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An alternative approach to estimating demand: Neural network regression with conditional volatility for high frequency air passenger arrivals

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ABSTRACT

In this paper we provide an alternative approach to analyze the demand for international tourism in the Balearic Islands, Spain, by using a neural network model that incorporates time-varying conditional volatility. We consider daily air passenger arrivals to Palma de Mallorca, Ibiza and Mahon, which are located in the islands of Mallorca, Ibiza and Menorca, respectively, as a proxy for international tourism demand for the Balearic Islands. Spain is a world leader in terms of total international tourist arrivals and receipts, and Mallorca is one of the most popular destinations in Spain. For tourism management and marketing, it is essential to forecast high frequency international tourist demand accurately. As it is important to provide sensible international tourism demand forecast intervals, it is also necessary to model their variances accurately. Moreover, time-varying variances provide useful information regarding the risks associated with variations in international tourist arrivals.

1. Introduction

Most of the articles in the literature of demand systems deal with a utility-based (or parametric) approach to modelling consumer demand. The traditional approach to quantifying consumer preferences assumes the existence of either an explicit or implicit direct (or indirect) utility function, uncovers the system of demand functions through the optimization process (or simply specifies them), and then tests a specified functional form of demand functions against relevant data to determine if the Slutsky properties implied by the theory (such as non-negativity, symmetry, homogeneity of degree zero in prices and income) are found to hold (see, for example, Basmann et al. (1987)).

Such an approach is valuable and necessary if the intent of the inquiry is to determine a specific characteristic (or characteristics) of the economic agent or variable under scrutiny. That is, estimation of the own-price elasticity of demand of a commodity may be the primary reason for the analysis. Concurrently, the validity of the specification of the functional form itself may be the chief point of inquiry. Economists undertake these exercises because they continue to search for a better understanding of how consumer preferences are formulated and how consumer demand is impacted by interventions such as changes in income, relative prices and demographics. The functional form is also useful in the construction of true cost of living indices, and thereby in allowing for predictions about how the true cost of living may change when prices and income change (see, for example, Basmann and Slottje (1987)). Most of the papers in the literature present different (and innovative methods) to explore such challenging questions.

There are, of course, other objectives of consumer demand studies and other approaches to analyzing consumer demand. The primary objective of demand analysis may be to forecast consumer demand for a given activity or commodity over time, and to determine what factor(s), if any, may impact the demand for that activity or commodity in the future. While it is possible to take traditional systems of demand functions and to estimate the parameters of the system-wide model (see Theil (1975, especially pp. 322–326)), and then to use those coefficient estimates for prediction and policy purposes, there are other ways in which to accomplish these aims. In some situations, the nature of the data themselves may present problems with using a standard approach to estimating consumer demand. If the data are high frequency

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with non-linearities, traditional systems of demand equations may be ill-equipped to deal with the potentially complicated estimation issues.

This paper shows that the use of statistical (non-parametric) models allows us to exploit the potentially rich vein of information that may be inherent in particular high frequency data under scrutiny by specifying explicitly the volatility inherent in the data over time, and to discover potential changes in consumer behavior based on the estimates of volatility that are extracted from the statistical model. The agnostic view (with respect to the functional form of the demand equations) taken by a statistical model of consumer demand may have other advantages over the traditional approach. Such models not only avoid the integrability problem (see Samuelson (1947)), but can be interpreted as what might be called "super-reduced form" equations and, therefore, avoid some, if not all, of the usual turmoil and debate about identifiability and specification. In this paper, we show that consumer demand for air travel can be forecasted effectively using a neural network model with conditional heteroskedastiticity that will be explained below.

Recent years have witnessed a vast development of nonlinear time series techniques (see, for example, Tong (1990) or Granger and Teräsvirta (1993)). From a parametric point of view, the Smooth Transition (Auto-)Regression, ST(A)R, proposed by Chan and Tong (1986), who called the model Smooth Threshold Auto-regression, and further developed by Luukkonen et al. (1988) and Teräsvirta (1994), has found a number of successful applications (see van Dijk et al. (2002) for a review). In the time series literature, the STAR model is a natural generalization of the Threshold Autoregressive (TAR) models, as pioneered by Tong (1978) and Tong and Lim (1980).

On the other hand, nonparametric models that do not make assumptions about the parametric form of the functional relationship between the variables to be modelled have become widely applicable due to computational advances (Härdle, 1990; Härdle et al., 1997; Fan and Yao, 2003). Another class of models, namely flexible functional forms, offers an alternative that leaves the functional form of the relationship partially unspecified. While these models do contain parameters, sometimes a very large number, the parameters are not globally identified. Identification, if achieved, is local at best, without imposing restrictions on the parameters. Usually, the parameters are not directly interpretable, as in parametric models. In most cases, these models are interpreted as nonparametric sieve (or series) approximations (Chen and Shen, 1998).

The neural network (NN) model is a prominent example of such a flexible functional form. Although the NN model can be interpreted as a parametric alternative (Kuan and White, 1994; Trapletti et al., 2000; Medeiros et al., 2006), its use in applied work is generally motivated by the mathematical result stating that, under mild regularity conditions, an NN model is capable of approximating any Borel-measurable function to any given degree of accuracy (see, for instance, Hornik et al. (1990), Gallant and White (1992), and Chen and White (1998)). NN models can also be interpreted as smooth transition models with flexible transition variables, as in Medeiros and Veiga (2005) or Medeiros et al. (2006).

This paper considers the case of NN models with GARCH (Generalized Autoregressive Conditional Heteroskedastic) errors (Engle, 1982; Bollerslev, 1986) (see also Poon and Granger (2003), McAleer (2005), and Andersen et al. (2006) for useful reviews of conditional variance models). Conditions for weak consistency and asymptotic normality of the quasi-maximum-likelihood estimator are derived. We apply the NN–GARCH model to describe the dynamics of daily air passenger arrivals at three different airports in the Balearic Islands, Spain. Our theoretical results are new and extend the work of Francq and Zakoïan (2004).

The number of air passenger arrivals is closely related to the number of tourists, as documented in Bartolomé et al. (2008). International tourism demand is important for many countries worldwide because of the tourist export receipts that they generate. Spain is one of the most visited countries in the world by international tourists, being second to France in terms of total of international tourist arrivals, and second to the USA in terms of international tourism receipts. Of the five major tourist regions in Spain, Mallorca in the Balearic Islands is one of the most popular destinations. It is clear that international tourist arrivals are important globally, as well as nationally for Spain. For purposes of tourism management and marketing, it is essential to be able to forecast the demand for tourism, as proxied by tourist arrivals, and their percentage changes accurately. As it is important to provide sensible tourist forecast intervals in addition to the forecasts themselves, it is also necessary to model the variances of the forecasts accurately.

Forecasting international tourism and their associated volatility has been considered previously in Chan et al. (2005) and Hoti et al. (2007) at the multivariate level, and in Shareef and McAleer (2007) at the univariate level. Bartolomé et al. (2008) considered different volatility models for passenger arrivals in five different airports in the Balearic Islands, including Mallorca. These papers have shown the importance and usefulness of both univariate and multivariate conditional volatility models, when used in conjunction with time series models of international tourist arrivals and their respective rates of growth.

The remainder of the paper is as follows. Section 2 reviews the economic relevance of tourism demand for the Balearic Islands. In Section 3.1, we introduce some important neural network concepts and introduce the main notation. Section 3.2 discusses parameter estimation and asymptotic theory. The empirical application is presented in Section 4. Finally, Section 5 gives some concluding comments.

2. Tourism demand in the Balearic Islands

In this paper we consider daily air passenger arrivals as a proxy for the daily demand for tourism in the Balearic Islands, Spain. We model and forecast the number of passenger arrivals at three different airports, namely Palma de Mallorca, Ibiza and Mahon, which are located in the islands of Mallorca, Ibiza and Menorca, respectively.

The Balearic Islands has a total population of just over 1 million people and are one of the leading sun and sand destinations in the Mediterranean. During 2006 the Balearic Islands received, by air and by sea, over 12.5 million tourists and, of these, approximately 12 million arrived by plane, and 9.77 million were international tourists. The tourism industry accounts for 48% of the total GDP in the Balearics. However, the tourism industry is affected by seasonality, as it is in many other Mediterranean destinations. Almost 9 million tourists visited the islands between the months of May and September, but only 3.5 million visited during the remaining seven months (CITTIB, 2007). Furthermore, the local economy is not only highly dependent on tourism, but the standardized sun and sand product also predominates, despite the efforts of diversification promoted by public and private initiatives (Aguiló et al., 2005).

The three main islands in the Balearics are Mallorca, Ibiza and Menorca (for purposes of simplicity, data for the small island of Formentera are integrated with Ibiza), and each has an international airport in their respective capital cities of Palma de Mallorca, Ibiza and Mahon. Although all the islands enjoy the same climate, there are differences in their economic structures, the number of tourist arrivals, seasonal patterns, and the profiles of tourists who visit each island. Mallorca accounts for 79% of Balearic regional GDP, while Menorca and Ibiza represent 9% and 12%, respectively (CAIB, 2004). In Mallorca, total demand from tourism