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Asymmetry in transport fuel demand: Evidence from household level data

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ABSTRACT

Models for gasoline demand for transportation activities generally assume that demand is perfectly reversible with respect to gasoline price (and income). The small literature which relaxes the reversibility assumption in gasoline demand argues technological fixation leads to this asymmetry and utilizes aggregate time-series model to find evidence in favour of asymmetry. In this research it is suggested that there could also be behavioural factors behind this asymmetric response, possibly due to the loss aversion nature of human beings as described in the prospect theory. For the first time, household level data was used to understand asymmetry in gasoline demand in response to changes in gasoline price and income. There was statistical evidence that gasoline price and income both can induce asymmetric changes in gasoline demand among households. Specifically, elasticity with respect to rising prices and falling income is larger than the elasticity with respect to falling prices and rising income respectively, which is consistent with loss aversion in gasoline purchase behaviour. There was also some evidence of heterogeneity in the asymmetric responses between urban and rural households. The results have implications for transport-related energy tax policies or subsidies, while the method can be applied directly for non-energy goods as well.

1. Introduction

Transportation is responsible for around one-fifth of total global energy consumption (Energy Information Administration, 2015). The sector is almost entirely dependent on petroleum fuel and as such provides a substantial challenge in addressing the energy trilemma goals (energy security, energy affordability and environmental sustainability). Within the transport sector, light duty vehicles are responsible for more than half of the total energy consumption. This is also the segment that is experiencing a large growth in the developing and emerging countries. Therefore energy use from the light duty vehicle segment remains high on the policy-makers' agenda and gasoline (or diesel) demand remains a key area of research interest.

Demand for transport fuels is possibly one of the most widely researched area in energy economics. Nearly all of this large literature assumes demand to be perfectly reversible, i.e. the demand responses to similar increases and decreases in prices are numerically equal. This view has been challenged in the 1990s by a number of researchers who suggested that gasoline and, to a larger extent, energy demand show substantial asymmetry during price rises and falls – specifically, demand falls faster during price rises, but does not recover as quickly during price reductions (Gately, 1992; Gately and Huntington, 2002; Dargay, 1992; Dargay and Gately, 1997; Sentenac-Chemin, 2012). Dargay and Gately (1997) argue that this asymmetry is due to asset or technology fixation – during price rises of the two oil shocks, people invested in more fuel efficient cars, which remained in use despite the subsequent price falls. Although no behavioural explanation was offered in this early literature, since Kahneman and Tversky's (1979) prospect

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theory came to light, it is now accepted that people value losses more than gains, which could also result in asymmetric responses to price and income changes. Therefore, it is likely that the asymmetric demand responses found in the previous transport energy literature were due to both asset fixation as well as behavioural reasons. This paper adds to the existing literature on demand for gasoline or transport fuel by asking three novel research questions: firstly, can asymmetry in gasoline demand be attributed to behavioural factors such as loss aversion, rather than only asset fixation, as hypothesized in previous literature. Secondly, can we use a new type of disaggregate household level data in order to understand asymmetric responses in gasoline demand, and if yes, what type of modelling approach can we suggest for using these types of data? Thirdly, are there any differences in the potential asymmetric responses between urban and rural households?

The paper is organized as follows. Section 2 reviews the relevant literature on imperfect reversibility in gasoline demand and its possible explanation through loss aversion. Section 3 presents the econometric method employed while Section 4 describes the data. Section 5 presents the results and Section 6 draws conclusions.

2. Review of the literature

Perfect reversibility of demand or symmetry in demand responses with respect to price means that demand reductions during an increase in prices will be fully compensated by demand increases during similar price falls (or vice versa), i.e. the elasticity of demand during price rises and price falls are equal. While such symmetry in responses forms the basis of classical demand and supply theory, there has been some evidence of asymmetric response in the supply side in the 1970s (e.g. Wolffram, 1971; Traill et al., 1978). In the energy and transport energy domain, there was a general observation in the 1990s that the sustained low gasoline prices after the two oil price shocks in the 1970s did not fully reverse the reduction in consumption caused by the price shocks. Dargay (1991) and Gately (1992) investigated the issue further and concluded that price asymmetry existed in the demand for transportation fuel in the US, UK, France and Germany. They argue that irreversible technology fixation, whereby people invest in fuel efficient technologies during a price rise but do not dispose of these when price falls, is responsible for the asymmetric response. This is the dominant view in the transportation energy literature as well, where behavioural attitudes or responses are not discussed.[1] Gately (1992) and Dargay (1992) also identified a second type of imperfect reversibility, known as hysteresis, which argues that the demand responses to price changes can be different on price history – more precisely, whether current price is above or below a previous maximum. Table 1 summarizes the major studies on imperfect reversibility of gasoline or transportation energy demand.

There is also a large body of literature which studies asymmetry in areas *outside* of transportation fuel demand. On the energy demand side, these include demand for petroleum products (Asali, 2011; Dargay and Gately, 1995; Broadstock et al., 2011), residential energy (Haas and Schipper, 1998), industrial energy (Adeyemi and Hunt, 2007), total energy (Dargay, 1992; Adeyemi et al., 2010). On the travel demand side, the examples include Gately (1992), Dargay (2001), Greene (2012) and Hymel and Small (2015) for car travel or Wadud (2014, 2015) for air travel; yet Frondel and Vance (2011) use household data to find travel demand in Germany was reversible with respect to prices. On the supply side, Wolffram (1971) and Traill et al. (1978) were the early research in agriculture economics, while recent applications include asymmetry in price transmission in the retail gasoline sector (Bacon, 1991; Borenstein et al., 1997). The econometric modelling approach remains the same in all of these studies: decomposition of the price variable into separate series of price rises and price falls in the model specification and utilization of primarily time-series (in some cases panel) information in a reduced form demand equation. Ryan and Plourde (2002) is the only study that employed a demand system framework instead of reduced form models for estimating asymmetric responses (but for non-transport oil demand). Nearly all of the studies use the variables (and their decomposition) at level, although the literature on asymmetric price transmission in the retail gasoline sector generally uses the variables in their first differenced and/or lagged differenced form (e.g. Borenstein et al., 1997) in order to tackle non-stationarity in long time-series data.

The role of technological changes or asset fixity raises some disagreement in the literature on asymmetric transport energy demand. Griffin and Schulman (2005) argue that once technological progress is included in the econometric model specification, then the evidence of asymmetry becomes weak; and as such, gasoline demand is reversible with respect to prices. Huntington (2006) for transport fuel and Adeyemi and Hunt (2007) for industrial energy find that the asymmetric specification is better than the symmetric specification combined with technological change as suggested by Griffin and Schulman (2005); yet Adeyemi et al. (2010) was inconclusive for aggregate energy demand. Given Dargay and Gately's (1997) explanation that the asymmetry in demand was 'caused' by technology fixation, the disagreement is possibly a result of the differences in the underlying definitions of asymmetric responses. Although Griffin and Schulman (2005) do not explicitly mention it, they appear to define asymmetry as the differences in 'behavioural' responses to positive and negative price changes after controlling for technical changes. On the other hand, not controlling for technological changes, as in most other studies, allows both 'behavioural' and 'technical' responses to be included in total asymmetric demand responses. The literature is further expanded to include an underlying stochastic trend to capture both technological changes and other exogenous policies, and still find asymmetry to be present in the UK for transport fuel (Broadstock et al., 2011). In these models the underlying trend could capture behavioural factors such as changes in taste (Hunt and Ninomiya, 2003).

The prospect theory by Kahneman and Tversky (1979) and Tversky and Kahneman (1991) offers another perspective to understanding the imperfectly reversible relationship of consumer demand with respect to some of the demand drivers. The three key elements of their theory are reference dependence, loss aversion, and diminishing sensitivity of the utility function. 'Reference

[1] Note that it is possible that the technology fixation results from the energy efficiency policies such as CAFE Standards in the United States rather than a response to price changes. However these researchers find asymmetric responses in countries where there were no such policies in place, too.