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Spectral density estimation of European airlines load factors for Europe-Middle East and Europe-Far East flights

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Abstract

Purpose In the airline industry the term load factor is defined as the percentage of seats filled by revenue passengers. The load factor is a metric that measures the airline's capacity and demand management. This paper aimed to identify serial and periodic autocorrelation on the load factors of the Europe-Mid East and Europe-Far East airline flights. Identifying the auto-correlation structure is helpful to develop the best fitted forecasting model of the load factors.

Methods The paper applies spectral density estimation to investigate the structure of serial and periodic autocorrelation on the load factors. Then the paper applied multivariate trend model to develop a forecasting model of the load factors of the regional flights. The multivariate trend model is fitted using the Prais–Winsten recursive autoregression methodology.

Results The primary analysis of the study identified that the airlines have better a demand than capacity management system for both the Europe-Mid East and Europe-Far East flights. The spectral density estimates showed that the load factors have both periodic and serial correlations for both regional flights. Therefore, in order to control the periodic autocorrelation, we introduce transcendental time functions as predictors of the load factor in the multivariate trend model. Finally, we build realistic and robust forecasting model of the load factors of the Europe-Mid East and Europe-Far East flights.

Conclusions The econometric estimation results confirm that the load factors of the Europe-Mid East and Europe-Far East flights are both seasonal and differ between flights. The analysis implies that the load factor is still far from stable and stabilizing policies by airlines has so far not been successful. The AEA may therefore continuously focus on the stabilization and the improvement of the load in the industry.

Keywords Airlines · Load factor · Spectral density estimation · Multivariate trend analysis

1 Introduction

The yield, revenue per unit of output sold, is a highly significant metric in the airline industry. By definition, it is only the mathematical outcome of two even more fundamental metrics: output sold and revenue earned. For more than five decades the yields across the industry as a whole has been in decline. These price declines explain a significant portion of the traffic growth throughout the period [33]. Broadly speaking, the yields will soften when (1) traffic growth is flat or insufficient to absorb output growth, (2) intense competition lower prices, and yields will harden when (2a) load factors are already high and output is growing slower than traffic, (2b) traffic growth is outstripping growth in output and (3) lower competition keeps prices unchanged. The fact that traffic, load factor, and revenue all will be affected by these type of adjustments, illustrates how intimately connected the variables are—all within the context of available output [37, 38].

This paper's main variable of interest is the airline industry load factor. The load factor measures the percentage of an airline's output that has been sold to paying passengers. Hence, the load factor is a measure of the extent to which supply and demand are balanced at prevailing prices. The achieved load factors for the industry as a whole conceal marked variations between different type of airliners, with regional carriers at the lower end of the spectrum and charter

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airlines generally achieving higher load factors than scheduled carriers [8]. The average load factors for individual airline enterprises masks variations between different markets and cabins. Economy cabins achieving higher load factors because customers tend to book further in advance and expect lower levels of seat accessibility than for premium cabins. The average load factors in the airline industry also conceal pronounced daily, weekly and, in particular, seasonal variations.

There are at least six load factors drivers in the airline industry. The *first* driver is the industry's output decisions relative to demand growth. The output growth must be brought into alignment with demand growth. The *second* driver is pricing. Fare reductions generally stimulate demand. Load factors are affected depending upon capacity decisions. The *third* driver is the traffic mix. Historically, the higher the proportion of business travellers carried by an airline, the lower the average seat factor. That is, the random element in demand for business travels (highly volatile demand) suggests a lower average load factor in business and first class cabins [31]. The *fourth* driver is refund policies. A carrier taking non-refundable payment at the time of reservation is likely to have relatively few no-shows and a relatively higher seat factor than carriers selling a high portion of fully flexible tickets. The *fifth* driver is commercial success. A success of product design, promotions, marketing communications, distributions, and service delivery will influence load factors. The *sixth* driver is revenue management. The effectiveness of revenue management systems (RMS) will influence load factors. The RMS capabilities, specifically the refinement of demand forecasting tools, will contribute significantly [30]. Depending on market conditions in the airline industry, there exist a trade-off between load and yield. Unless demand is particularly strong and output growth is under firm control, it is likely that rising yields will be associated with downward pressure on load factors. In contrast, a falling yield tends to be associated with higher load factors. The trade-off suggests that airline carriers will generally want to arrive at a capacity, which targets a load factor balances between the costs of turning passengers away and the costs of meeting all peak demand and oversupplying the market ("double-edged sword"). In general, therefore, from an operational perspective it is easier to manage an airline when load factors are at 64 % than when they are at 84 % [9]. The size of the load factor is therefore a measure of success in the airline industry. However, the success factor is challenged by the fact that demand is volatile and fluctuates in units of single seat-departures in different origin and destination markets. In contrast, the capacity can only be delivered in units of available aircrafts for the particular flight-leg. That is, routes designed to serve the origin and destination markets are broadly fixed in the short run. Furthermore, the necessity to maintain both high flight completion rates, the integrity of network connections, and aircraft/crew assignments, may

make it almost impossible for a scheduled passenger carrier to cancel a significant number of its lightly loaded flights [4].

The main objective of this paper is to build econometric models that can capture the variations of load factors for Europe-Middle East and Europe-Far East airline flights. The paper's target population is airlines that are members of the Association of European Airlines (AEA). We use multivariate time series econometric model to analyse the temporal evaluation of load factor. The best well-fitted econometric model may improve the accuracy of forecasting the load factor of these specific flights. However, in order to build the best fitted model for the load factor we are encountered to several challenges. First, we need to evaluate characteristics of available seat kilometre and revenue passenger kilometre on the load factor. Second, we need to have solid knowledge about the autocorrelation structure of the load factor. Classically, we think that the intensity of autocorrelation of time series data diminishes with more distant lags.

However, in reality, the true autocorrelation structure of the load factor has the periodic autocorrelation (i.e., load factor it is highly seasonal). Consequently, we have to identify the structure of both serial and periodic autocorrelations on the load factor. Third, once we identify the autocorrelation structure of the load factor, then we will deal with mechanisms to control it during model fit.

In this study, we advance the classical multivariate trend analyses to control the periodic autocorrelation by expressing the time effect of the load factor as a dynamic (can be linear or nonlinear) function of the parameters [29]. Furthermore, in order to control for the serial autocorrelation we apply Prais–Winsten recursive autoregression estimation [34]. Finding the best suitable mathematical relationships of the dynamic time effect of the load factor and controlling serial correlation is therefore the most important task of this study. The best fitted econometric model may bring superior forecasting tools and techniques, and new information to the AEA.

2 Literature review

The airline industry plays an essential role in the establishment of today's global economy. According to Doganis [15] the airline industry gives the impression of being both cyclical and strappingly subjective to external dynamics. The international airline industry is complex, dynamic, subject to rapid change, innovation, and marginally profitable. By considering procedures determining tariff levels in an origin-destination market, airline pricing refers to various service facilities and capacities for a set of airline products.

Revenue management is the process of determining the number of seats available at each tariff level. The revenue management of the airline is therefore a function of its tariff strategy and associated load factors. According to Kellner [27]

the success of the airline is determined by its ability to make unit revenues (i.e., the product of yield and load factor) higher than its unit costs. Therefore, in addition to minimize the unit cost, the important task of the airline manager is to simultaneously maximize the product of yield and load factor [21].

Yield management is the assortment of schemes, strategies and tactics the airline enterprises use to systematically manage demand for their services and products [25]. The fundamental units for yield management are load factors, pricing and cost of the airlines [26]. Passenger load factor (or only load factor) is a measure of the degree of airline passenger carrying capacity. The load factor is a quantity of the extent to which supply and demand are balanced at prevailing prices [18]. In short, load factor is defined as the ratio of the revenue passenger kilometre to available seat kilometre in the given origin destination flight [14, 4].

The load factor is a measure of the performance and efficiency of an airline. The airline's load factor directly reflects their competency and performance. The high load factor with appropriate pricing is a condition for the efficient operation of an airline enterprise [40]. Thus, it is enlightening for the performance of the airline to highlight factors that affect the load factors [22].

Generally, operational factors play a significant role in affecting the load factor and therefore capacity. Specifically, operational factors such as distance covered by journey, tourists, codeshare agreement (is an aviation business arrangement where two or more airlines share the same flight) and market concentration HHI index (a commonly accepted measure of market concentration) are among the most important factors that have positive and significant effect on the load factor [32]. Moreover, the GINI index (a measure the degree of price dispersion, or price inequality in the airline of the same flight) is discovered as the main factor that negatively affects the load factor. Other important factors are airport features, performance limitation, flight conditions, seasonality of demand, time of traveller schedule, frequency of flights and dynamic route networks [32, 24].

3 The data and methodology

3.1 The data

The dataset is obtained from the *Association of European Airlines (AEA)* and is downloaded from http://www.aea.be/research/traffic/index.html. The data is collected for the period 1991 to 2013 and contains information about Available Seat-Kilometres (**ASK**), Revenue Passenger-Kilometres (**RPK**) and Load factor (**LF**).

Moreover, Europe-Far East (**EF**) is defined as any scheduled flights between Europe and points east of the Middle East region, including Trans-Polar and Trans-Siberian flights. Europe-Middle East (**EM**) is defined as any scheduled Terminating flights between Europe and Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Saudi Arabia, Syria, United Arab Emirates, Yemen and the Democratic Republic of Yemen (Available at www.aea.be).

3.2 Methodology

3.2.1 One way analysis of variance (ANOVA)

One way analysis of variance (ANOVA) is used to see the existences of the main differences of a certain random variables with a single treatment over its levels. The linear statistical model for ANOVA is given as([6, 43]:

$$y_{ij} = \mu + \alpha_i + \varepsilon_{ij}, \quad i = 1, 2, 3, \ldots, a \ and \ j$$
$$= 1, 2, 3, \ldots, n \tag{1}$$

where: μ the grand mean of y_{ij}, α_i the i_{th} level effect on y_{ij} and $\varepsilon_{ij} \sim iidN(0, \sigma^2)$. The bootstrapping estimation method is applied to estimate the model parameters. Usually the method of estimation of the model parameters is either using ordinal least square (OLS) or generalized least square (GLS) estimators according to the parameters are fixed or random, respectively [17, 11]. Nevertheless, modern econometric methods used bootstrapping to acquire thorough information about the estimated parameters. In this particular case we apply the Bias-Estimation Bootstrap technique. The estimation method gives information about bias of the estimates due to resampling in addition to the estimates of OLS or GLS [13].

3.2.2 Signal processing

Signal processing represents a time series as a stochastic sum of harmonic functions of time [20]. Signal processing helps to identify the autocorrelation structure of the time series data. The signal processing stochastic model for stochastic process in discrete time is given as [23, 35]:

$$y_t = \mu_t^* + \sum_k [a_k \cos(2\pi \upsilon_k t) + b_k \sin(2\pi \upsilon_k t)] \tag{2}$$

Where: μ_t^* is the mean of the series at time t, a_k, b_k (Fourier transformation coefficients of *cosine* and *sine* waves) are

Table 1 Estimates of RPK (in million) and ASK (in million) of the EM and EF flights

Flights	Estimates of Revenue Passenger Kilometre (RPK in million)						Estimates of Available Seat Kilometre (ASK in million)					
	Statistic	Estimates	Bias	Std. Error	95 % Confidence Interval		Statistic	Estimates	Bias	Std. Error	95 % Confidence Interval	
					Lower	Upper					Lower	Upper
EM-Flights	Mean	1696.92	1.863	42.52	1617.65	1784.05	Mean	2450.76	1.53	56.82	2333.1	2566.78
	Std. Deviation	729.94	−2.44	24.39	680.11	774.73	Std. Deviation	936.96	−3.0	30.01	869.19	991.55
	Std. Error Mean	43.94					Std. Error Mean	56.40				
EF-Flights	Mean	9671.81	−1.77	185.7	9317.00	10,023.0	Mean	12,375.32	10.46	193.21	12,005.0	12,754.61
	Std. Deviation	3059.35	−6.34	95.64	2853.89	3229.34	Std. Deviation	3292.10	−5.48	99.73	3089.31	3486.857
	Std. Error Mean	184.15					Std. Error Mean	198.16				
Estimation Method	Bootstrap results are based on 1000 bootstrap samples											

independent zero mean normal random variables, v_k are distinct frequencies.

The mean, variance and covariance of the spectrum of the time series data are derived as follows:

$$E[y_t] = E[\mu_t^*] + E\left\{ \sum_k [a_k\cos(2\pi v_k t) + b_k sin(2\pi v_k t)] \right\}$$
$$E[y_t] = \mu_t^* + \sum_k E[a_k\cos(2\pi v_k t) + b_k sin(2\pi v_k t)]$$
$$\therefore E[y_t] = \mu_t^* \tag{3}$$

$$Var[y_t] = E\{[y_t] - E[y_t]\}^2$$
$$Var[y_t] = E\left\{ \mu_t^* + \sum_k [a_k\cos(2\pi v_k t) + b_k sin(2\pi v_k t)] - \mu_t^* \right\}^2$$
$$\therefore Var[y_t] = E\left\{ \sum_k [a_k\cos(2\pi v_k t) + b_k sin(2\pi v_k t)] \right\}^2 \tag{4}$$

$$Cov[y_t, y_{t-\tau}] = E\{(y_t - E[y_t])(y_{t-\tau} - E[y_{t-\tau}])\} \tag{5}$$

Since $y_t - E[y_t] = \sum_k [a_k\cos(2\pi v_k t) + b_k\sin(2\pi v_k t)]$ and $y_{t-\tau} - E[y_{t-\tau}] = \sum_k [a_k\cos(2\pi v_k t - \tau) + b_k\sin(2\pi v_k t - \tau)]$

Therefore, Eq. 5 can be expressed as:

$$Cov[y_t, y_{t-\tau}] = E\left\{ \left(\sum_k [a_k\cos(2\pi v_k t) + b_k\sin(2\pi v_k t)] \right) \left(\sum_k [a_k\cos(2\pi v_k t - \tau) + b_k\sin(2\pi v_k t - \tau)] \right) \right\} \tag{6}$$

Spectral density is a powerful tool to analyse the nature of the autocorrelation of the time series data in the Fourier space that contains infinite sum of sine and cosine waves of different amplitudes [16, 3]. This creates good prospect to remove the problem of autocorrelation and to choose appropriate an econometric model that capture the possible variations of the time series data. Estimation techniques of spectral density can involve parametric or non-parametric approaches based on time domain or frequency domain analysis. A common parametric technique involves fitting the observations to an autoregressive model. A common non-parametric technique

Table 2 Comparison of ASK, RPK and load factor of EM and EF flights

Variables	Comparison of flights	Mean Difference	Std. Error Difference	t-cal	Sig. (2-tailed)	95 % Confidence Interval of mean difference	
						Lower	Upper
ASK (in million)	EFVs. EM	9924.55721	212.85460	46.625	0.001	9519.21193	10,340.48847
RPK (in million)	EFVs. EM	7974.88996	186.52502	42.755	0.001	7628.94166	8335.74600
LF (in percent)	EFVs. EM	−9.09385	0.51125	17.787	0.001	10.09983	8.11099
Estimation Method	Bootstrap results are based on 1000 bootstrap samples						

Table 3 Prais-Winsten recursive parameter estimation of a linear regression of RPK (in million) in response to ASK (in million)

Predictor	Estimators	Std. Error	t-cal	Sig.	R Square	Model Std. Error
ASK	0.776	0.013	58.912	0.0000		
Constant	−205.356	34.683	−5.921	0.0000	0.927	115.788

is the periodogram. The important advantage of applying the periodogram spectral estimator is determining possible hidden "periodicities" in the time series [36].

3.2.3 Ljung–Box test

There are a number of parametric methods that detect autocorrelation. However, the Ljung–Box test is preferable in this case because it simultaneously detects the existence and the order of autocorrelation on the time series data. The Ljung–Box test procedure is given as [10]: the Null Hypothesis H_0: serial correlation equals zero up to order h versus H_1: at least one of the serial correlations up to lag h is nonzero. The test statistic of Ljung–Box is given as:

$$Q = n(n+2) \sum_{l-1}^{h} \frac{\widehat{\rho}_l^2}{n-l} \qquad (7)$$

where: n is the sample size, $\widehat{\rho}_l$ is the sample autocorrelation at lag l, and h is the number of lags being tested. The null hypothesis is rejected for α level of significance if $Q > \chi^2_{l-\alpha,h}$.

3.2.4 Multivariate trend analysis

The aim of the trend analysis is to get the best fitted model to be applied for forecasting the long run behaviour of the series
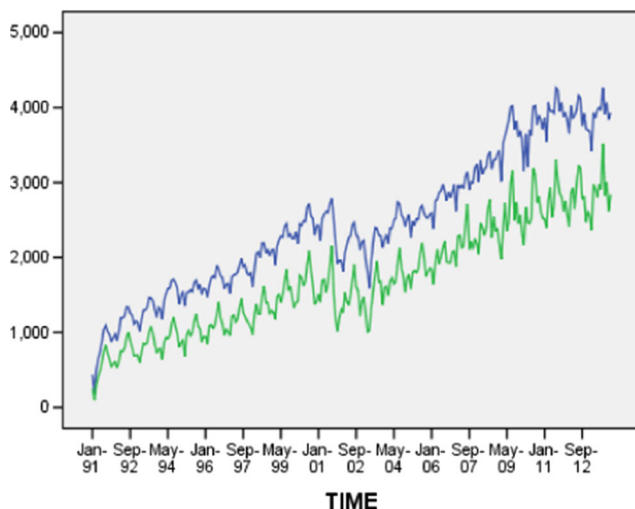
Fig. 1 Time Series Plot of ASK and RPK (in million) of EM flights

Key: —— ASK —— RPK

as a function of time [28]. The general form of multivariate trend analysis is given as [5, 41].

$$y_{it} = f_i(t; \beta_i) + \varepsilon_{it} \qquad (8)$$

$\varepsilon_{it} = U\left(\varepsilon_{it-1}, \varepsilon_{it-2}, \dots \varepsilon_{it-h}; \rho_{i1}, \rho_{i2}, \dots, \rho_{ih_i}\right) + v_{it}$ and $v_{it} \sim iiDN(0, \sigma^2_{iv})$ where: $f_i(t; \beta_i)$ is any real valued function of time "t" and a vector of parameters $\beta_i = \left(\beta_{i0}, \beta_{i1}, \beta_{i2}, \dots, \beta_{ik_i}\right)$, $U\left(\varepsilon_{it-1}, \varepsilon_{it-2}, \dots \varepsilon_{it-h}; \rho_{i1}, \rho_{i2}, \dots, \rho_{ih_i}\right)$ is a linear function of ε_{it-ij}, ρ_{ij} and $j=1,2,3,\dots.h_i$, ε_{it} and v_{it} are random error terms.

To find suitable estimation method of the model parameters, it is necessary to have acquaintance about the mathematical structure of $f_i(t; \beta_i)$. In this case we have two major categories of $f_i(t; \beta_i)$, linear and nonlinear models [41]. If the model is linear then we simply apply the ordinary least square (OLS) estimation method to estimate the model parameters [39, 20].

3.2.5 Steps of controlling serial autocorrelation

After controlling for periodic autocorrelation by setting the time effects as a function of time, we need to remove the serial correlation. Therefore, the following steps (algorithm) are used to remove serial correlation:

Step 1:   First estimate the model fit residuals as [43, 7]:

$$\widehat{\varepsilon}_{it} = y_{it} - f_i\left(t; \widehat{\beta}_i\right) \qquad (9)$$

Step 2:   Determine the structure of autocorrelation. At this step we use the Ljung–Box test of autocorrelation.

Step 3:   If we do not reject our null-hypothesis we take the model fit is free from the problem of autocorrelation. Otherwise, we apply the Prais–Winsten estimation recursive estimation to remove serial correlation [44, 19, 42, 12, 1, 34]. The estimated variance covariance matrix is given as:

Table 4 Prais-Winsten recursive parameter estimation of a linear regression of RPK (in million) in response to ASK (in million)

Predictor	Estimators	Std. Erro	t-cal	Sig.	R Square	Model Std. Error
ASK	0.914	0.015	59.147	0.0000		
Constant	−1648.14	198.94	−8.284	0.0000	0.928	378.461
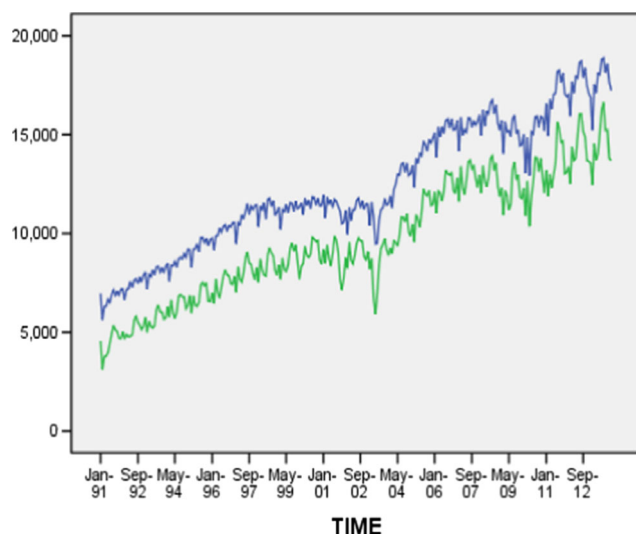
Fig. 2 Time Series Plot of ASK and RPK (in million) of EF flights

Key: ▬ ASK   ▬ RPK

$$\widehat{\Omega}_i = \frac{1}{1-\widehat{\rho}_i^2} \begin{bmatrix} 1 & \widehat{\rho}_i & \widehat{\rho}_i^2 & \cdots & \widehat{\rho}_i^{n-1} \\ \widehat{\rho}_i & 1 & \widehat{\rho}_i & \cdots & \widehat{\rho}_i^{n-2} \\ \widehat{\rho}^2 & \widehat{\rho} & \ddots & \cdots & \vdots \\ \vdots & \vdots & & 1 & \widehat{\rho}_i \\ \widehat{\rho}_i^{n-1} & \widehat{\rho}_i^{n-2} & \cdots & \widehat{\rho}_i & 1 \end{bmatrix} \quad (10)$$

The inverse of the variance covariance matrix can be expressed as:

$$\widehat{\Omega}_i^{-1} = \widehat{\psi}_i{}',\widehat{\psi}_i \quad where \quad \widehat{\rho}_i = \frac{\sum\limits_{t=2}^{n} \widehat{\varepsilon}_{it}\widehat{\varepsilon}_{it-1}}{\sum\limits_{t=1}^{n} \widehat{\varepsilon}_{it-1}^2} \quad and \quad (11)$$

$$\widehat{\psi}_i = \begin{bmatrix} \sqrt{1-\widehat{\rho}_i^2} & 0 & 0 & \cdots & 0 \\ -\widehat{\rho}_i & 1 & 0 & \cdots & 0 \\ 0 & -\widehat{\rho}_i & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix}$$

Step 4:   Transform the original trend equation as [2]:

$$\widehat{\psi}_i[y_{it}] = \widehat{\psi}_i[f_i(t;\beta_i)] + \widehat{\psi}_i[\varepsilon_{it}] \quad (12)$$

where: $[y_{it}]$ denotes the vector of stacked output variables $[y_{it}]$ for $t=1,2,3,\ldots,T$, $[\varepsilon_{it}]$ is similarly constructed from the error terms and $[f_i(t;\beta_i)]$ denotes the stacked Regressors vector.

Step 5:   Re-estimate model parameters using the data transformed according to Eq. 12.

Step 6:   Repeat from Step 1 to Step 5 unless the Ljung–Box test of autocorrelation confirms that there is no serial correlation on the random error terms.

4 Results and discussions

4.1 Assessment of the regional characteristics of load factors

To construct the best fit of multivariate trend model it is indispensable to follow up the relationship between the flight load factors (LF) for the Europe-Middle East (EM) and the Europe-Far East (EF) with RPK and ASK.

The bootstrap estimates of the results for the RPK and ASK of the EM and EF flights are given in Table 1. From Table 1 we can see that estimates of mean RPK (in million) of the EM and EF flights are 1696.92 (with bias +1.863) and 9671.81 (with bias −1.77), respectively. Estimates of mean ASK (in million) of the EM and EF are 2450.76 (with bias +1.53) and 12,375.32 (with bias +10.46), respectively. This result suggests that the EF flights have higher RPK and ASK than the EM flights. Furthermore, the average of 753.84 and 2703.51 ASK (in million) is out of use for every month in the EM and EF flights, respectively. The estimation result of Table 2 shows that in average the EF flights have 7974.89 RPK (in million) and 9924.56 ASK (in million) more than the EM flights. Moreover, the LF of the EF flights is 9.093 % higher than the EM flights.

The evaluation of the results in Table 3 jointly with Fig. 1, and Table 4 jointly with Fig. 2 show that there are strong correlation (coefficients of determination 92.7 and 92.8 %, respectively) and positive linear relationships between RPK and ASK in both EM and EF flights. Conferring to the estimation results of Table 3 and Table 4, fit of the linear regression model using the

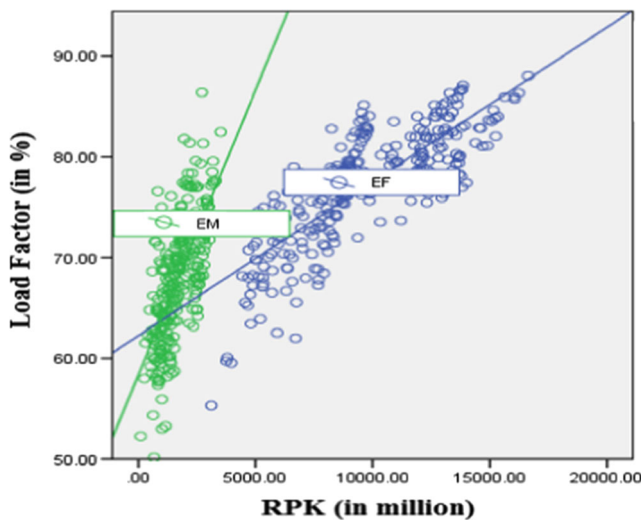|	Flights	Predictor	Estimators	Std. Error	t-cal	Sig.	R Square	Model Std. Error
Table 5 Prais-Winsten recursive parameter estimation of a linear regression of Load Factor (in percentage) in response to RPK (in million)	EM	RPK	0.02	0.001	24.852	0.0000		
		Constant	34.459	4.072	8.462	0.0000	0.693	2.751
	EF	RPK	0.003	0.000	14.059	0.0000		
		Constant	52.739	1.912	27.589	0.0000	0.642	2.621

Fig. 3 Scatter Plot of load factor (in %) versus RPK (in million)

Prais-Winsten recursive parameter estimation indicates that for a million increases in ASK, the RPK for the EM and EF flights is increased by 0.776 and 0.914 million, respectively. This result suggests that managerial decision taken by the airlines to balance supply and demand is generally good for both the EM and EF flights.

Nevertheless, in order to evaluate the airlines managerial capacity in relation to demand and capacity management we need to study the estimation results in Table 5 jointly with Fig. 3. These estimation results show that there exist moderate (coefficients of determination of 69.3 and 64.2 %, respectively) and positive linear relationship between LF and RPK in both EM and EF flights. The fit of linear regression using the Prais-Winsten recursive parameter estimation indicates that for a million increases in RPK, the LF of the EM and EF flights is increased by 0.02 and 0.03 %, respectively. Estimation results from Table 6 jointly with Fig. 4 show that there exist weak (coefficients of determinations of 16.6 and 20.7 % respectively) linear relationships between LF and ASK for both EM and EF flights. Therefore, the closer analysis from Tables 5 and 6 confirm that relatively the airliners have better demand management than capacity management for the EM and EF flights.

4.2 Assessment of the structure of autocorrelation of load factors (LF)

The correct autocorrelation structure for time series analysis is challenging. However, one powerful method for identification is the spectral density analysis. The spectral density is a non-parametric analysis able to give graphical information about how the autocorrelation function behaves in Fourier space.

One of the main graphical methods of spectral density estimation is the response of periodogram for the autocorrelation function frequency of the time series data. This method is extremely sensitive to the optimal autocorrelation structure. Another major method for spectral density estimation is the response of density for the autocorrelation function frequency of the time series data. This method is sensitive to the weighted autocorrelation structure of the data. Therefore, both frequency plots have important information about the autocorrelation structure for the load factor. The result of the non-parametric spectral density estimation and the parametric Ljung–Box test of the load factors of the EM and EF flights is given in Table 7.

The estimation of the periodogram and spectral density for the LF for the EM flights suggests that there exists strong periodic autocorrelation. The periodic autocorrelations are observed after jumping a specific number of months. The yearly repetitive plot of LF of the EM flights over months indicates that there are periodic dependencies. That is the monthly configured patterns for the EM flight's load factor shows some regularity. The smallest LF is observed in May growing until August every year. Once it reaches its peak in August, it starts to decline until November. From November to April the next year the load factor show a stable growth. The cycle stops when the load factor suddenly drops from April to May to find its minimum. The plots for the periodogram and the spectral density suggest that the LF distribution of the EM flight has serial correlation up to a certain number of lags in months. The Ljung-Box test detect that the LF is serially correlated with the order of 15 months and dissipated after 16th month.

The periodogram and the spectral density of the load factor for the EF flights indicate strong periodic autocorrelation. The periodic autocorrelations are observed after a specific number of months. The yearly repetitive

Table 6 Prais-Winsten recursive parameter estimation of a linear regression of Load Factor (in percentage) in response to ASK (in million)

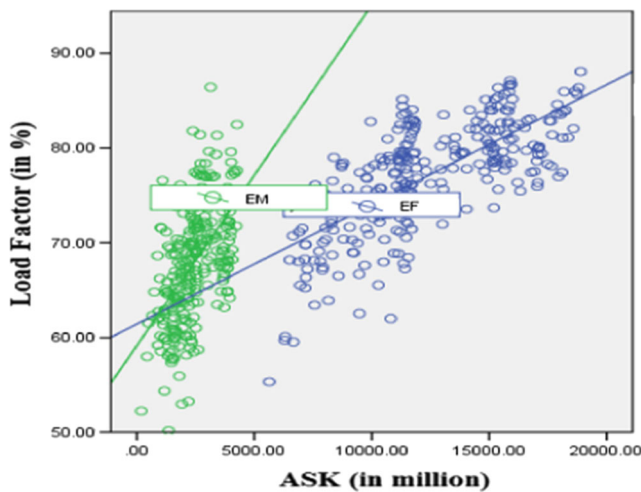| Flights	Predictor	Estimators	Std. Error	t-cal	Sig.	R Square	Model Std. Error
EM	ASK	0.004	0.001	7.366	0.0000		
	Constant	57.396	1.542	37.222	0.0000	0.166	4.254
EF	ASK	0.001	0.000	8.443	0.0000		
	Constant	62.166	1.83	33.978	0.0000	0.207	3.224

Fig. 4 Scatter Plot of load factor (in %) ASK (in million)

plot over months suggests that there are strong periodic dependencies. As for the EM flights, the monthly-configured patterns of LF of the EF flights show some regularity. As for the EM flights the smallest LF is observed in May growing until August. After reaching its peak in August it starts to decline until December. From December to January the following year the load factor show a growth. The cycle stops when the load factor drops from January to May to find its minimum. The plots of the periodogram and the spectral density

suggest that the LF distribution of the EF flight has serial correlation for several months. The Ljung-Box test statistic detects that the LF is serially correlated with the order of 13 months and dissipated after 14th month.

4.3 Fitting load factors using a multivariate trend model

The analyses above recognise that both the RPK and ASK for the EF flights are higher than for the EM flights. Similarly, the average LF for the EF flights is higher than for the EM flights. Moreover, above we also found that the LF has different echelons (magnitudes) of linear correlation with RPK for the EM and EF flights. Besides, the analyses prevails that the linear correlation of LF with ASK is weak for both flights. Therefore, using these variables (both RPK and ASK) as common exogenous cohorts for the prediction of the load factor is inappropriate. Therefore, we can explicitly fit the trend model of the EM flight and the EF flight. We are only left with time as a predictor of LF for both flights. Thus, rather than other models, for example panel data regression model, we apply multivariate trend models.

The analyses of the autocorrelation structure have shown that both periodic and serial correlations exist for the LF. More importantly, the structure of autocorrelation is different for two flights. This is showing that

Table 7 The structure of autocorrelation of load factor of EM and EF flights of airlines under the AEA

Regions	Monthly distributions of load factor across regions over time	Autocorrelation structure of load factor using Periodogram	Autocorrelation structure of load factor using Density	Ljung-Box Q Chi-Sq	DF	Sig.
EM Flights				122.41	15	.000
EF Flights				22.59	13	0.047
Key						

Table 8 The fits of multivariate trend model of the load factor of EM and EF flights

Parameter Estimates	Components of $f_i(t;\beta_i)$	Estimates	Std. Error	t-cal	Approx. Significance	Model Std. Error	Forecasting of Load factor of 2014 (in %)			
							Month	Expected	LB	UB
Rho (AR1-EM)		0.47065	0.05403	8.7109	0.00000	3.10843	Jan	68.48439	62.36979	74.59898
Time function Coefficients	t	0.04047	0.00440	9.2040	0.00000		Feb	70.82609	64.7115	76.94069
	$Sin(\omega_2 t)$	−0.89069	0.23959	−3.7176	0.00025		Mar	73.48739	67.37279	79.60199
	$Sin(\omega_3 t)$	1.56918	0.30565	5.1340	0.00000		Apr	75.61921	69.50461	81.7338
	$Sin(\omega_6 t)$	−2.44483	0.41552	−5.8838	0.00000		May	71.20958	65.09498	77.32418
	$Cos(\omega_1 t)$	0.66278	0.12738	5.2032	0.00000		Jun	73.23854	67.12394	79.35313
	$Cos(\omega_2 t)$	2.19048	0.23959	9.1428	0.00000		Jul	78.23464	72.12004	84.34924
	$Cos(\omega_3 t)$	−2.05430	0.30510	−6.7332	0.00000		Aug	82.73358	76.61898	88.84817
	$Cos(\omega_6 t)$	−3.04910	0.41357	−7.3726	0.00000		Sep	76.83852	70.72392	82.95312
Constant of EM Flights		62.35790	0.70356	88.6320	0.00000		Oct	72.66656	66.55196	78.78115
							Nov	70.39743	64.28283	76.51203
							Dec	71.76413	65.64953	77.87873
Rho (AR1-EF)		0.5381	0.0507	10.603	0.0000	2.278	Jan	81.15884	76.67778	85.63989
Time function Coefficients	t	0.0250	0.0074	3.3849	0.0008		Feb	84.1656	79.68454	88.64665
	$ln(t)$	2.4256	0.5892	4.1171	0.0001		Mar	84.06061	79.57955	88.54167
	$Sin(\omega_2 t)$	−0.8707	0.1710	−5.093	0.0000		Apr	80.45579	75.97473	84.93685
	$Sin(\omega_3 t)$	2.1558	0.2242	9.6166	0.0000		May	78.56003	74.07897	83.04109
	$Sin(\omega_6 t)$	−2.4322	0.3252	−7.480	0.0000		Jun	81.36409	76.88303	85.84515
	$Cos(\omega_2 t)$	−0.3753	0.1709	−2.196	0.0289		Jul	85.53465	81.05359	90.01571
	$Cos(\omega_3 t)$	−2.1171	0.2235	−9.471	0.0000		Aug	87.12244	82.64139	91.6035
	$Cos(\omega_4 t)$	0.7073	0.2664	2.6552	0.0084		Sep	86.38518	81.90413	90.86624
Constant of EF Flights		62.3631	1.9255	32.387	0.0000		Oct	84.91345	80.4324	89.39451
where: $t=12$ *(Current year-1991)+ Current month* and $\omega_l = \frac{\pi}{l}, l = 1, 2, 3\ldots.$ are periods							Nov	82.93511	78.45405	87.41616
							Dec	81.52201	77.04095	86.00306

the time effect on the LF is not simply fixed or random effects; rather it is dynamic and uniquely associated with the regional flights. Therefore, we will use transcendental time functions as LF predictors to control for periodic autocorrelation in our multivariate trend model. The fit of the multivariate trend model of the LF of the EM and EF flights is given in Table 8. The significance of the harmonic time function confirms the seasonality LF for the EM and EF flights. The significance of time (t) for the fitted model suggests that the LF is improving (growing) with time for both flights. However, the significance of the natural logarithm of time ($ln (t)$) in the model for the EF flights suggests that the LF performances improvements of the airlines are better for the EF flights than for the EM flights.

In Fig. 5 (left side) we report the comparison of the actual and the predicted values for the load factors. From the Figure we can see that the fit of the multivariate trend model is found to be robust and realistic for the load factor forecast of both flights. Furthermore, in Fig. 5 (right side) we give the plots of the monthly forecasted LF values with upper and lower 95 % prediction intervals for the year 2014.

5 Conclusions and recommendations

5.1 Conclusions

This study applied advanced econometric analysis on the load factor (LF) of flights of Europe-Middle East (EM) and Europe-Far East (EF) of Association European Airlines (AEA). The econometric analysis provides the following conclusions. The mean RPK for the EM and EF flights are 1696.92 and 9671.81 million, respectively. Likewise, the mean ASK for the EM and EF are 2450.76 and 12,375.32 million, respectively. Therefore, both in airline transportation demand and capacity the EF flights are higher than for the EM flights. However, the average LF of the EM flights is 9.094 % higher than for the EF flights.
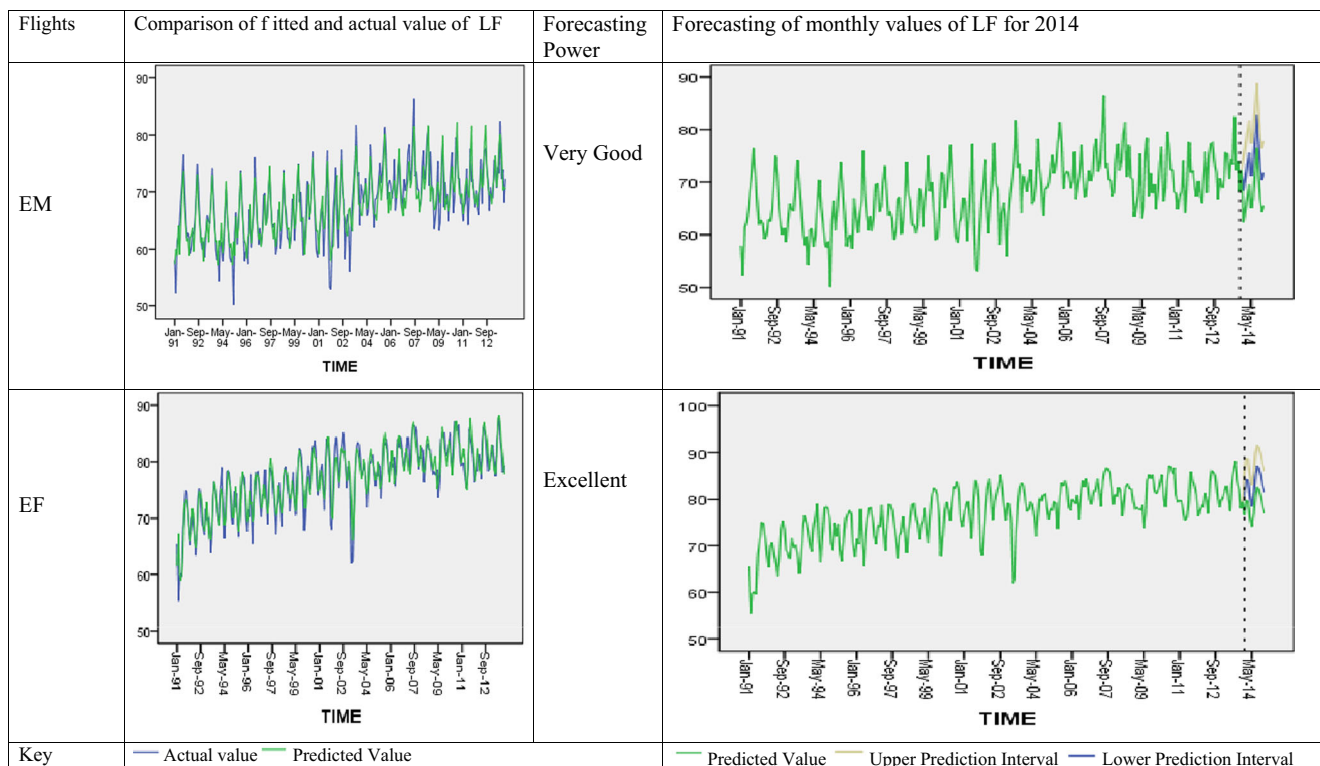
Flights	Comparison of fitted and actual value of LF	Forecasting Power	Forecasting of monthly values of LF for 2014
EM		Very Good	
EF		Excellent	
Key	— Actual value — Predicted Value		— Predicted Value — Upper Prediction Interval — Lower Prediction Interval

Fig. 5 The comparison of fit of multivariate time trend model with the actual value

The LF for both EM and EF flights are significantly positive correlated with both the RPK and ASK. This generally showed that the airlines have good reaction strategy to their demand. More importantly, we found significant correlation of LF with RPK for the EM and EF flights. However, the significance of correlation of LF with ASK is weak for the EM and EF flights. This confirms that the airlines have better demand than capacity management system for both the EM and the EF flights.

The LF of both EM and EF flights has periodic (season-to-season) correlations. The smallest LF for EM flights is observed in November, December and January then started to grow until July, August and September, and then declining until November. The smallest LF of EF flights is observed in January then it started grow until July, and then declining until December. Furthermore, the LF of both EM and EF flights has serial (month to month) correlations. The LF of EM and EF flights have correlation order of 15 and 13 months, respectively.

Since we have no common exogenous input for the EM and EF flights, we fit multivariate trend model. Using the fitted model we have given forecasted the monthly values for the LF with upper and lower 95 % prediction intervals for 2014.

5.2 Recommendations and policy implications

This paper has applied econometric models to analyse the LF of EM and EF flights of airlines of the AEA.

Our results have important managerial policy implications and may suggest the following policy recommendations. Fit of the LF using the multivariate time series model is found more robust and realistic. The AEA may therefore use the model for prediction of the LF for the distribution of relevant flights. Hence, it is recommended that the AEA apply the model to regional flights. In the airline industry, in addition to decreasing the airlines cost, the profitability of a given airline is dependent on the joint maximization of yield and LF. In order to push up the LF and the yield simultaneously, and to produce strategic decisions about the profitability of airlines, the AEA may extend the LF analysis to individual airlines. The outcome of such analysis will give rigorous information about the LF. Consequently, the AEA will have quantitative input on how to restructure the yield management, network design, etc. with respect of specific flights over time. The econometric analysis have identified that the demand management of the airlines is better than the capacity management. In this regard, the AEA is recommended to keep up with the existing demand management strategy and improvement is needed on the strategy of capacity management. Finally, as suggested by many international industry studies, the airline industry is seasonal. In this paper, we find that the LF of the EM and EF flights are both seasonal and differ between flights. The result implies that the LF is far from stable and

stabilizing policies by airlines has so far not been successful. The AEA may therefore continuously focus on the stabilisation and the improvement of the LF for the industry.

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