deterministic sequence can be readily captured by a sinusoidal function, even though the sequence in question is not periodic. As such, nonlinear coefficients can be represented by a deterministic time-dependent coefficient model without first specifying the nature of the asymmetric adjustments. The nature of the approximation is such that the standard linear model, Equation 2, emerges as a special case when all values of \( A_i \) and \( B_i \) in Equation 4 are equal to 0. Thus, the specification problem of the model is transformed into one of selecting the proper frequencies to include in Equation 4.

In this article, we do this using the four-step procedure suggested by the authors (Ludlow and Enders, 2000, pp. 338–9), which is one possible strategy to identify the particular Fourier coefficients to include in the model. We also make use of the Enders–Ludlow critical values for the null hypothesis \( A_i = 0 \) or and \( B_i = 0 \) (\( \rho^* \) and \( F^* \)), which are the result of a Monte Carlo experiment to calculate the appropriate critical values for an AR(1) model. Although our regressors are not lagged dependent variables, the results obtained by Enders and Hoover (2003) suggest that the difference between the Enders–Ludlow critical values and the appropriate ones should not be very significant. Nevertheless, we will also make use of Schwarz Bayesian Criterion (SBC) to select the appropriate frequencies and then to confirm whether the coefficients belong in the model. In so doing, we avoid the problem of a possible overfitting in the model.

Although in Ludlow and Enders (2000) Equation 2 is assumed to be a simple linear AR(1), this methodology can also be applied to a more general model, where the intercept term and the coefficients of all explanatory variables may fluctuate over time (Becker et al., 2002). Therefore, applying the methodology described here to our generic Equation 1 and restricting ourselves to only two possible frequencies for all the regressors and to four frequencies for the productivity regressors result in the following general model:

\[
\begin{align*}
\text{Profitability} & = x_0 + x_1 \text{Prod}_{lt} + x_2 \text{Prodc}_{lt} + x_3 \text{Size}_{lt} + x_4 \text{Solv}_{lt} + x_5 \text{Base}_{lt} + \\
& + \sum_{j=1}^{2} \left[ a_{0j} \sin \left( \frac{2\pi \cdot k_{0j}}{T} \cdot t \right) + b_{0j} \cos \left( \frac{2\pi \cdot k_{0j}}{T} \cdot t \right) \right] + \\
& + \sum_{j=1}^{4} \left[ a_{1j} \sin \left( \frac{2\pi \cdot k_{1j}}{T} \cdot t \right) + b_{1j} \cos \left( \frac{2\pi \cdot k_{1j}}{T} \cdot t \right) \right] \cdot \text{Prod}_{lt} + \\
& + \sum_{j=1}^{4} \left[ a_{2j} \sin \left( \frac{2\pi \cdot k_{2j}}{T} \cdot t \right) + b_{2j} \cos \left( \frac{2\pi \cdot k_{2j}}{T} \cdot t \right) \right] \cdot \text{Prodc}_{lt} + \\
& + \sum_{j=1}^{4} \left[ a_{3j} \sin \left( \frac{2\pi \cdot k_{3j}}{T} \cdot t \right) + b_{3j} \cos \left( \frac{2\pi \cdot k_{3j}}{T} \cdot t \right) \right] \cdot \text{Size}_{lt} + \\
& + \sum_{j=1}^{4} \left[ a_{4j} \sin \left( \frac{2\pi \cdot k_{4j}}{T} \cdot t \right) + b_{4j} \cos \left( \frac{2\pi \cdot k_{4j}}{T} \cdot t \right) \right] \cdot \text{Solv}_{lt} + \\
& + \sum_{j=1}^{4} \left[ a_{5j} \sin \left( \frac{2\pi \cdot k_{5j}}{T} \cdot t \right) + b_{5j} \cos \left( \frac{2\pi \cdot k_{5j}}{T} \cdot t \right) \right] \cdot \text{Base}_{lt} + \epsilon_t
\end{align*}
\]
cost to income is higher than the values observed in the European banking sector (Goddard et al., 2001, p. 15) while the return on equity is lower.

As mentioned above, the study is concerned with the relationship between the bank’s profitability and its productivity, size, capitalization and portfolio composition. The Return on Assets (ROA) and the Return on Equity (ROE) are used as profitability variables. The productivity variables are labour productivity (Prodl), measured as the ratio between net income and the number of employees, and capital productivity (Prodc), measured as the ratio between net income and the number of branches. Three different size variables were used, the log of total assets (Sizea), the formula $-1/(\text{total deposits}/1\,000\,000)$ (Sized) and the log of bank product (Sizep). Bank capitalization, determined as the ratio of between own funds and total assets, and portfolio composition, determined as the ratio between total deposits and total assets, are represented by Solv and Base, respectively.

All data are in 1995 real terms, converted using the GDP deflator, with the exception of the number of agencies and the number of employees. Table 3 reports descriptive statistics of the variables used in the model, where the heterogeneity of the banks included in sample showed in Tables 1 and 2 can be confirmed.

V. Results

In accordance with the strategy of identification of the Fourier coefficients suggested in Ludlow and Enders (2000), we begin estimating the general model (Equation 5) without the inclusion of the Fourier coefficients, that is, assuming that the resulting coefficients would be invariable.

The first empirical results are revealed to be weak when ROE is used as a profitability variable. Equally, of the three size variables used, only Sized is statistically significant. To save space, the results are only
discussed for the model employing ROA and Sized as variables of profitability and size, respectively.

With regard to the estimation results without Fourier coefficients, we conclude that, based upon conventional t-ratios, the constant term (Constant) and the banks’ portfolio composition (Base) are not statistically significant explanations for the changes in the banks’ profitability. Therefore, these are excluded from the estimations. The model appears to fit well with an adjusted $R^2$ of 74.6% and an F-statistic that rejects the joint hypothesis that the coefficients on all variables are not significantly different from zero. These first results without Fourier coefficients confirm the a priori expectations that the bank performance (ROA) is positively explained by the bank labour and capital productivity (Prodl and Prodc), the bank size (Sized) and the bank capitalization ratio (Solv).

Next, we test the existence of nonlinear relationships among the dependent variable ROA and the explanatory variables used in the study. In other words, we proceed to identify the particular Fourier coefficients to include in our model. The specification problem of the model now consists in selecting the proper frequencies to include in the Fourier coefficients (when they exist).

Table 3. Descriptive statistics of the variables used in the model (1990–2005)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROA</td>
<td>0.0064</td>
<td>0.0048</td>
<td>-0.0166</td>
<td>0.0179</td>
</tr>
<tr>
<td>ROE</td>
<td>0.1349</td>
<td>0.1048</td>
<td>-0.3521</td>
<td>0.5352</td>
</tr>
<tr>
<td>Prodl</td>
<td>3.0454</td>
<td>2.4157</td>
<td>-4.5241</td>
<td>12.8048</td>
</tr>
<tr>
<td>Prodc</td>
<td>56.8958</td>
<td>53.9621</td>
<td>-112.8874</td>
<td>358.6027</td>
</tr>
<tr>
<td>Sizea</td>
<td>13.9296</td>
<td>1.1561</td>
<td>11.3567</td>
<td>16.1486</td>
</tr>
<tr>
<td>Sized</td>
<td>-2.0841</td>
<td>2.7260</td>
<td>-15.7479</td>
<td>-0.1124</td>
</tr>
<tr>
<td>Sizepb</td>
<td>10.2772</td>
<td>1.0887</td>
<td>8.0775</td>
<td>12.5612</td>
</tr>
<tr>
<td>Solv</td>
<td>0.0610</td>
<td>0.0292</td>
<td>0.0257</td>
<td>0.1635</td>
</tr>
<tr>
<td>Base</td>
<td>0.8426</td>
<td>0.0935</td>
<td>0.5027</td>
<td>0.9543</td>
</tr>
</tbody>
</table>

Notes: The variables have been deflated using GDP deflator with 1995 as a base year.

Table 4. Estimation results (dependent variable ROA)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Parameters</th>
<th>Coefficients</th>
<th>SE</th>
<th>t-Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prodl</td>
<td>$z_1$</td>
<td>0.00008083</td>
<td>0.0000898</td>
<td>9.00483</td>
</tr>
<tr>
<td>Prodc</td>
<td>$z_2$</td>
<td>0.0000589</td>
<td>0.0000049</td>
<td>11.94012</td>
</tr>
<tr>
<td>Sizea</td>
<td>$z_3$</td>
<td>0.0002957</td>
<td>0.0000604</td>
<td>4.89554</td>
</tr>
<tr>
<td>Sized</td>
<td>$z_4$</td>
<td>0.0187000</td>
<td>0.0046618</td>
<td>4.00407</td>
</tr>
<tr>
<td>Sin($\omega_01$)*Constant</td>
<td>$a_{01}$</td>
<td>-0.0011860</td>
<td>0.0001690</td>
<td>-7.01778</td>
</tr>
<tr>
<td>Cos($\omega_01$)*Prodl</td>
<td>$b_{11}$</td>
<td>0.0002117</td>
<td>0.0000454</td>
<td>4.66259</td>
</tr>
<tr>
<td>Sin($\omega_12$)*Prodl</td>
<td>$a_{12}$</td>
<td>0.0002129</td>
<td>0.0000598</td>
<td>-3.55755</td>
</tr>
<tr>
<td>Cos($\omega_12$)*Prodl</td>
<td>$b_{12}$</td>
<td>0.0002573</td>
<td>0.0000431</td>
<td>5.97020</td>
</tr>
<tr>
<td>Sin($\omega_21$)*Prodc</td>
<td>$a_{21}$</td>
<td>0.0002056</td>
<td>0.0000461</td>
<td>4.45474</td>
</tr>
<tr>
<td>Sin($\omega_31$)*Prodc</td>
<td>$a_{31}$</td>
<td>0.0000108</td>
<td>0.0000024</td>
<td>4.43538</td>
</tr>
<tr>
<td>Cos($\omega_41$)*Sized</td>
<td>$b_{31}$</td>
<td>-0.0004914</td>
<td>0.0000684</td>
<td>-7.18558</td>
</tr>
<tr>
<td>Cos($\omega_41$)*Sized</td>
<td>$b_{32}$</td>
<td>0.0002774</td>
<td>0.0000581</td>
<td>4.77379</td>
</tr>
<tr>
<td>Sin($\omega_42$)*Solv</td>
<td>$a_{41}$</td>
<td>-0.0104000</td>
<td>0.0027589</td>
<td>-3.78107</td>
</tr>
<tr>
<td>Sin($\omega_52$)*Solv</td>
<td>$a_{42}$</td>
<td>-0.0085751</td>
<td>0.0027403</td>
<td>-3.12925</td>
</tr>
<tr>
<td>Cos($\omega_51$)*Base</td>
<td>$b_{51}$</td>
<td>-0.0005987</td>
<td>0.0001904</td>
<td>-3.23210</td>
</tr>
<tr>
<td>Cos($\omega_52$)*Base</td>
<td>$a_{52}$</td>
<td>-0.0005755</td>
<td>0.0001904</td>
<td>-3.02178</td>
</tr>
</tbody>
</table>

Observations 160
F(4,93)* 1051.497
F(17,93) 303.870
$R^2$-adjusted 0.943
SBC -910.184

Note: *The F-statistic for the joint hypothesis that the coefficients $z_1$, $z_3$, $z_4$ and $z_4$ are equal to 0.

These results, as well as those for all the other models that use ROE and the size variables Sizea and Sizepb, are available on request from the authors.
and are statistically significant) associated with the various explanatory variables. Following the above-mentioned four-step identification strategy, we obtain the results presented in Table 4.

As can be observed, the introduction of the Fourier coefficients into the model improves the quality of the adjustment, resulting in an adjusted $R^2$ of 94.3%. This increase in the global significance of the model can also be verified by the $F$-statistic associated with the hypothesis of nullity of the invariable coefficients ($x_1 = x_2 = x_3 = x_4 = 0$), which increased four times (from 269.4 to 1051.5). The significance is further confirmed by the obtaining of a quite inferior value for $SBC$ (which decreased from –792.848 to –910.184). The significance is further increased in the global significance of the model can also be verified by the $t$-test statistic associated with the hypothesis of nullity of the pairs sin/cos of the Fourier coefficients ($t$).

Additionally, we do not accept any coefficient whose inclusion does not result in a decrease of the $SBC$, which is a model selection criteria that trades off a reduction in the sum of squared residuals for a more parsimonious model and therefore avoids a possible problem of overfitting in the model. 13 Fourier coefficients were included in the model. The inclusion of Fourier coefficients is accepted even for the regressors that previously had not revealed statistically significant explanations for the alterations in the performance of the banks (Constant and Base), which means that both present an exclusively nonlinear relationship with the profitability variable $ROA$. The Fourier coefficients included in the model and the associated frequencies $k_{ji}$ are reported in Table 5 below.

As we can see, all the variables (with the exception of the constant term) have more than one single frequency associated. The variable $Prodl$ has $k_{11} = 14, k_{12} = 5, k_{13} = 2$ and $k_{14} = 13$ associated with coefficients $b_{11}, a_{12}, b_{13}$ and $b_{14}$, respectively; $Prodc$ has $k_{21} = 10$ and $k_{22} = 18$ associated with $a_{21}$ and $a_{22}$; $Sized$ has $k_{31} = 1$ and $k_{32} = 8$ associated with $b_{31}$ and $b_{32}$; $Solv$ has $k_{41} = 8$ and $k_{42} = 11$ associated with $a_{41}$ and $a_{42}$; and $Base$ has $k_{51} = 30$ and $k_{52} = 16$ associated with $b_{51}$ and $a_{52}$. Using the $t^*$-test statistic, almost all the Fourier coefficients are significantly different from 0 at the 1% level. The exceptions are $a_{12}, a_{42}, b_{51}$ and $a_{52}$, which are only statistically significant at the 5% level.

An important aspect to point out is the behaviour of the coefficients of the model along the sample. As can be seen through the graphic representation of the estimated coefficients (Fig. 2), all the variables present a nonlinear relationship with profitability. Focusing our attention on the variables with a constant part in the associated coefficients, we can see that, although made with base in the standard critical values $t$ and $F$, but rather in the critical values $t^*$ and $F^*$ (not presented, are available on request from the authors).3

As mentioned earlier, the tests to the statistic significance of the Fourier coefficients should not be confirmed by the obtaining of a quite inferior value for $SBC$, which is a model selection criteria that trades off a reduction in the sum of squared residuals for a more parsimonious model and therefore avoids a possible problem of overfitting in the model. 13 Fourier coefficients were included in the model. The inclusion of Fourier coefficients is accepted even for the regressors that previously had not revealed statistically significant explanations for the alterations in the performance of the banks (Constant and Base), which means that both present an exclusively nonlinear relationship with the profitability variable $ROA$. The Fourier coefficients included in the model and the associated frequencies $k_{ji}$ are reported in Table 5 below.

As we can see, all the variables (with the exception of the constant term) have more than one single frequency associated. The variable $Prodl$ has $k_{11} = 14, k_{12} = 5, k_{13} = 2$ and $k_{14} = 13$ associated with coefficients $b_{11}, a_{12}, b_{13}$ and $b_{14}$, respectively; $Prodc$ has $k_{21} = 10$ and $k_{22} = 18$ associated with $a_{21}$ and $a_{22}$; $Sized$ has $k_{31} = 1$ and $k_{32} = 8$ associated with $b_{31}$ and $b_{32}$; $Solv$ has $k_{41} = 8$ and $k_{42} = 11$ associated with $a_{41}$ and $a_{42}$; and $Base$ has $k_{51} = 30$ and $k_{52} = 16$ associated with $b_{51}$ and $a_{52}$. Using the $t^*$-test statistic, almost all the Fourier coefficients are significantly different from 0 at the 1% level. The exceptions are $a_{12}, a_{42}, b_{51}$ and $a_{52}$, which are only statistically significant at the 5% level.

An important aspect to point out is the behaviour of the coefficients of the model along the sample. As can be seen through the graphic representation of the estimated coefficients (Fig. 2), all the variables present a nonlinear relationship with profitability. Focusing our attention on the variables with a constant part in the associated coefficients, we can see that, although

![Fig. 1. Residuals of the estimation – model](image)

**Table 5. Fourier coefficients of the model**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>$a_{11}$</th>
<th>$b_{11}$</th>
<th>$a_{12}$</th>
<th>$b_{13}$</th>
<th>$b_{14}$</th>
<th>$a_{21}$</th>
<th>$a_{22}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t$-Ratio</td>
<td>–7.02</td>
<td>–7.02</td>
<td>–4.66</td>
<td>–3.56</td>
<td>5.97</td>
<td>4.45</td>
<td>–4.44</td>
</tr>
<tr>
<td>Frequency ($k_{ji}$)</td>
<td>$k_{01} = 3$</td>
<td>$k_{11} = 14$</td>
<td>$k_{12} = 5$</td>
<td>$k_{13} = 2$</td>
<td>$k_{14} = 13$</td>
<td>$k_{21} = 10$</td>
<td>$k_{22} = 18$</td>
</tr>
<tr>
<td>$R^2$</td>
<td>–0.000491</td>
<td>0.000277</td>
<td>–0.010400</td>
<td>–0.008575</td>
<td>–0.000599</td>
<td>–0.000575</td>
<td>–0.000575</td>
</tr>
<tr>
<td>Frequency ($k_{ji}$)</td>
<td>$k_{31} = 1$</td>
<td>$k_{32} = 8$</td>
<td>$k_{41} = 8$</td>
<td>$k_{42} = 11$</td>
<td>$k_{51} = 30$</td>
<td>$k_{52} = 16$</td>
<td>$k_{52} = 16$</td>
</tr>
</tbody>
</table>

3 Note that $F^*$ does not correspond to the critical value associated to the hypothesis of nullity of all the Fourier coefficients but instead to the critical value associated to the test of nullity of the pairs $sin/cos$ of the Fourier coefficients ($a_{ji} = b_{ji} = 0$).
the coefficients of \textit{Prodl}, \textit{Prodc} and \textit{Solv} always continue to assume positive values along the sample, the variable \textit{Sized} has a coefficient that assumes negative values in some parts of the sample. This continues to be in agreement with the remaining empirical evidence that, as mentioned in a synthesis by Naceur and Goaied (2001), has been supporting the existence of a positive or negative effect on the relationship between the bank’s size and its profitability.

Another important aspect to mention is the consistency presented by the Fourier model. The fact that the introduction of the Fourier coefficients into the model in order to not cause a significant alteration in the estimated values of the coefficients $a_1$, $a_2$, $a_3$ and $a_4$ means that the model has a high degree of consistency.

With reference to the model (Table 4), one may then rank the statistically significant explanatory variables in terms of their contribution to explaining the banks’ profitability according to the absolute values of their $t$-ratios. In so doing and taking into consideration that the relevant analysis concerns the coefficients associated with the explanatory variables that have a constant (invariable) part, one finds the following ranking (in decreasing order of importance) for the more important determinants: (1) capital productivity, (2) labour productivity, (3) bank size and (4) bank capitalization.

\section*{VI. Conclusion}

The main objective of this study is to analyse the determinants of banks’ profitability in the Portuguese banking sector during the period 1990 to 2005. This article extends the established literature on modelling the
banks’ profitability by applying Fourier coefficients to detect for possible nonlinearities between the performance variables and the explanatory variables. In so doing, we verify that the introduction of the Fourier coefficients in the analysis quite improved the quality of the adjustments, the need to accept the existence of nonlinear relationships among the variables involved in the study thus becoming evident.

The findings of this article therefore suggest that the best performing banks in the Portuguese banking sector are those which have endeavoured to improve their capital and labour productivity, those which have maintained a high dimension and, finally, those which have been able to reinforce their capital structure. Despite not having a variable for market concentration, the statistical significance of market share suggests that the SCP is supported, validating Molyneux and Forbes (1995).

References
