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The dynamics of fuel demand and illegal fuel activity in Turkey

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ABSTRACT

We expose the dynamics of road fuel demand by employing maximum entropy resampling based interval estimates in a fixed width rolling window framework. Our approach facilitates using a uniform specification in a sequential procedure while also providing robust and efficient estimates that can evolve over time. Ours is also the first study to develop a method for estimating illegal fuel activity. To demonstrate our methodology, we use monthly data between 2003–2012 and focus on the demand for diesel and gasoline in Turkey. The results show estimated monthly illegal activity ranging between 5–23 million liters over the last six years.

1. Introduction

Studying how the consumption of transport fuels responds to price and income changes can provide important insights and implications for growth, trade, resistance to macroeconomic shocks, energy security, refinery investments, carbon emissions and optimal taxation, among others. Accordingly, articles estimating the demand functions of gasoline as well as diesel fuel constitute a major research area in the economics literature. In a recent survey study, Dahl (2012) catalogs a total of 247 gasoline demand studies and 63 diesel demand studies conducted since 1966 for about 120 countries. The majority of these studies use different time series techniques in order to estimate mainly the price and the income elasticities of fuel demand. The reported results differ from study to study and even within a single study. The short-run price elasticities vary in the ranges of $[-1.7,0.6]$ and $[-0.9,2.1]$, while the income elasticities range between $[-2.6,3.0]$ and $[-0.9,33]$ for gasoline and diesel respectively.

Notwithstanding the inconsistent results, a common feature of the majority of the existing studies is that they assume constant demand functions and estimate averaged coefficients for sample periods from 8 years to as long as 44 years. This may not be a plausible assumption because, in today's world of rapidly changing economic conditions, policy makers need to make decisions by taking into account the latest trends and updated information. In addition, recent studies such as Hughes et al. (2008) and Park and Zhao (2010) show that the price and income elasticities can show time-varying changes. Moreover, there is an ongoing debate on whether or not energy demand shows asymmetric responses to changing prices. In a frequently cited paper, Gately and Huntington (2002) measure asymmetric behavior by using distributed lag models to decompose the price and the income data into three types: increases to a historical maximum, decreases to a historical minimum, and recoveries. In response, Griffin and Schulman (2005) argue that the suggested asymmetry methodology captures in reality the effects of energy-saving technological change. Later studies such as Adeyemi and Hunt (2007) and Adeyemi et al. (2010) provide mixed-results on the issue.

Our objective in this study is to use a novel time series analysis technique and sequentially estimate the demand functions of diesel fuel as well as gasoline at intervals much shorter than those attempted in the previous studies. By doing this, we aim to analyze the dynamics of the price and income elasticities of demand for fuel, and demonstrate how these elasticities can display responses as well as irresponses to various changes in economic conditions. The second and equally important objective of our study is to propose a method to estimate illegal fuel activity. In the energy economics literature, there exist no studies that empirically investigate the dynamics of black market activity in the fuel oil sector. In fact, research regarding illegal energy use is limited to only a few studies focusing on electricity theft such as Smith (2004), Mimmi and Ecer (2010) and Tasdoven et al. (2012). It goes without saying that an instrument for measuring illegal activity and its resulting tax losses is useful especially for developing countries, where fuel smuggling is a major concern due to the lack of effective inspection and monitoring mechanisms.

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Our methodology is based on performing bootstrap interval estimates by employing maximum entropy resampling in a fixed-width rolling window framework. It is well established that simulation based estimation can provide significantly more accurate results in small samples in comparison to the conventional inferences based on the asymptotic distribution theory (Horowitz, 2003; MacKinnon, 2006). Proposed by Vinod (2004) and further discussed by Vinod (2006, 2008) and Vinod and de Lacalle (2009), maximum entropy bootstrap (meboot) is a relatively new resampling scheme specifically designed for the analysis of strongly dependent time series. In a large scale simulation study, Yalta (2015) shows that meboot can provide substantial asymptotic improvements in smaller sample sizes, making it particularly useful for rolling window estimation.

In order to demonstrate our methodology, we use monthly data between January 2003 and December 2012 in order to estimate the demand functions for diesel and gasoline in Turkey. Performing this analysis for Turkey is useful for a number of reasons. First, Turkey is heavily dependent on energy imports and, as of 2012, its import share of oil exceeds 92.4% (Ministry of Energy and Natural Resources, 2013). This makes it crucial to investigate the sensitivity of Turkish diesel and gasoline demand with respect to price and income changes. Second, the last decade in Turkey has been marked by important economic changes, resulting in its GDP to triple in dollar terms. Consequently, it is of interest to examine whether there have been any changes or shifts in the price and income elasticities of demand for diesel and gasoline. Third, fuel smuggling is a major source of concern in Turkey due to the proximity to the oil rich regions of Iraq, Iran, and the Caspian Sea. This makes the country an excellent candidate for examining the dynamics of illegal fuel activity.

There exist a number of previous studies which estimate the gasoline and/or diesel demand in Turkey. Baltagi and Griffin (1983) investigate the demand for gasoline in the OECD countries between 1960–1978 and find that both the price and the income elasticities are statistically insignificant in Turkey. In a follow-up study, Baltagi and Griffin (1997) compare different estimation methods for the 1960–1990 period and report for Turkey that the short-run price and income elasticities range between $[-0.28,0.37]$ and $[-0.38,0.05]$ respectively. Sterner et al. (1992) also focus on the OECD countries and estimate for the 1960–1985 period that, based on different specifications, the price elasticity for gasoline in Turkey is in the range of $[-0.5,-1.1]$ while the income elasticity remains within [1.1,1.3]. Birol and Guerer (1993) consider six developing countries between 1970–1990 and, by applying a partial adjustment model, conclude that the short-run price and income elasticities of demand for gasoline in Turkey are -0.18 and 0.39 respectively whereas the long-run elasticities are -0.75 and 1.63 in that order. They also report that, for diesel, the short-run price and income elasticities are 0.06 and 1.17 with long-run counterparts of 0.15 and 3.0. More recently, Erdogdu (2014) estimates the demand for gasoline, diesel and liquefied petroleum gas (LPG) by also employing a partial adjustment model. Using quarterly data between 2006–2010, he estimates the short-run price elasticity of gasoline as -0.21 and the short-run price elasticity of diesel as 0.07. The short-run income elasticities are in turn found as 0.13 and 0.71. He also calculates the long-run elasticities and finds that the long-run price elasticity of gasoline is -0.48 and that of diesel is 0.16 with the corresponding long-run income elasticities being 0.30 and 1.64 respectively. Finally, Hasanov (2015) focuses on the 2003–2014 period and estimates gasoline and diesel demand functions by using four different specifications namely a partial adjustment model, a distributed lag model, an autoregressive distributed lag model and an error correction model. He concludes that gasoline consumption in Turkey reacts to income neither in the short-run nor in the long-run. In addition, he finds that gasoline consumption reacts to prices only in the short-run, but not in the long-run. He also finds that diesel demand does not respond to prices in the short-run while the price elasticity is -0.28 in the long-run. He reports the short-run and long-run income elasticities for diesel demand respectively as 0.18 and 1.47.

The above studies are similar to those discussed in the extensive survey study by Dahl (2012) in that they assume constant demand functions and estimate coefficients that are averaged for sample periods from 4 years to 25 years. As a result, our analysis, which employs monthly data together with an advanced bootstrap procedure to perform small sample rolling-window estimates can help better understand the time varying dynamics of fuel demand, while also reconciling the earlier findings.

The rest of the paper is organized as follows. In the next section, we introduce the methodology adopted, the models specified, the data set gathered, and the estimation procedure followed in our analysis. In Section 3, we present and explain the empirical results. This is followed by an overview of the illegal fuel activity in Turkey along with the discussion of our estimated black market diesel and gasoline volume as well as the resulting tax losses incurred by the government. The conclusion section provides a brief summary and a review of policy implications and future research directions.

2. Empirical framework

2.1. Methodology

Our methodology is based on performing interval estimates by using fixed-width rolling windows in conjunction with the meboot data generation process (DGP). Meboot is a computation intensive technique for constructing simulated empirical probability density functions (EPDF) of various parameters or test statistic estimates in a time series framework. The process involves creating independent replications of a series by using the maximum entropy principle, which is used in Bayesian probability for avoiding unnecessary distributional assumptions under insufficient information. This is done by maximizing Shannon's information $H = E(-\ln f(x))$ subject to a mass-preserving and a mean-preserving constraint in order to construct a cumulative maximum entropy density $f(x)$, which is maximally noncommittal with regard to the missing information. This uniform density subsequently becomes the basis for creating the aforementioned independent replications, which have the property of satisfying the ergodic theorem, Doob's theorem, and the central limit theorem. Once a large number of such replications are created, the nonparametric bootstrap scheme is employed for constructing the numerical sampling distribution of a given parameter estimate without needing the standard distributional assumptions underlying the classical normal regression model (CNRM). In a large scale simulation study, Yalta (2015) appraises the small sample performance of meboot in estimating level relationships involving combinations of I(0) and I(1) variables. Using a total of 1470 experiments and 5.03×10^9 regressions, the author shows that the above procedure can give substantial asymptotic improvements in models and sample sizes similar to the ones used in this study. In addition, the method is found to be robust to serially dependent errors thanks to providing size distortions of less than 10% in the presence of first order autocorrelation as high as 0.8.[1]

Our approach provides several important advantages for the estimation of energy demand models. First and foremost, the simulation based confidence intervals provided by meboot help obtain tighter and more robust price and income elasticities. Second, the meboot interval estimates are valid under different forms of nonstationarity, including those that are difficult to determine such as multiple structural breaks or long memory. This in turn facilitates level specifications by obviating shape-destroying transformations such as differencing or detrending. It also avoids specification errors due to pretesting for unit roots or cointegration. Furthermore, because meboot is robust to serial correlation, it is more suitable for rolling windows estimation where the same

[1] The bootstrap literature is vast and a more detailed account is outside the scope of the present paper. For a discussion of the method of bootstrap from the perspective of economists, the reader is referred to Efron and Tibshirani (1993) and Davison and Hinkley (1997). To obtain more information regarding the meboot DGP, see Vinod (2006, 2008), Vinod and de Lacalle (2009), and Yalta (2015).