Applying forecasting Revenue Management techniques to enrolment management in a university centre

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Abstract *Revenue Management methodology is shown to be an innovative application for fixed capacity firms or service entities which require a management system that supports pricing and inventory decision-making. The present research study takes one of the elements of this philosophy – demand forecasting and estimation - as a theoretical basis and applies it to the case study. The aim is to obtain the predicted demand of enrolments in each academic year. This will support the improvement and optimisation of the operations related to capacity management in a university centre.*

Keywords: Revenue Management, Forecasting, Monte Carlo Simulation, Teaching centre, enrolment

1. Introduction

Revenue Management (hereafter RM) has been as a successful management philosophy which has shown important benefits for those firms which have implemented it (see, for example, Smith et al., 1992; Cook, 1998; Lieberman, 1993; Cross 1997). Given the advantages reflected in increases of profitability and earnings, there has been a broadening of the sectors in which it is applied (McGill and van Ryzin, 1999, Chiang et al., 2007 and Guadix et al., 2011).

On the other hand, the complexity of the management of university public centres requires the implementing of management tools which help the management teams concerned to make correct and agile decisions. The Bologna plan's regulation (Royal Decree 1393/2007 and its modification in the Royal Decree 861/2010) establishes a new system of Degrees, Masters and PhDs. It also emphasises the quality guarantee systems which must be used to be able to be soundly evaluate the official university Degrees and PhDs every six years and the Masters every four years. The aim of this is to maintain accreditations. This therefore involves a new management philosophy which must especially stress that correct decision-making contributes to obtaining short and medium-term results.

RM can be broken down into what Chiang et al. (2007) call major problems. These allow centring its application on a specific part to improve management, as well as making understanding it easier: capacity control, pricing, auctions, overbooking and forecasting. We will centre on forecasting. This is in turn related to two concepts: estimation and forecasting. Estimation enables finding the model which best describes the data observed and forecasting lets us predict future values based on these models (Talluri and van Ryzin, 2005).

The novelty of this work is its analysis of applying forecasting techniques in the RM area in a sector and context that has not been explored before: enrolment forecasting. To do so, we will carry out a review of the forecasting and estimation techniques applied in RM which are best adapted to the study case and analyse the results obtained.
The resulting information will allow the quantity of students in each academic year to be foreseen. This optimize the distribution of the demand-related requirement of space and infrastructures, betters the experience and training concerning the matter, anticipates the needs of covering the seats available in each subject and, finally, supports the decision-making about enrolment management.
In Spain, all Public Universities use the same software for the information management needed in this research. This ensures the possibility of replicating the study and drawing conclusions adapted to each case.

2. Methodology

The data to carry out the study have been extracted from the application used for academic data management (Universitas XXI-Académico). It was necessary to work out a tailor-made report issued by the University's Computing and Communications Services. These data refer to two degrees taught in the same Faculty from the 2009/2010 academic year (the first academic year in which the degrees were taught) until 2012/2013, including personal and academic information about the students' background.
Next, there was a review and refining of the data via the study of statistical graphs and dynamic tables. This led to the removal of duplicated data and other data. The Minitab version 15 software was used to confirm some premises before applying the technique selected.
Given that the enrolment process requires a forecast or prediction per subject and per degree, a disaggregated forecast was opted for. Regarding the type of data available, it was noted that in most cases the enrolment applications in each subject are accepted. That is to say, the number of people who apply for a subject is the same as the number of students who successfully enrol. The data obtained are censured (see, for example, Zeni, 2001a; Zeni, 2001b, Cleophas et al, 2009, in other sectors) but they include approximately all the information of the enrolments demanded.
From the forecasting techniques proposed by different authors (Lee, 1990; Weatherford and Kimes, 2003; Talluri and van Ryzin, 2005, Zakhary et al., 2009; Bayoumi et al., 2013), the Monte Carlo Simulation was chosen. It was applied by MsExcel (version 2010).
Lastly, to analyse the forecasting error level or robustness, we used the recommended indicators (Rajopadhye et al., 2001): Median Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE) and, for the specific case of the Monte Carlo simulation (Zakhary et al., 2009), Symmetric Mean Absolute Percentage Error (SMAPE). In this section, the 2012/2013 academic year has been taken as the base period for the forecasting carried out for the 2013/2014 academic year (the year with the most recent data available).

3. Estimation and forecasting in Revenue Management

Lee (1990) makes an important contribution by highlighting the difference between estimation and forecasting. He clarifies that to obtain estimations we base ourselves on the past and on the data available to propose a statistical model, while forecasting produces unknown future values according to the data available.
In our case, after carrying out a review of the estimation techniques (Talluri and van Ryzin, 2005) frequently used in RM (Mean squared error–MSE, Maximum Likelihood Estimation–ML),we concluded that the technique which is best adapted to the study and to the model which will be applied is the method of moments. This takes the empirical means in the data observed as an estimator. Having selected the technique, tests were made (a P-P scatter chart or point cloud and a Kolmogorov-Smirnov test). These allowed it to be confirmed that in general terms the number of enrolments variable in an academic year, given the specific degree, is distributed normally. In this way, we obtain the estimated values for each of the subjects of the different degrees.

From the point of view of data forecasting, there was first a review of the different techniques noted by diverse authors in the RM field and their requirements. Specifically, the different types of techniques include: Exponential Smoothing (with a linear tendency and a trend and seasonal adjustment – Holt-Winters method), Moving Averages, Linear Regression, the ARIMA Method and the Simulation Method (Lee, 1990; Weatherford and Kimes, 2003; Talluri and van Ryzin, 2005).
Exponential Smoothing and ARIMA were ruled out due to needing to have a group of significant periods - in our case we only have four periods. The application of lineal regression requires the fulfilling of premises which our case does not have. These, as well as other reasons, led us to select the Simulation Method - specifically, the Monte Carlo simulation - to do the forecasting. Simulation is frequently used in the RM field (Baker and Collier, 1992, Talluri and van Ryzin, 1999, Aziz et al., 2011). The Monte Carlo technique has been successfully tested in the hotel sector for forecasting reservations in general (Zakhary et al., 2009; Bayoumi et al., 2013). It also supplies good results compared to other techniques (Rajopadhye et al., 2001, carries out a comparison with estimations with the Holt-Winters method). Based on Zakhary et al. (2009), we established 1000 iterations per simulation.

4. Results and conclusions

Table 1 presents the results obtained with respect to the forecasting of enrolments for each of the degrees in a subsequent academic year[1].

	Degree Finance and Accounting (DFIAC)			**Tourism Degree (DTOU)**		
	Mean	**Minimum**	**Maximum**	**Mean**	**Minimum**	**Maximum**
First. 1st. semester	727	645	824	384	324	427
First. 2nd. semester	780	738	859	357	337	369
Second. 1st. semester	366	326	389	277	255	302
Second. 2nd. semester	348	330	375	218	116	268
Third. 1st. semester	236	195	271	159	94	198
Third. 2nd. semester	224	192	270	204	188	226

Table 1: Forecasting of students who will enrol in the 2013/2014 academic year, per academic year and semester in each degree

The DFIAC degree is shown as the most important one in terms of the capacity needed. Our attention is drawn to the reduction in the number of enrolments in the second academic year with respect to the first, mainly in this degree. This tells us about the dropout level and the repetition of subjects of the first academic year. This fact is also attributed to the novelty of the degree. The detailed information per subject shows us as well information about which subjects are more difficult and have a greater number of repeat students.
Table 2 shows the results of the error measurements. In general, the forecasting produces higher levels for DFIAC than for DTOU. This may be due to its higher variances. The recent launching of this degree could explain this particularity, as there is greater uncertainty. This will normalise as time passes. It can be noted that the resultant SMAPE shows approximate results with those obtained by Zakhary et al. (2009) in their application of the Monte Carlo simulation. This backs the robustness and the good level of exactitude of our forecasting results concerning enrolment.

Degree Finance and Accounting (DFIAC)			**Degree Tourism (DTOU)**		
MAD	**MAPE**	**SMAPE**	**MAD**	**MAPE**	**SMAPE**
47.6	12.1	13.2	29.1	9.8	10.2

Table 2: Results of the error measurements in the 2013/2014 academic year DFIAC and DTOU

[1] Although there is disaggregated information available, it has been left out here for space reasons. For the same reason, neither the results of the normality tests nor the estimated parametres are included.

The forecasts obtained allow us to foresee the decision about the capacity and number of classrooms that will be needed in the next academic year to meet the demand. As each classroom can be assigned to a group, the maximum capacity per group to be offered during the enrolment process will also be known. Moreover, the information appears disaggregated and shows a forecast of enrolments per subject. This allows those in which a higher demand was foreseen - although they were in the same academic year - to be assigned with classrooms of greater capacities. This broadens the range of possibilities for decision-making about the assigning of classrooms-group-subject.

We can therefore conclude that estimation and forecasting – one of the main problems of RM - can provide numerous advantages in this new context for managers of training centres. They permit the improvement of RM and also facilitate the decision-making process. From the research perspective, as this field is still young, it will be necessary to test the different techniques and the results that each of them provides.

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