Transportation Research Part A 44 (2010) 16–38

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Forecasting automobile petrol demand in Australia: An evaluation of empirical models

Zheng Li, John M. Rose, David A. Hensher *

Institute of Transport and Logistics Studies, Faculty of Economics and Business, The University of Sydney, NSW 2006, Australia

ARTICLE INFO

Article history:
Received 13 July 2008
Received in revised form 1 September 2009
Accepted 8 September 2009

Keywords:
Petrol demand forecasting
Automobiles
Time series data
The partial adjustment model
The autoregressive integrated moving average model
Elasticities
Trend-fitting approaches
Exponential smoothing
Forecasting effectiveness

ABSTRACT

Transport fuel consumption and its determinants have received a great deal of attention since the early 1970s. In the literature, different types of modelling methods have been used to estimate petrol demand, each having methodological strengths and weaknesses. This paper is motivated by an ongoing need to review the effectiveness of empirical fuel demand forecasting models, with a focus on theoretical as well as practical considerations in the model-building processes of different model forms. We consider a linear trend model, a quadratic trend model, an exponential trend model, a single exponential smoothing model, Holt's linear model, Holt–Winters' model, a partial adjustment model (PAM), and an autoregressive integrated moving average (ARIMA) model. More importantly, the study identifies the difference between forecasts and actual observations of petrol demand in order to identify forecasting accuracy. Given the identified best-forecasting model, Australia's automobile petrol demand from 2007 through to 2020 is presented under the "business-as-usual" scenario.

1. Introduction

The influences underlying the consumption of fuel for transport activity have received a great deal of attention since the first oil *crisis* in the early 1970s (Espey, 1996). In addition to attempts to determine the key influences on petrol consumption, many studies examining fuel demand have been undertaken to predict future demand (Banaszak et al., 1999; Murat and Ceylan, 2006; Ediger and Akar, 2007). More recently, environmental concerns such as climate change have become increasingly important in the desire to understand global fuel demand, with a particular emphasis on the transport sector, given that 14% of global greenhouse gas emissions are estimated to be produced from this sector (Hensher, 2008). In looking at transport fuel demand, many studies have concentrated on automobile petrol demand, given that car usage represent one of the major consumers of fuel, and petrol is the dominant fuel source for the current passenger car fleet (for studies that do not look solely at automobile petrol demand, see e.g., Birol and Guerer, 1993; Samimi, 1995).

The prediction of fuel consumption has become an increasingly important tool for energy planning, with the primary purposes often cited as: to (i) help policy makers develop appropriate pricing and taxation systems, (ii) help decide future investments and decisions on oil reserves to improve energy security, (iii) aid in addressing emission and pollution issues in advance, and (iv) allow for planning of future energy needs, as well as to identify national infrastructure and research and development requirements. Understanding the determinants of transport fuel demand represents a key to the development

* Corresponding author. Tel.: +61 2 93510071; fax: +61 2 93510088.
E-mail addresses: z.li@itls.usyd.edu.au (Z. Li), j.rose@itls.usyd.edu.au (J.M. Rose), d.hensher@itls.usyd.edu.au (D.A. Hensher).

0965-8564/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tra.2009.09.003

of transport and environmental policies. Moreover, it is critical for decision makers to recognize the nature of fuel demand so that they can implement corresponding policies and regulations to ensure sustainable development.

In the transport and energy literature, petrol demand forecasting is an important topic with hundreds of studies undertaken to date (see e.g., Banaszak et al., 1999; Murat and Ceylan, 2006; Ediger and Akar, 2007). Researchers have used various types of modelling methods to estimate petrol demand. Whilst some studies have examined different approaches, these have typically only explored theoretical differences, usually without undertaking an empirical comparison of the practical usefulness in forecasting fuel demand (see e.g., Hunt et al., 2003).

The purpose of this paper is to address this gap in the literature by empirically comparing the effectiveness of different forecasting models in fuel demand forecasts. In doing so, we describe not only the theoretical elements of the various models, but also the set of practical considerations that define the appeal of specific models. We test the accuracy of each of the models by measuring forecast errors from a hold out sample. In total, eight models are built, namely a linear trend model, a quadratic trend model, an exponential trend model, a single exponential smoothing model, Holt's linear model, Holt–Winters' model, a partial adjustment model (PAM), and an autoregressive integrated moving average (ARIMA) model. The empirical data used to test alternative model specifications is drawn from Australia.

The organisation of this paper is as follows. In the following section, an overview of Australian automobile petrol demand is provided. This is followed by a brief literature review and data description, and the different forecasting models are presented. Model results are then provided, including an evaluation of the forecasting performance of each model, as well as the presentation of long term demand forecast predictions from the best-forecasting models. Conclusions are then drawn along with a discussion of the major findings, as well as some key recommendations.

2. Australian automobile petrol demand

In 2005, the total number of road transport vehicles in Australia was estimated to be over 13.9 million. Of these, approximately 80% were classified as passenger cars (ABS, 2006a). A significant characteristic of automobile usage in Australia is the high reliance on petrol, with 94% of automobiles using petrol as the primary source of combustion in Australia (ABS, 2007a). Over the period 1 November 2004 to 31 October 2005, approximately 28.967 billion litres of road transport fuel was consumed. 64.6% (i.e., 18.713 billion litres) was petrol, 30.0% diesel fuel (i.e., 8.69 billion litres) with the remaining consumption representing other fuels (ABS, 2006b). During the period, passenger automobiles represented the major end users of petrol. In total, automobiles consumed 15.856 billion litres of petrol or 85% of total road petrol consumption in Australia (ABS, 2006b).

These figures can be further broken down into different vehicle types. In Australia, approximately 85% of total petrol attributable to road travel was consumed by passenger cars over the period 1 November 2004 to 31 October 2005, and articulated and rigid trucks (two main types of freight vehicles) used 65% of road diesel during the same period (ABS, 2006b). If light commercial vehicles and non-freight carrying trucks are also considered, the diesel share of goods vehicles would be much higher than 65%.

Coupled with high petrol consumption, Australia has also exhibited strong growth in car ownership. From 2001 to 2005, the number of automobiles increased by 12.5%, with fuel consumption by road motor vehicles increasing by 11.6%. Road traffic for the corresponding period increased from 206,383 to 31,972 million tonne–kilometres (ABS, 2006b). Whilst there exist many possible causes for this, the two key drivers of these increases are thought to be (i) continuing growth in household incomes and (ii) increases in population, given that Australian population increased by 5.1% over the period 2001–2005, and meanwhile the average individual income jumped by 24% according to the Australian Bureau of Statistics.

3. Literature review

The study of automobile fuel consumption is not new. Over the past four decades, many econometric studies have examined the demand for fuel. Whilst the purposes of these studies are diverse, a significant concern has been to analyse the effects on petrol consumption resulting from the threat of fuel energy scarcity (Espey, 1996). More recently, environmental concerns have been cited as a key reason behind the desire to understand and model global fuel demand.

It is expected that an increase in price would lead to a decrease in the quantity demanded (a negative price elasticity), and rising income is expected to stimulate petrol usage (a positive income elasticity). Also it can be expected that petrol demand would decline when income decreases, as less transport activities would be required in a less affluent economy. An interesting question is the extent to which a decrease in price would lead to rising demand for fuel.

Breunig and Murphy (2007) have found that Australia's petrol demand response to price decreases is not significantly different from zero in the short-run. That is, petrol demand would remain at the same level given a decrease in price in the short-run. In another world, a lower price would not have an impact on petrol consumption in the short term. Breunig and Murphy also showed that the long-run demand responsiveness to petrol price increases and decreases is symmetrical. The estimated elasticities represent the percentage change in petrol demand resulting from 1% change of price or income.

One of the most common models for forecasting transport fuel demand and estimating elasticities is the partial adjustment model (PAM). The rational for a PAM is that it always takes time to fully respond to a change, and hence the instantaneous reaction is part of the ultimate level (Sterner and Dahl, 1992). For example, car drivers may respond to an increase in