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Measuring uncertainty of traffic volume on motorway concessions: a time-series analysis

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Abstract

This paper presents a method to build up a confidence interval for the evolution of traffic in motorway concessions, based on a univariate time-series model. The main advantage of this method, compared to traditional traffic models, is that it allows to avoid the error in the prediction of the explanatory variables. The results obtained show that the use of a time-series model represents a feasible alternative to assess traffic uncertainty in existing concessions, when long series of traffic data are available.

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Keywords: traffic; motorway; time-series; unit root; concession

1. Introduction

Traditionally, the first steps in long-term traffic models are based on the establishment of a relationship between transportation demand and certain explanatory variables for which available information and prediction capacity are greater than for traffic itself. Then, in successive steps, transportation mode choice and route choice models are applied (Department of Transport, 2006).

However, in certain cases (as discussed below) one could expect that the evolution of traffic itself contributes better information than other variables. Then, the use of univariate time-series models may be an alternative tool to predict the traffic volume and to build a confidence interval for the forecast, when there are available data for traffic during a long enough period.

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In any case, building a confidence interval for traffic forecasts is a complex issue in traditional transportation models. As De Jong et al. (2007) and Matas et al. (2012) state, the literature on quantifying uncertainty in traffic forecasts is fairly limited. In most traffic studies, the issue of uncertainty is addressed by considering different scenarios for the exogenous variables (for example, different rates of economic growth). However, this procedure does not really quantify uncertainty if it does not provide the likelihood of each alternative forecast (Matas et al., 2012). Therefore, statistical methods are needed to quantify uncertainty.

A statistical analysis of traffic uncertainty should consider both the uncertainty due to model inputs and the uncertainty due to the model itself. The uncertainty associated with model inputs can be measured by estimating the probability distributions of exogenous variables. From these distributions can be obtained, using an analytical method or a simulation process, the contribution of the uncertainty in the inputs to the uncertainty in predicting traffic (Boyce and Bright, 2003). To this must be added the model specification errors and errors in the determination of the parameters of the model (Brundell-Freij, 2000; Beser Hugosson, 2005).

The work of De Jong et al. (2007) obtained as one of its main conclusions that the uncertainty due to the inputs of the model is much more important than the uncertainty due to the model itself. This may lead to the reflection that, when there is appropriate information on the evolution of traffic in a relatively stable environment, it may be more useful an analysis based on traffic time-series that the development of a complex traffic model.

Possibly, the choice of a univariate time-series model is not suitable for the evaluation of a new road infrastructure project, but it may be appropriate in other cases, for example, the appraisal of an existing motorway concession. In this regard, it is noteworthy that one could expect future developments of secondary markets of infrastructure concessions (Alcaraz and Sánchez Soliño, 2015), which in turn will require the development of analytical tools for making proper assessments of traffic in such concessions.

2. Unit root analysis

A first step in the characterization of time-series is the analysis of stationarity. In order to perform a unit root (or non-stationarity) test of time-series, we start from an autoregressive model that can be expressed as:

$$y_t = \alpha + \rho y_{t-1} + \varepsilon_t \tag{1}$$

where:
y_t : random variable
α : intercept (constant)
ρ : constant parameter
ε_t : white noise

Subtracting the term y_{t-1} from both sides of equation (1), we obtain:

$$y_t - y_{t-1} = \alpha + (\rho - 1)y_{t-1} + \varepsilon_t \tag{2}$$

In order to make the calculation easier, we can say $\beta = \rho - 1$, so equation (2) can be written as follows:

$$y_t - y_{t-1} = \alpha + \beta y_{t-1} + \varepsilon_t \tag{3}$$

Then, we could try to estimate the parameter β by using Ordinary Least Squares (OLS), and calculating the t-statistic to test whether β is significantly different from 0. If we cannot reject the hypothesis that $\beta = 0$, then we can say that the process has a unit root, and cannot reject that the y_t variable is non-stationary. However, if the true value of ρ is 1 ($\beta = 0$), then the OLS estimator of ρ is biased towards zero (Pindyck & Rubinfield, 1998). Then the use of OLS could lead us to incorrectly reject the non-stationarity hypothesis.

To solve this problem, Dickey-Fuller (1979, 1981) used a Monte Carlo simulation to calculate the correct critical values for the distribution of the t-statistic when $\rho = 1$. Additionally, other authors have obtained these critical values, such as McKinnon (McKinnon, 1990, 2010). If the t-statistic obtained in our estimation is greater than the