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Policy implications of considering pre-commitments in U.S. aggregate energy demand system[☆]

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ABSTRACT

Linear approximations of the Generalized Almost Ideal Demand System and Almost Ideal Demand System for U.S. energy are compared to contrast the explicit inclusion and exclusion of pre-committed consumption levels. Results indicate that pre-commitment levels, the quantity of a good that is consumed in the short run with little regard for price, helps to better explain energy demand in the U.S. compared to the system that does not explicitly consider pre-commitments. Policy implications are if pre-commitments are a legitimate assumption, larger price changes are necessary to achieve a given policy objective than if there are no pre-commitments.

1. Introduction

Energy commodities strongly influence the economies of industrialized nations. What makes these commodities unique are the capital and products that depend on them. Oil derivatives, for example, are virtually without substitutes in their roles, including powering and lubricating internal combustion engines. Own-price demand elasticities of energy commodities are expected to be highly inelastic. Such inelastic short run own-price elasticities are consistently found in the literature (Bohi and Zimmerman, 1984; Gately and Huntington, 2002; Krichene, 2002; Cooper, 2003; Labandeira et al., 2012). Inelastic own-price elasticities imply that price increases have little impact on quantity demanded in the short run. Inelastic elasticities arise because energy dependent capital is expensive and purchased in advance by industry and individuals to produce short-run levels of output. These elasticities, however, do not take into account the potential effect of pre-commitment to energy consumption.

Pre-commitments are defined as the quantities of goods that are consumed in the short run with little regard for price; demand is almost perfectly price inelastic. If individuals have committed to consume a given quantity of a commodity then a price change for that commodity will have little effect over that portion of the demand curve. Over the committed portion of demand, the commodity can be treated as non-discretionary with correspondingly inelastic price elasticity. Once pre-commitments have been satisfied price variations have a larger impact on quantity demanded. This portion of the demand curve can be thought of as discretionary.

Households make many decisions that commit them to energy use in the short run. In deciding where to live (location and size) and which automobile to purchase, a consumer is committing to energy consumption. House location and automobile type for a large part determines commuting costs to work. The household is committing to these costs to remain employed. A discretionary component of the demand for gasoline would be purchasing a tank of gas to go on vacation. Size of the house for a large part determines heating and cooling costs. Although a household may adjust temperature settings (discretionary component), most people have a minimum or maximum temperature they are willing to accept; they do not completely turn off the HVAC equipment (pre-commitment). Purchases of other energy using appliances (TVs, computers, stoves, etc.) also have some pre-commitment level associated with them based on their energy efficiency. Businesses make similar decisions that commit them to certain levels of energy use.

The demand for energy may be more accurately modeled by considering these pre-commitments. Relative to elasticity estimates that do not control for pre-commitment levels, estimated own-price elasticity estimates should be larger in absolute value (more elastic) by including pre-commitment levels. To understand this idea, assume demand can be broken into two components: pre-commitment level consumption (having elasticity near zero) and discretionary consump-

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[☆] This study reflects the work and views of the authors and does not necessarily reflect the views of their organizations.

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tion. Ignoring these two components during estimation would result in an elasticity measure that is a weighted average of the two components. A weighted average of both components misrepresents both components with an elasticity measure that is too large in the pre-commitment portion of the demand curve and too small for the discretionary portion. Ignoring pre-commitment levels will lead to an elasticity measure that is too inelastic. But, one must be careful on the interpretation and use of the estimated elasticities.

All elasticities (e.g. own and cross-price) estimated from a model with explicit consideration of pre-commitments only apply to the discretionary component of consumption and not the pre-commitment levels. Pre-commitment levels by assumption have elasticities equal to zero. In models not explicitly considering pre-commitment levels, the estimated elasticity applies to all consumption. With pre-commitment level scenarios, own-price elasticities are more elastic in the discretionary portion, but much less elastic near the pre-commitment level boundary (nearly perfectly inelastic). Raising the price of a nearly perfectly inelastic good does not do much to curtail quantity demanded. This difference in elasticities must be accounted for in policy analysis.

By modeling the energy system with pre-commitments, the effects of pre-commitments on the elasticities for these commodities can be obtained. Estimation of a system also allows energy commodity interdependencies to be examined, while taking into account error relationships across equations in the system. Specifically, the objective of this study is to examine how accounting for pre-commitment levels influences demand responses to price changes. To accomplish this objective, two systems of demands for oil, coal, and natural gas are estimated. The two systems, which are nested, are compared to examine explicit consideration of pre-commitments on elasticities values. The Generalized Almost Ideal Demand System (GAIDS), which endogenously estimates pre-commitment levels, is compared to the Almost Ideal Demand System (AIDS), which is nested in the GAIDS model and does not explicitly consider pre-commitment levels. By estimating both systems, this study addresses the gap in the literature of the lack of explicitly considering pre-commitments in energy demand studies and the potential ramifications of this omission.

2. Literature review

Models have been developed to quantify and predict energy demand. Although the specific approaches vary, the vast majority of models fall into the category of the lagged endogenous models, which model energy demand as a linear or log linear function of wealth and indexes of price and lagged prices (Dahl and Sterner, 1991). Current and lagged price structures allow for both short and long-run price elasticities to be estimated. In most cases, short run is the marginal effect of current price, while long run is the marginal effect of the lagged price. Dagher (2012) provides an excellent review of the literature focusing primarily on natural gas elasticities but intermixing results on electricity. She notes that only four studies on natural gas elasticities are found in the literature during 2000–2007, but almost 70 studies in each of the seventies and eighties decades.

Early reviews of energy demand literature include Taylor (1977), Bohi and Zimmerman (1984), and Dahl and Sterner (1991). One clear inference from these reviews is that estimated demand elasticities vary considerably from study to study. Dagher (2012) notes one must use consensus estimates from these reviews cautiously as often standard errors are not given. Taylor (1977) states own-price elasticities are around −0.15 in the short run, but more elastic in the long run being around −1. Bohi and Zimmerman (1984), for example, provide consensus estimates of short-run (long-run) own-price elasticities for residential natural gas of −0.1 (−0.5), but note elasticities are uncertain for commercial and industrial sectors.

Dahl and Sterner (1991) in their review of over 100 studies, find the average short-run, own-price elasticity of gasoline is −0.26 and the long-run, own-price elasticity is −0.86. Implications of these elasticities are that past prices have a larger impact on quantity demanded than the current price and that purchasing habits are slow to adjust to price changes. Dahl and Sterner (1991) note the studies surveyed take different approaches on seasonality. They find that there is a striking difference between the results obtained when seasonality is taken into account compared to annual measures. Dahl and Sterner (1991) conclude that seasonal data may be inappropriate because the results are unpredictable and lack robustness, especially in the long run.

Cooper (2003) uses a lagged endogenous model to independently model oil demand for 23 countries. U.S. own-price elasticity is found to be −0.06 in the short run and −0.45 in the long run. Krichene (2002) simultaneously estimated world demand models: one for oil and one for natural gas. In doing so, she is able to take advantage of the robustness and simplicity of the lagged endogenous model while accounting for interdependencies. She finds that short-run, own-price demand elasticities are −0.02 for oil and −0.01 for natural gas (both are non-significant) for the most recent period estimated (1973–1999). Krichene (2002, p. 567) states "…crude oil demand is highly price-inelastic in the short run, as energy consumption is essentially determined by fixed capital…" Lin (2011) estimates oil supply and demand simultaneously using monthly data, but decomposes prices and quantities into Organization of the Petroleum Exporting Countries (OPEC) and non-OPEC, yielding one of the most elastic measures for oil own-price elasticity of −0.95.

Substitution between fuel sources has also been examined. Blackorby and Russell (1989) indicate when there are two or more inputs, the Morishima elasticities are the correct measures of substitution. Energy sources in the U.S. being are generally found to be substitutes (Serletis et al., 2010, 2011; Serletis and Shahmoradi, 2008; Stern, 2012). Serletis and Shahmoradi (2008) examine the substitutability of coal, natural gas, and crude oil in the U.S. using the two semi-nonparametric forms, Fourier and asymptotically ideal demand models. Own-price elasticity estimates for the asymptotic and Fourier models are −0.64 and −0.25 for oil, −1.51 and −1.01 for natural gas, and −0.33 and −0.40 for coal. Income elasticities indicate all commodities are normal goods with natural gas being a luxury good. Their estimates of Morishima elasticities of substitution are generally less than one indicating a limited ability of the U.S. economy to substitute between energy commodities. Joutz et al. (2009) estimates for residential natural gas national own-price elasticities are less negative at −0.09 for the short run than for the long run at −0.18. U.S. regional short run own-price elasticities are estimated to range between −0.13 and 0.01 with long run elasticities being between −0.25 and −0.01.

Several studies have compared parametric to nonparametric models for energy demand (Zarnikau, 2003; Xiao et al., 2007; Karimu and Brannlund, 2013). Karimu and Brannlund (2013) argue that energy demand models relying on parametric models are less robust and more likely to be misspecified than nonparametric models. They argue most parametric models in energy demand are chosen for their computational convenience and ease of interpretation, not for their ability to explain underlying behaviors. Karimu and Brannlund (2013) reject the log-linear specification in favor of a nonparametric specification. The nonparametric model generates own-price elasticities of −0.18 to −0.19 for aggregate energy demand. Zarnikau (2003) found a non-parametric kernel estimator was superior to three common parametric specifications (linear, log-linear, and translog) in electricity consumption. Using the same data set and a different criterion, Xiao et al. (2007) found the translog and AIDS models outperformed the log-linear and linear, which is the opposite of the ranking found by Zarnikau (2003). Xiao et al. (2007, p. 166) conclude "These findings highlight what is already obvious to many energy economists, namely that model selection remains a very difficult task and different model selection criteria may steer one towards different model choices." Stern (2012, p. 326) in his meta-analysis concludes on the topic of interfuel substitution there