A Comprehensive Analysis of Household Transportation Expenditures Relative to Other Goods and Services: An Application to United States Consumer Expenditure Data

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July 2008

Abstract

Recent increases in fuel prices has heightened interest in examining the impact of rising vehicle operating expenses on household transportation expenditures, in relation to expenditures on other categories of consumption. Previous research has generally examined transportation-related expenditures in isolation or in relation to just one or two other categories of consumption due to complexities associated with attempting to analyze all categories of consumption simultaneously. This paper applies a multiple discrete continuous nested extreme value (MDCNEV) model to analyze household expenditures for transportation-related items in relation to a host of other consumption categories. The model system presented in this paper is capable of providing a comprehensive assessment of how household consumption patterns (including savings) would be impacted by increases in fuel prices or any other household expense. The MDCNEV model presented in this paper is estimated on disaggregate consumption data from the 2002 Consumer Expenditure Survey data of the United States. Model estimation results show that a host of household and personal socio-economic, demographic, and location variables affect the proportion of monetary resources that households allocate to various consumption categories. Sensitivity analysis conducted using the model demonstrates the applicability of the model for quantifying consumption adjustment patterns in response to rising fuel prices. It is found that households adjust their food consumption, vehicular purchases, and savings rates in the short run. In the long term, adjustments are also made to housing choices (expenses), calling for the need to ensure that fuel price effects are adequately reflected in integrated microsimulation models of land use and travel.

Keywords: consumer expenditure, transportation expenditure, fuel prices, vehicle operating expenses, multiple discrete continuous nested extreme value model, econometric modeling, evaluating impacts of fuel price increase

1. Introduction

The year 2008 is proving to be a defining moment in the history of transportation and is likely to be remembered as the year when the tide turned, particularly in the United States. Fuel prices rose to record levels shattering all previous records, including those set during the fuel crisis of the late 1970s and early 1980s. Transit agencies around the country are reporting significant increases in ridership (APTA, 2008), and for the first time since that fuel crisis, total vehicle miles of travel (VMT) showed a decline between 2007 and 2008 in the United States (FHWA, 2008). This measure of travel demand declined by a little over two percent, with the nation traveling 20 billion fewer vehicle miles through the first five months of 2008 in comparison to the same period in 2007 (FHWA, 2008). Fuel prices had been steadily rising since 2003, but it appears that the record set in 2008 at $4 per gallon has proved to be a tipping point where travelers started making adjustments to their travel behavior, resulting in the drop in VMT. Media reports describing adjustments that people are making in consumption patterns and activity-travel behavior in response to higher gas prices abound (MSNBC, 2008a, 2008b, 2008c, 2008d).

The higher fuel prices have had a dramatic impact on the automotive industry in the past several months. The big three automakers in the United States, who have relied heavily on the sales of large vehicles such as SUVs and trucks, have reported record losses of staggering figures in the past year (Austin, 2008). Toyota, which sells more fuel-efficient vehicles including the popular Prius gas-electric hybrid car in the United States, sold more vehicles than General Motors in the most recent quarter for which sales figures are available (Krisher, 2008). Households are clearly migrating to smaller and more fuel-efficient hybrid vehicles as they turnover their vehicle fleet in the household in response to the high price of fuel. In the United States, the rise in fuel prices has been simultaneously met with a slumping housing market and record housing foreclosure rates, resulting in households losing the equity that they thought they had built up in their homes. These economic forces have created the perfect storm requiring households to adjust their consumption patterns, activity-travel behavior, and expenditures for various commodities and goods. There is a growing concern, in particular, that high fuel prices are going to have an adverse impact on individual/household quality of life at the disaggregate level and on overall economic growth at the aggregate level in many countries around the world, including developing countries (Olvera *et al.*, 2008).

How do households respond when the price of fuel increases? How do household adapt their consumption patterns, in terms of the monetary expenditures allocated to various categories of goods and services? Household activity-travel patterns are closely related to household consumption patterns and monetary expenditures. When households engage in more consumption of goods and services outside the home (such as eating out, going to the movies, shopping), this directly leads to more activities and travel consistent with the behavioral paradigm that travel demand is a derived demand. Unfortunately, there has been very little work examining household expenditure patterns across the entire range of goods and services consumed by households and how these patterns change in response to price increases in the transportation sector. There is very little understanding of the types of trade-offs or adjustments that households would make in their consumption patterns. What are the short-term and long-term elasticities of consumption patterns in response to fuel price increases? In addition, there has been little work (other than some recent work by Anas, 2007) in the area of integrating activity-travel demand and monetary expenditures or consumption patterns in a unified framework. Given that dimensions of travel, consumption, and monetary expenditures are all closely inter-related, and major advances have been made in modeling complex inter-related phenomena, the time is ripe to move in the direction of developing integrated models of activity-travel demand and monetary expenditures of consumption. Before such integrated models can be developed, however, human consumption patterns and monetary expenditures for various goods and services need to be understood and modeled.

This paper presents a comprehensive analysis of consumer expenditures in the United States using disaggregate consumption data from the 2002 Consumer Expenditure Survey conducted by the Bureau of Labor Statistics (BLS). A multiple discrete continuous nested extreme value (MDCNEV) modeling methodology is employed in this paper to explicitly recognize that people choose to consume various goods and commodities in differing amounts. The methodology accommodates the possibility of zero consumption of certain commodities and the nesting structure in the model accounts for correlations between the stochastic terms of the utilities of different expenditure categories. The paper also provides estimates of short-term and long-term impacts on household consumption patterns in response to increases in fuel prices to show how the modeling methodology is suited to answering the types of questions raised in this introductory section of the paper. By considering a comprehensive set of expenditure categories, the model is able to provide a full picture of household adjustment patterns.

The paper starts with a brief discussion of this topic in the next section. Some key references that address transportation-related expenditures are identified and discussed to place this piece of work in the context of existing literature on the subject. The modeling methodology, data set, estimation results, and sensitivity analysis are then presented in the subsequent sections of the paper in that order. The final section offers concluding thoughts and directions for future research.

2. Understanding Transportation-Related Consumer Expenditures

The field of travel behavior has long recognized that travel demand is a derived demand, derived from the human desire and need to participate in activities and consume goods and services distributed in time and space (Jones, 1979; Jones *et al.*, 1993; Bhat and Koppelman, 1999; Pendyala and Goulias, 2002). While most travel demand models recognize this activity-based nature of travel demand, they ignore the consumption side of the enterprise, possibly due to the lack of data about and/or the inherent difficulty with modeling consumption patterns and the monetary expenditures associated with such patterns. A recent attempt by Anas (2007) to develop a unifying model of activities and travel and monetary expenditures is an exception and provides a framework for considering the integration of these concepts. As mentioned in the previous section, the rise in fuel prices has provided a major impetus to move in the direction of comprehensive modeling of activity-travel demand and human consumption and monetary expenditure patterns.

It is possible that much attention has not been paid to the expenditure side of the enterprise because the cost of transportation in many developed countries has been rather stable or even decreasing (on a per-mile basis) for many years. This has certainly been the case in the United States for nearly 30 years, since about the late 1970s. There is considerable research that has documented the relative inelasticity of demand to fuel price increases (Puller and Greening, 1999; Nicol, 2003; Hughes *et al.*, 2006; Bhat and Sen, 2006). This has been true in several other developed countries as well. For example, Moriarty (2002) analyzes data for Australia and several OECD countries and finds that the transport expenses share of household income has been fairly constant in recent decades at the aggregate level, although substantial variations do exist across demographic groups defined by income and regional location. The study also notes that, in developed countries, private motoring costs dominate total household transport expenses, coming in at about 80 percent of total household transportation expenditures. However, the trend of a constant transport expenditure share may not hold any longer. In fact, recent studies using Consumer Expenditure Survey data in the United States (Gicheva *et al.*, 2007; Cooper, 2005) has reiterated the notion of fuel price inelasticity by showing that household-level fuel expenditures increase in proportion to the increase in fuel prices. Based on this evidence, the recent sharp increase in fuel prices, coupled with the relative price inelasticity of behavior/demand, is likely to result in an increase in household fuel expenditures for transportation. For example, the Bureau of Labor Statistics in the United States reports that, between 2004 and 2005, household fuel expenditures for transportation increased by 26 percent, an amount that roughly coincides with the increase in fuel prices themselves. Such increases in fuel expenditures are likely to significantly decrease the disposable income available to households, which in turn may impact the overall consumption patterns for various goods and services as cost of living rises (Fetters and Writer, 2008). In addition, increases in fuel-related expenditures may result in reductions of household savings, unless the household specifically adjusts all other consumption patterns to compensate for the rise in fuel expenditures. Any changes in consumption patterns are likely to have an impact on activity-travel demand as well.

Given that transportation accounts for nearly 20 percent of total household expenses and 12-15 percent of total household income, it is no surprise that the study of transportation expenditures has been of much interest. In fact, the study of household expenditure patterns can be traced as far back as the middle of the 19th century (*e.g.*, Engel, 1857). Several early household expenditure studies did focus on transportation-related expenses to assess the proportion of income and total household expenditures that are related to transportation (*e.g.*, Prais and Houthakker, 1955; Oi and Shuldiner, 1962). Nicholson and Lim (1987) offer a review of several early studies of household transportation-related expenditures. More recently, there has been a surge in studies examining household transportation expenditures, at least partly motivated by the rising fuel prices around the world and the growing concern about modal access to destinations for poorer segments of society that may not have access to a personal automobile.

Recent work by Thakuriah and Liao (2005, 2006) has examined household transportation expenditures using 1999 and 2000 Consumer Expenditure Survey data in the United States. The first piece of work explores the impact of several factors on household vehicle ownership expenditures, including socio-economic characteristics and geographic region of residence in the country. They note that households with one or more vehicles spend, on average, 18 cents of every dollar on vehicles. In their second piece of work, they estimate Tobit models to understand the relationship between transportation expenditures (termed mobility investments) and ability to pay (measured by income). They find that there is a cyclical relationship between transportation expenditures and income. As income increases, transportation expenditures increase; as transportation expenditures increase, so does income – presumably because transportation expenditures facilitate access to distant jobs that offer higher income.

There has been some work examining transportation expenditures in relation to expenditures on another commodity or service. For example, Choo *et al.* (2007) examine whether transportation and telecommunications tend to be substitutes, complements, or neither. For this analysis, they examine consumer expenditures for transportation and telecommunications using the 1984-2002 Consumer Expenditure Survey data in the United States. They find that all income elasticities are positive, indicating that demand for both transportation and telecommunications increases with increasing income. Vehicle operating expenses (fuel, maintenance, and insurance) are relatively less elastic than entertainment travel and other transportation expenses to income fluctuations. Another study, by Sanchez *et al.* (2006), examines transportation expenditures in relation to housing expenditures. Noting that housing and transportation constitute the two largest shares of total household expenditures, they argued that these two commodities should be considered together as there is a potential trade-off between these expenditures. Indeed, there is a vast body of literature devoted to the traditional theory that households trade-off housing costs with transportation costs in choosing a residential location. Using cluster analysis techniques, they find that such a trade-off relationship does indeed exist and that these expenditures cannot be treated in isolation of one another. Gicheva *et al.* (2007) study the relationship between fuel prices, fuel-related expenditures, and grocery purchases by households. Using detailed Consumer Expenditure Survey data and scanner data from a large grocery chain on the west coast of the United States, they perform a statistical analysis to determine the extent to which rising fuel prices are affecting food purchasing and expenditures. They find that household fuel expenditures have gone up directly with rising fuel prices, and that households have adjusted food consumption patterns to compensate for this.

They find that expenditure on food-away-from-home (eat-out) reduces by about 45-50 percent for a 100 percent increase in fuel price. However, the savings on eating out are partially offset by increased grocery purchases for eating in-home. Within grocery purchases, they also find that consumers substitute regular shelf-priced products with special promotional items to take advantage of savings.

The three studies reviewed in the previous paragraph clearly indicate that transportation expenditures ought not to be studied in isolation as there are relationships in consumer expenditures across commodity categories. Unfortunately, there has been virtually no work that considers transportation expenditures in the context of consumer expenditures for the full range of commodities, goods, and services that households consume. In the present context of rising fuel prices, it is absolutely imperative that the profession adopt a holistic approach that considers transportation expenditures in the context of all other expenditures and household savings. This paper aims to accomplish this goal by developing and estimating a multiple discrete continuous nested extreme value (MDCNEV) model of household expenditures. The model can then be used to understand the trade-offs that households make in response to rising fuel prices, and quantify the short- and long-term price elasticities of demand.

3. Modeling Methodology

The methodology adopted in this paper uses a resource allocation modeling framework, in which the household income is apportioned among an extensive set of annual household expenditures, including housing, utilities, food, alcohol and tobacco products, clothing and apparel, personal care, household maintenance, entertainment, education, health care, business services, and a variety of transportation expenditures including vehicle purchases, vehicle insurance, fuel and motor oil, vehicle operating expenses, air travel, and public transportation. Along with these expenditure categories, the methodology accounts for household savings.

The MDCNEV modeling methodology used in this paper, formulated by Pinjari and Bhat (2008), is an extension of the original non-nested version called the multiple discrete continuous extreme value (MDCEV) model formulated by Bhat (2005, 2008). The MDCEV framework is a utility maximization-based resource allocation model, and is based on the assumption that households spend on different types of goods and services to satisfy needs and desires. This is achieved by incorporating diminishing marginal returns with increasing expenditure in each good/service to represent satiation effects. The model also allows for corner solutions in that households may choose not to spend on certain categories (*e.g.*, alcohol and tobacco products). The MDCNEV model extends the MDCEV modeling framework to incorporate unobserved interdependencies among various categories of goods and services. More specifically, the nested extreme value extension of the MDCEV model captures correlations between the stochastic utility terms of different expenditure categories. This section presents the model formulation; the discussion on the MDCEV model is drawn from Bhat (2005, 2008) and that of the MDCNEV model is drawn from Pinjari and Bhat (2008).

Consider the following additive non-linear functional form for utility (Bhat, 2008):

$$U(\boldsymbol{t}) = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k}\psi_k \left\{ \left(\frac{t_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right\};\ \psi_k > 0, \alpha_k \le 1, \gamma_k > 0 \quad (1)$$

In the above utility function, the total utility derived from the allocation process is assumed to be the sum of sub-utilities derived from the proportions allocated to each alternative *k*. Specifically, $U(\boldsymbol{t})$ is the total utility derived from allocating a non-negative amount t_k of the total budget to each consumption (or expenditure) category (or alternative) *k*, including savings[1]; and ψ_k, α_k and γ_k are the parameters associated with alternative *k*, each of which is discussed below.

The term ψ_k in the above utility function corresponds to the marginal random utility of one unit of consumption of alternative k at the point of zero consumption for the alternative (as can be observed from computing $\partial U(\boldsymbol{t})/\partial t_k \,|_{t_k=0}$, which is equal to ψ_k). ψ_k controls the discrete choice consumption (or not) decision for alternative *k*. Thus, this term is referred to as the baseline preference parameter for alternative *k*. The reader will note here that along with the discrete choice decision, ψ_k also controls the continuous choice decision (how much to consume) for alternative *k* (as can be observed from the presence of ψ_k in the expression for the marginal utility of consumption for non-zero consumption: $\partial U(\boldsymbol{t})/\partial t_k \,|_{t_k>0}$).

To complete the baseline parameter specification, the baseline parameters are expressed as functions of observed and unobserved attributes of alternatives and decision-makers as below:

[1] The terms "consumption" and "expenditure" are used interchangeably in this paper, as are the terms "category" and "alternative".

$$\psi(z_k, \varepsilon_k) = \exp(\beta' z_k + \varepsilon_k) \tag{2}$$

In the above expression, the observed attributes are specified through the vector z_k of attributes characterizing alternative k and the decision-maker.[2] The unobserved attributes are (or the stochasticity is) introduced through a multiplicative random term ε_k that captures unobserved (to the analyst) characteristics affecting ψ_k.

The role of α_k is to reduce the marginal utility with increasing consumption of alternative *k*; that is, it represents a satiation (or non-linearity) parameter. When α_k = 1 for all *k*, this represents the case of absence of satiation effects or, equivalently, the case of constant marginal utility. As α_k moves downward from the value of 1, the satiation effect (or the diminishing marginal utility effect) for alternative *k* increases. When $\alpha_k \to 0$, the subutility function for alternative *k* collapses to $U_k = \gamma_k \psi_k \ln\left(\frac{x_k}{\gamma_k} + 1\right)$. α_k can also take negative values and, when $\alpha_k \to -\infty$, this implies immediate and full satiation (*i.e.*, infinite decrease in the marginal utility).

The term γ_k (γ_k >0) is a translation parameter that serves to allow corner solutions (zero consumption) for alternative *k*. However, it also serves as a satiation (or non-linearity) parameter capturing diminishing marginal utility with increasing consumption. Values of γ_k closer to zero imply higher rate of diminishing marginal utility (or lower consumption) for a given level of baseline preference. For alternatives that are always consumed by all decision-makers in the data (such as, housing, utilities, and food) there is no discrete choice. Thus γ_k is not applicable for such alternatives and the sub-utility for such alternatives becomes $U_k = \frac{1}{\alpha_k} \psi_k t_k^{\alpha_k}$.

Having discussed the functional form of the utility structure and the role of each parameter in the utility function, the budget allocation problem may now be formulated. From the analyst's perspective, the household maximizes the random utility subject to a linear budget constraint and non-negativity constraints on t_k:

[2] For notational simplicity, a subscript for decision-makers (or households) is not included. The coefficient vector β captures the impact of z_k on the baseline utility.

$$\sum_{k=1}^{K} t_k = T \text{ (where } T \text{ is the total budget) and } t_k \geq 0 \ \forall\ k \ (k = 1,2,...,K) \tag{3}$$

The analyst can solve for the optimal consumption pattern by forming the following Lagrangian and applying the Kuhn-Tucker (KT) conditions:

$$L = \sum_k \frac{\gamma_k}{\alpha_k} \left[\exp(\beta' z_k + \varepsilon_k)\right] \left\{ \left(\frac{t_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right\} - \lambda \left[\sum_{k=1}^{K} t_k - T \right], \tag{4}$$

where λ is the Lagrangian multiplier associated with the budget constraint. The KT first-order conditions for the optimal consumptions $(t_k^*; k = 1,2,...,K)$ are given by:

$$\exp(\beta' z_k + \varepsilon_k) \left(\frac{t_k^*}{\gamma_k} + 1 \right)^{\alpha_k - 1} - \lambda = 0 \text{, if } t_k^* > 0, \ (k = 1, 2, \ldots, K) \tag{5}$$

$$\exp(\beta' z_k + \varepsilon_k) \left(\frac{t_k^*}{\gamma_k} + 1 \right)^{\alpha_k - 1} - \lambda < 0 \text{, if } t_k^* = 0, \ (k = 1, 2, \ldots, K)$$

Now, without any loss of generality, let the first alternative be an alternative to which the individual allocates some non-zero amount of consumption. For this alternative, the KT condition may be written as:

$$\lambda = \exp(\beta' z_1 + \varepsilon_1) \left(\frac{t_1^*}{\gamma_1} + 1 \right)^{\alpha_1 - 1} \tag{6}$$

Substituting for λ from above into Equation (5) for the other alternatives (k = 2,…, K), and taking logarithms, one can rewrite the KT conditions as:

$$V_k + \varepsilon_k = V_1 + \varepsilon_1 \text{ if } t_k^* > 0, \ (k = 2, 3, \ldots, K)$$

$$V_k + \varepsilon_k < V_1 + \varepsilon_1 \text{ if } t_k^* = 0, \ (k = 2, 3, \ldots, K) \tag{7}$$

where, $V_k = \beta' z_k + (\alpha_k - 1) \ln \left(\frac{t_k^*}{\gamma_k} + 1 \right)$, ($k$ = 1, 2, 3,…, K).

The stochastic KT conditions of Equation (7) can be used to write the joint probability expression of expenditure allocation patterns (*i.e.*, the consumption patterns) if the density function of the stochastic terms (*i.e.*, the ε_k terms) is known. In the general case, let the joint probability density function of the ε_k terms be $g(\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_K)$, and let M alternatives be chosen out of the available K alternatives, and that the consumption amounts of the M

alternatives be $(t_1^*,\ t_2^*,\ t_3^*,\ ...,\ t_M^*)$. As given in Bhat (2008), the joint probability expression for this consumption pattern is as follows:

$$P(t_1^*,\ t_2^*,\ t_3^*,\ ...,\ t_M^*,\ 0,\ 0,\ ...,\ 0) = \ |J| \int_{\varepsilon_1=-\infty}^{+\infty} \int_{\varepsilon_{M+1}=-\infty}^{V_1-V_{M+1}+\varepsilon_1} \int_{\varepsilon_{M+2}=-\infty}^{V_1-V_{M+2}+\varepsilon_1} \cdots \int_{\varepsilon_{K-1}=-\infty}^{V_1-V_{K-1}+\varepsilon_1} \int_{\varepsilon_K=-\infty}^{V_1-V_K+\varepsilon_1}$$

$$g(\varepsilon_1,\ V_1-V_2+\varepsilon_1,\ V_1-V_3+\varepsilon_1,\ ...,\ V_1-V_M+\varepsilon_1,\ \varepsilon_{M+1},\ \varepsilon_{M+2},\ ...,\ \varepsilon_{K-1},\ \varepsilon_K) \quad (8)$$

$$d\varepsilon_K d\varepsilon_{K-1} ... d\varepsilon_{M+2} d\varepsilon_{M+1} d\varepsilon_1 \ ,$$

where J is the Jacobian whose elements are given by (see Bhat, 2005) $J_{ih} = \frac{\partial[V_1 - V_{i+1} + \varepsilon_1]}{\partial t_{h+1}^*} = \frac{\partial[V_1 - V_{i+1}]}{\partial t_{h+1}^*};\ i, h = 1, 2, \ldots, M-1.$

In the probability expression above, the specification of $g(\varepsilon_1,\ \varepsilon_2,\ \ldots,\ \varepsilon_K)$ (*i.e.*, the error term structure) determines the form of the consumption probability expressions. To derive the MDCNEV probability expressions, Pinjari and Bhat (2008) used a nested extreme value distributed structure that has the following joint cumulative distribution:

$$F(\varepsilon_1, \varepsilon_2, .., \varepsilon_K) = \exp\left[-\sum_{\text{ð}=1}^{S_K}\left\{\sum_{i\in \text{ð}^{\text{th}}\text{nest}} \exp\left(-\frac{\varepsilon_i}{\theta_{\text{ð}}}\right)\right\}^{\theta_{\text{ð}}}\right] \quad (9)$$

In the above expression, $\text{ð}(=1,2,...,S_K)$ is the index to represent a nest of alternatives, S_K is the total number of nests the K alternatives belong to, and $\theta_{\text{ð}}(0 < \theta_{\text{ð}} \le 1; \text{ð} = 1,2,...,S_K)$ is the (dis)similarity parameter introduced to induce correlations among the stochastic components of the utilities of alternatives belonging to the ð^{th} nest.[3]

Without loss of generality, let $1,2,...,S_M$ be the nests the M chosen alternatives belong to, let $q_1, q_2, ..., q_{S_M}$ be the number of chosen alternatives in each of the S_M nests (hence $q_1 + q_2 + ... + q_{S_M} = M$). Using the nested extreme value error distribution assumption specified in Equation (9) (and the above-identified notation), Pinjari and Bhat (2008) derived that the expression in Equation (8) simplifies to the following probability expressions for the MDCNEV model:

[3] This error structure assumes that the nests are mutually exclusive and exhaustive (*i.e.*, each alternative can belong to only one nest and all alternatives are allocated to one of the S_K nests).

$$P(t_1^*, t_2^*, ... t_M^*,\ 0,...,0) =$$

$$|J| \frac{\prod\limits_{i \in \{\text{chosen alts}\}} e^{\frac{V_i}{\theta_i}}}{\prod\limits_{\mathfrak{s}=1}^{S_M} \left(\sum\limits_{i \in \mathfrak{s}^{\text{th}}\text{nest}} e^{\frac{V_i}{\theta_{\mathfrak{s}}}} \right)^{q_{\mathfrak{s}}}} \sum_{r_1=1}^{q_1} \cdots \sum_{r_{\mathfrak{s}}=1}^{q_{\mathfrak{s}}} \cdots \sum_{r_{S_M}=1}^{q_{S_M}} \left\{ \prod_{\mathfrak{s}=1}^{S_M} \left[\frac{\left(\sum\limits_{i \in \mathfrak{s}^{\text{th}}\text{nest}} e^{\frac{V_i}{\theta_{\mathfrak{s}}}} \right)^{\theta_{\mathfrak{s}}}}{\sum\limits_{\mathfrak{s}=1}^{S_k} \left\{ \left(\sum\limits_{i \in \mathfrak{s}^{\text{th}}\text{nest}} e^{\frac{V_i}{\theta_{\mathfrak{s}}}} \right)^{\theta_{\mathfrak{s}}} \right\}} \right]^{q_{\mathfrak{s}} - r_{\mathfrak{s}} + 1} \left(\prod_{\mathfrak{s}=1}^{S_M} sum(X_{r\mathfrak{s}}) \right) \left(\sum_{\mathfrak{s}=1}^{S_M} (q_{\mathfrak{s}} - r_{\mathfrak{s}} + 1) - 1 \right)! \right\} \quad (10)$$

In the above expression, $sum(X_{r\mathfrak{s}})$ is the sum of elements of a row matrix $X_{r\mathfrak{s}}$ (see Appendix A for a description of the form of the matrix $X_{r\mathfrak{s}}$).

As indicated in Pinjari and Bhat (2008), the general expression above represents the MDCNEV consumption probability for any consumption pattern with a two-level nested extreme value error structure. This expression can be used in the log-likelihood formation and subsequent maximum likelihood estimation of the parameters for any dataset with mutually exclusive groups (or nests) of interdependent alternatives (*i.e.*, mutually exclusive groups of alternatives with correlated utilities) and multiple discrete-continuous choice outcomes. Further, it may be verified that the MDCNEV probability expression in Equation (10) simplifies to Bhat's (2008) MDCEV probability expression when each of the utility functions are independent of one another (*i.e.*, when $\theta_{\mathfrak{s}} = 1$ and $q_{\mathfrak{s}} = 1\ \forall \mathfrak{s}$, and $S_M = M$).

4. Data Description

The source of data used for this analysis is the 2002 Consumer Expenditure (CEX) Survey (BLS, 2004). The CEX survey is a national level survey conducted by the US Census Bureau for the Bureau of Labor Statistics (BLS, 2003). This survey has been carried out regularly since 1980 and is designed to collect information on incomes and expenditures/buying habits of consumers in the United States. In addition, information on individual and household socio-economic, demographic, employment, and vehicle characteristics is also collected. The survey program consists of two different surveys – the Interview Survey and the Diary Survey (BLS, 2001). The Diary Survey is a self-administered instrument that captures information on all purchases made by a consumer over a two-week period. The Diary allows respondents to record all frequently made small-scale purchases. The Interview Survey is conducted on a rotating panel basis administered over five quarters and collects data on quarterly expenditures on larger-cost items, in addition to all expenditures that occur on a regular basis. Each component of the CEX survey queries an independent sample of consumer units which is representative of the US population. For this analysis, the 2002 Interview Survey data available at the National Bureau of Economic Research (NBER, 2003) archive of Consumer Expenditure Survey microdata extracts was used.

NBER processes the original CEX survey data of BLS to consolidate hundreds of expenditure, income, and wealth items into 109 distinct categories (Harris and Sabelhaus, 2000). These microdata extracts are provided at the NBER website in two different files – a family file that contains household level income, expenditure, and basic household demographics, and a member file that contains additional demographic information on each household member. In order to facilitate the analysis and modeling effort of this paper, the data was further processed in the following manner:

1. Different family files containing the annual expenditures were merged to form an annual expenditures file for the year 2002.
2. The annual family file was integrated with the member file to form a single file including both individual and household level information.
3. Only households with complete information on all four quarters were extracted and selected for analysis. Other screening and consistency checks were applied as well.
4. The 109 categories of expenditure and income were further consolidated. Appropriate groups were aggregated to calculate net household annual income (after taxes), and form 17 broad categories of annual expenditure. The first column of Table 1 provides the list of all aggregate expenditure categories, and the subcategories within these expenditure categories.
5. An annual household savings variable was computed by subtracting total annual expenditure from the total net annual income. If savings were negative (which is possible when households go into debt on their credit cards, for example), then the savings variable was recoded to zero.
6. A budget variable was created by adding expenditures across all 17 expenditure categories and savings. If the income is greater than the sum of expenditures (*i.e.*, for households with positive savings), the budget is equal to the income; otherwise, the budget is equal to the sum of expenditures (as there is no savings).

7. All expenditures and savings were converted into proportions (or percentages) of the budget variable.

The final sample for analysis includes 4084 households with the information identified above. Descriptive statistics for expenditures on the 17 categories are furnished in Table 1 for this sample of households. It is found that all households incurred expenditures for housing, utilities, and food. Housing expenditures account for about 19 percent of income across all households, while food accounts for about 13 percent (see figures in parenthesis under the column "for all HHs" within the main "Average Household Expenditure ($/yr)" column). For all other categories, at least some households did not allocate any expenditure at all. More than 90 percent of households incur expenditures in each of the clothing, personal care, household maintenance, health care, business services, and entertainment and recreation categories. About three-quarters of the households incurred expenditures for alcohol and tobacco products while a lower 65 percent of households spent resources on education.

With regard to transportation-related expenses, the categories are maintained at a detailed disaggregate level to facilitate an understanding of relative expenditures for transportation related items. About one-quarter of the sample reports expenditures on vehicle acquisition. More than 90 percent of sample incurs expenditures on fuel and motor oil and vehicle operating and maintenance expenses. About 80 percent of the sample has vehicle-insurance related expenses, suggesting that a sizeable number of households operate motor vehicles with no insurance or have insurance costs paid for them (possibly by an employer or self-employed business). About one-third of the sample reports spending money on public transportation and air travel. All together, expenditures on transportation-related items account for about 15 percent of household income, a figure that is quite consistent with reported national figures.

Only about 63 percent of the households report savings of greater than zero. All other households report savings of zero or less; all negative values were recoded to zero. It is possible that some households have assets that are not sources of regular income and therefore not captured in this survey. Some households may have large lump-sum payments in a given year, for example, in the context of a large down payment for a housing purchase or a car purchase. In such years, savings may be less than or equal to zero for these households. Finally, households in the lower income brackets may not be able to save as they live paycheck-to-paycheck. A more detailed analysis of the data showed that many households in the zero savings category did indeed fall into the lower income brackets. By recoding the savings as zero and retaining these households in the sample, issues of sample selection bias are avoided in this paper.

The MDCNEV formulation adopted in this paper is supported by the information in the last column of the table where it is found that no household consumes just one single category beyond housing/food/utilities. All households consume at least two additional categories beyond these three essential items, which are consumed by every household. The MDCNEV model is able to account for such multiple category consumption patterns, where households spend resources on several categories and no resources on others. The MDCNEV model is able to do this without having to deal with sample selection or zero-inflation data issues. Moreover, the MDCNEV model is based on the theory of random utility maximization, which is a theoretical framework embodying much of discrete choice modeling in the field of transportation and consumer demand.

5. Model Estimation Results

The MDCNEV model was estimated by normalizing the expenditures in each category by the total budget, so that the endogenous allocations to individual categories are in the form of percentages. Explanatory variables in the model included household socio-economics, personal demographics, and residential and regional location variables. Non-linear effects of vehicle ownership were captured, either by introducing dummy variables for different car ownership levels or by using a spline specification for multi-car households. These variables will be described later in the context of the discussion of the model estimation results.

Model estimation results are presented in Table 2. The baseline preference constants in the first row are introduced with the housing category as the base category (*i.e.*, the housing category is introduced with an effective coefficient of zero). These constants do not have any substantive interpretations, and simply capture generic tendencies to spend in each category as well as accommodate the range of the continuous variables in the model. However, all baseline preference constants, except the one for food, are negative, indicating the much higher percentage (100%) of individuals spending a non-zero amount of their budget on housing relative to other categories.

All satiation parameters (α_k) are fixed to zero in this model estimation effort to facilitate the estimation process. Several different model specifications were tried and the specification where all satiation parameters were set to zero yielded the most intuitive results with the best goodness-of-fit (see Bhat, 2008 for empirical identification constraints that generally need to be imposed when the satiation and translation parameters are both considered). The translation parameters (γ_k) presented in the third row capture the variation in the extent of non-linearity (or the extent of decrease in marginal utility) across different expenditure categories. Thus, these parameters account for diminishing marginal returns or satiation effects in consumption of various categories. These parameters also facilitate zero consumption on multiple categories (corner solutions). There are no translation parameters for the housing, utilities, and food categories because these items are consumed by all households. For all other expenditure categories, as the magnitude of γ_k increases, the rate of decrease in the marginal utility (*i.e.*, satiation effects) decreases and the proportion of spending increases. All of the parameters are statistically significant, indicating that there are zero consumption patterns and satiation effects for all categories. The value is highest for the vehicle purchase and savings categories, indicating that households are likely to allocate a large proportion of their budget to acquiring a vehicle and to savings, if they expend any money in these categories. The lowest value is for personal care, education, and public transportation, suggesting that the lowest proportion of money is allocated to these categories and satiation is reached very quickly for most households in these categories. These findings are all consistent with the descriptive statistics in Table 1.

The coefficients associated with an array of explanatory variables are provided in the next several rows of the table. If there are no coefficients corresponding to a variable for certain expenditure categories, it implies that these categories constitute the base expenditure categories off which the coefficients on that variable for other categories need to be interpreted. Thus, a positive (negative) coefficient for a certain variable-category combination means that an increase in the explanatory variable increases (decreases) the likelihood of budget being allocated to that expenditure category relative to the base expenditure categories. For example, as household size increases, the proportion of total budget expended on utilities and food increases relative to other categories, while the proportion expended on housing decreases. It is possible that, as household size increases, income increases as well; as such, even though households do not allocate less absolute dollar amounts to housing, the proportion of income accounted for by housing decreases, contributing to this negative coefficient. The presence of children contributes to higher proportions of income allocated to housing, clothing, education, and vehicle purchases, but lower proportions allocated to alcohol/tobacco and savings. As the number of workers increases, so does the proportion allocated to numerous categories including alcohol/tobacco, clothing, education, vehicle purchases, other transportation expenses, and savings. All of these findings are consistent with expectations as higher proportions of resources need to be allocated to several categories to raise children or support multi-worker households. Higher income groups tend to spend a lower proportion of their resources on numerous expenditure categories including, for example, utilities, food, personal care, health care, and transportation. Indeed, as the budget available goes up, one would expect the proportions allocated to these items to go down, and this is corroborated by the negative coefficients. The exception is air travel, where the proportion allocated to air travel goes up with income. Also, the middle income group spends a higher proportion on vehicle purchases, possibly due to the cost of a vehicle constituting a large proportion of their income.

Multicar households tend to allocate a greater proportion of their income to vehicle purchases, presumably to add more vehicles or replace existing ones, as evidenced by the positive coefficients associated with two- and three-car households. As expected, these households also allocate higher proportions of income to fuel and motor oil. The continuous variable representing the number of vehicles positively impacts the proportion of expenditure for vehicle insurance and vehicle operation and maintenance, and reduces the proportion allocated to public transportation. However, there are non-linear effects of car ownership on proportions allocated to these expenditure categories. Non-linear effects of car ownership were captured by introducing two variables defined as follows:

For households with two or more vehicles,

NCar2 = Max {0, number of vehicles in household – 1}.

For households with three or more vehicles,

NCar3 = Max {0, number of vehicles in household – 2}.

These variables are found to have negative coefficients associated with them for vehicle insurance and vehicle operation and maintenance. This means that the rate of increase in proportion of income allocated to these categories (as vehicle ownership increases) decreases as the number of vehicles owned by a household goes beyond two. Also, as the number of vehicles goes beyond two, household savings appear to constitute a smaller percentage of income.

Home owners tend to spend a smaller proportion on housing, food, alcohol/tobacco, clothing, and public transportation, but a higher proportion for utilities and household maintenance. These findings are consistent with the notion that home owners are, on average, higher income than home renters, but home maintenance can prove expensive. Similarly, the negative coefficient on the savings variable does not necessarily mean that home owners save less; it simply means that the proportion of their income (which is higher than that for renters) allocated to savings is lower.

Virtually all of the other findings are consistent with expectations. Also, the remaining variables do not have a significant impact on vehicle acquisition or maintenance/operation related expenditure percentages. As such, the remaining findings are noted only briefly. In comparison to Caucasians, other ethnic groups spend a lower proportion on alcohol/tobacco and entertainment and recreation, but spend a higher proportion for public transportation. These findings suggest that there are differences across ethnic groups with respect to income, transportation expenditures, and use of transportation modes. Males allocate a larger proportion to alcohol/tobacco, but less to clothing and education. Those who are younger allocate higher proportions to housing, alcohol/tobacco, entertainment, and education, but lower proportions to health care and business services and welfare activities. Higher education is associated with greater allocation of resources to education and business services. Those who are married allocate higher proportions to health care and business services, but lower proportions to alcohol and tobacco (presumably due to family influence). Those who are widowed/separated/divorced allocate lower proportion to clothing, but higher proportion to health care, presumably because these individuals are either elderly or seek counseling.

Those in urban areas allocate higher proportion of income to housing, reflecting the higher prices of housing in urban areas. They also spend higher proportions on public transportation, once again reflecting the urban area effect. Several regional differences are also noted with those in the Northeast spending higher proportions of income on housing, clothing, entertainment, and public transportation (relative to those in the South). Midwesterners spend higher proportions for household maintenance and education as well. Those in the West not only spend higher proportions for all of these aforementioned categories, but also for air travel. On the other hand, they spend smaller proportion for utilities and for savings. In general, these findings reflect regional differences in housing prices, income levels, and prices of goods and services (BLS, 1998).

Several configurations for nests among different alternatives were considered and estimated, and later refined based on intuitive and statistical considerations. The final specification includes four nests:

1. Housing, utilities, household maintenance, and business services and welfare activities
2. Food, alcohol/tobacco products, and entertainment and recreation
3. Clothing and apparel, and personal care
4. New/used vehicle purchase, fuel and motor oil, vehicle insurance, and vehicle operation and maintenance.

The nesting parameters are shown in Table 2; all of the parameters are significantly greater than zero and less than one, suggesting that the nesting structure adopted here is appropriate for modeling household consumption patterns for multiple categories. This means that there is a high degree of correlation among alternatives within individual nests. This is quite reasonable as there may be several common unobserved factors that could affect all alternatives within a nest. Households that are "home-oriented" may allocate higher proportions of income to all categories in the first nest, those that are "out-of-home oriented" may allocate higher proportions to all categories in the second nest, those that are "personal appearance oriented" may allocate higher proportions to all categories in the third nest, and those that are "driving-oriented" may allocate higher proportions to the fourth nest categories. These personal and household orientations or proclivities/attitudes may constitute unobserved factors that simultaneously impact household percent expenditures on categories within individual nests.

The log-likelihood value for the MDCEV model with only the constants and satiation/translation parameters is -150620. The corresponding value at convergence for the fully specified MDCEV model is -146552.7 and that for the fully specified MDCNEV model is -142821.6 (for four additional parameters corresponding to the four nests). The likelihood ratio test statistic comparing the MDCEV and MDCNEV is 7462.3, which is much higher than the critical χ^2 value with four restrictions at any level of significance. This suggests that the MDCEV model form may be rejected in favor of the MDCNEV model adopted in this paper.

6. Sensitivity Analysis

The model presented in this paper can be used to analyze how households adjust their consumption patterns in response to increases in expenditures in one or more of the 17 expenditure categories considered in the paper. In the context of the current fuel price increase, such sensitivity analysis can shed light on how households respond and adjust to rising expenditures on fuel and motor oil.

Between 2003 and 2008, fuel prices in the United States have more than doubled. In order to test the impact of such a fuel price increase on consumption patterns, it is assumed that household fuel and motor oil expenditures double while household incomes remain constant. This is a reasonable assumption in light of findings reported in several studies in the literature (reviewed earlier in this paper) suggesting that fuel demand is highly price inelastic. Such an increase in fuel and motor oil expenditures is likely to significantly decrease the disposable income available to households, which in turn may impact overall consumption and savings patterns. Results of the sensitivity analysis conducted in this study are consistent with this conjecture and offer quantitative estimates of the adjustments that would occur as a result of the change in proportion of income allocated to the fuel and motor oil category of expenditure.

Policy simulations were carried out in this study for two different scenarios, a short-term scenario and a long-term scenario. For both scenarios, the total budget (or total annual income) was assumed constant and to remain the same, while the fuel expenditures were assumed to double. For example, if a household's expenditure on fuel was 5 percent of its total budget (or income) in the base case, it was increased to 10 percent in the policy scenario. Subsequently, the model estimates were used to apportion the remaining 90 percent of available budget among the remaining expenditure categories and savings. For the short-term scenario, however, several fixed or long-term expenditures were assumed to remain constant and unaffected by rising fuel prices. These categories included housing, utilities, education, health care, and vehicle insurance. Expenditure allocations could change only for the other categories. For the long-term scenario, no expenditure category was assumed to be fixed in value.

Policy scenario simulation results are shown in Table 3. The average increase in terms of percentage points (*i.e.*, the increase in the percentage of total budget allocated to fuel expenditures after doubling each individual's fuel expenditure, averaged across all individuals) is 2.95. The percent values shown in the table are average percent values predicted by the model for both the base case and policy scenario (where fuel prices double), while the difference of these two provides the average drop in percentage points for the various non-fuel expenditure categories (the sum of these drops across the different non-fuel expenditure categories is -2.95). As expected, the table shows that adjustments are made across the board, even in the short-term. The two largest adjustments are made in savings and food expenditures. Savings take a hit as households have to spend more resources for fuel. Next food consumption takes a hit as households tend to eat-out less often and purchase less expensive or promotional items from the grocery store for their meals at home. These findings are consistent with several reports (Peterson, 2006; Gicheva *et al.*, 2007) and anecdotal evidence and poll data reported recently in the media (Linn, 2008; MSNBC, 2008b, 2008d). The next category most affected is that of vehicle purchases, another finding that is consistent with recent reports of lagging sales of vehicles for virtually all automobile manufacturers (MSNBC, 2008a). It is very possible that households are postponing vehicle purchases or buying a cheaper/smaller car in response to rising fuel prices, even in the short term. Other categories that take a hit include discretionary spending items such as entertainment and recreation, clothing and apparel, and alcohol and tobacco products. It is interesting to note that vehicle operating and maintenance expense category also shows an adjustment. This may be due to households choosing to use regular grade fuel (as opposed to premium fuels), traveling fewer vehicle miles, and servicing their vehicle less frequently (*e.g.*, having an oil change done every 5000 miles instead of 3000 miles). Finally, household maintenance projects also seem to be potentially postponed as households grapple with the increase in fuel price.

The long-term shifts in expenditure patterns generally mirror the patterns seen in the short term, except that one can clearly see the longer-term dynamics that may occur. Besides savings, food, and vehicle purchases (which experienced the largest shifts in the short-term as well), housing and utilities show major adjustments in percent expenditures. The drop in percentage points allocated to housing is 0.50 while that for utilities is 0.28. These findings suggest that, in the longer term, households may shift to less expensive housing, smaller housing (where utility costs would be lower), and potentially, housing that is closer to destination and job opportunities. The lower percent for vehicle operating and maintenance costs is also indicative of this. It is interesting to note that there is no appreciable shift in share of expenditure for public transportation, suggesting that individuals would first make adjustments elsewhere before they shift to public transportation in any significant way. This is a very critical finding with key implications for the transit industry. Although there are likely to be minor shifts to transit in response to higher fuel prices, it is likely that these shifts will be largely inconsequential even in the long run, unless transit services are dramatically improved. Households will cut back on everything from housing to discretionary recreation and travel so that they can absorb the higher percent of income that they must allocate to fuel. This is consistent with the recent finding that the elasticity of vehicular travel to fuel prices appears to be about -0.1. Between 2007 and 2008, fuel price has increased by about 20 percent while the vehicle miles of travel has reduced about 2 percent (FHWA, 2008). In other words, even a doubling (100 percent) of fuel price will bring about only a 10 percent decrease in vehicle miles of travel. Thus, it is clear that households are making a range of adjustments across various expenditure categories to accommodate the fuel price increase and maintain a largely steady level of vehicular travel (Pendyala, 2008). On the other hand, many of these adjustments (such as less entertainment and recreation, food consumption, and vehicle purchases) suggest that rising fuel prices can have substantial effects on the economy as people decrease their discretionary activity engagement and goods consumption. In turn, these behavioral adjustments will have effects on spatial distribution of population and employment, and on activity-travel patterns and demand, that need to be reflected in integrated activity-based microsimulation models of land use and travel.

7. Conclusions

Rising fuel prices has the profession concerned for a number of reasons. First, higher fuel prices could lead to lower levels of vehicular travel which, in turn, may lead to lower fuel tax revenues that are often the sole source of funding for infrastructure projects. Until revenue streams and sources adjust in response to these changes, infrastructure projects that counted on a certain level of fuel tax revenue may have to be put on hold. Second, higher fuel prices could adversely affect individual and household quality of life. Some individuals may not be able to afford commuting to jobs that are farther away, and may have to change to a less desirable or lower paying job that is not as distant. This may happen to lower income households more so than others. As a result, rising fuel prices may have a disproportionately harsher impact on the lower strata of society, who are the least able to absorb the higher costs of transport. This social inequity is of concern to transportation professionals who grapple with the issue of how best to provide viable alternative means of transportation for the traveling public. Rising fuel prices could also disproportionately impact food consumption patterns and nutrition, and family health care for lower income groups. Third, higher fuel prices affect public transit agencies that must fuel their buses, and yet continue operating service at the same level without raising fares. Fourth, higher fuel prices could have adverse effects on the economy. As individuals allocate higher proportions of their income to transportation, they are forced to make adjustments in other categories of expenditure. Discretionary consumption is reduced, purchases of major items such as household appliances are postponed or eliminated, savings rates are cut back, and overall economic activity slumps. This is not to say that there are no benefits of higher fuel prices. Reduced travel demand may yield environmental benefits and energy savings, congestion reduction, shift to sustainable modes of travel such as cycling and walking, and fewer vehicular emissions. Although these benefits are well-recognized, it would be preferable if these benefits could be realized without having a deterioration in household quality of life and overall economic activity and growth.

It is in this context that this paper presents a comprehensive analysis of household expenditures across an array of commodities and services consumed by households. While previous research focused exclusively on transportation expenditures or one or two categories besides transportation, this study examines the entire array of expenditure patterns across all categories. A multiple discrete continuous nested extreme value (MDCNEV) model is formulated and estimated on a comprehensive data set compiled from the 2002 Consumer Expenditure Survey data of the United States. The model system is capable of considering non-zero consumption/expenditure on multiple categories, zero consumption/expenditure on multiple categories, and correlations among utilities of similar categories of expenses. The modeling methodology is extremely flexible and accommodates differential satiation effects to reflect diminishing returns associated with household expenditures on various categories. Model results show that a range of household socio-economic and demographic characteristics affect the percent of income or budget allocated to various categories and savings. The nesting structure was found to offer superior statistical goodness-of-fit in relation to a model specification that does not incorporate a nesting structure (*i.e.*, assumes independence across all category utilities).

The model was used to perform a sensitivity analysis to examine how households would adjust their consumption patterns, both in the short and long term, in response to increases in fuel price. It is found that, in the short term, households make adjustments in their savings rates, food consumption (such as eating out), and vehicle purchases. In the long term, households make similar adjustments to these categories, but also make major shifts in housing and utilities expenditures, suggesting that adjustments are made to residential location and/or housing unit type. Vehicle operating and maintenance expenses are also cut back, suggesting that individuals drive less, shift to more fuel-efficient vehicles in the long run, and cut back on the level of maintenance.

This study has several important implications for the field. From a methodological standpoint, the paper offers a robust approach for modeling household consumption patterns, including expenditures for transportation. As the profession moves towards integrated modeling of household and individual consumer choices, this approach makes it possible to incorporate considerations of monetary expenditures in activity-based models of travel demand. Such an integrated framework would allow activity-based travel demand models to lend themselves more directly to evaluating quality of life issues. From a policy standpoint, the analysis methodology and empirical results presented in this paper offer key insights into how consumers adjust their expenditures in response to rising fuel prices. It is found that individuals get affected in all categories as they try to maintain mobility levels and absorb the higher costs of fuel. It can be seen that individuals do not shift appreciably to transit, and yet cut back on such essential items as housing and food. These effects are likely to be more pronounced for lower income groups. The analysis conducted in this paper for the entire sample could be undertaken for various strata of society to examine the differential impacts of fuel price increases on consumption patterns and household welfare. Policymakers could use the information to formulate welfare strategies (*e.g.*, having more income groups qualify for subsidized housing or food) and transportation policies (*e.g.*, diverting funds to public transit enhancements) that would minimize the adverse impacts on the vulnerable segments of society. Ongoing research is focused on validating the results of this study with real-world data, conducting social equity comparisons across population subgroups, and exploring more disaggregate representations of expenditure categories.

REFERENCES

Anas, A. (2007) A Unified Theory of Consumption, Travel, and Trip Chaining. *Journal of Urban Economics*, 62(2), 162-186.

APTA (2008) Public Transit Ridership Continues to Grow in First Quarter of 2008: Almost 88 More Million Trips Taken than 2007 First Quarter. News Release, June 2, 2008. American Public Transit Association, Washington, D.C. http://www.apta.com/media/releases/080602_ridership_report.cfm

Austin, D. (2008) Effects of Gasoline Prices on Driving Behavior and Vehicle Markets. Congressional Budget Office, No. 2883, Washington, D.C.

Bhat, C.R. (2005) A Multiple Discrete-Continuous Extreme Value Model: Formulation and Application to Discretionary Time-Use Decisions. *Transportation Research Part B*, 39(8), 679-707.

Bhat, C.R. (2008) The Multiple Discrete-Continuous Extreme Value (MDCEV) Model: Role of Utility Function Parameters, Identification Considerations, and Model Extensions. *Transportation Research Part B*, 42(3), 274-303.

Bhat, C.R., and Koppelman, F.S. (1999) Activity-Based Modeling of Travel Demand. In R.W. Hall (ed.) *The Handbook of Transportation Science*, Kluwer Academic Publishers, Norwell, Massachusetts, 35-61.

Bhat, C.R., and Sen, S. (2006) Household Vehicle Type Holdings and Usage: An Application of the Multiple Discrete-Continuous Extreme Value (MDCEV) Model. *Transportation Research Part B,* 40, 35-53.

BLS (1998) Homeowner Expenditures Take More Out of Budgets in Northeast and West. *Monthly Labor Review the Editor's Desk*, U.S. Department of Labor Bureau of Labor Statistics, Washington, D.C. http://www.bls.gov/opub/ted/1998/Dec/wk3/art02.htm.

BLS (2001) BLS Interview Survey Form 2001. U.S. Department of Labor Bureau of Labor Statistics, Washington, D.C. http://www.bls.gov/cex/#forms.

BLS (2003) 2002 Consumer Expenditure Interview Survey Public Use Microdata Documentation. U.S. Department of Labor Bureau of Labor Statistics, Washington, D.C. http://www.bls.gov/cex/csxmicrodoc.htm#2002.

BLS (2004) Consumer Expenditures in 2002. U.S. Department of Labor, Bureau of Labor Statistics, Report 974. Washington, D.C.

Choo, S., Lee, T., and Mokhtarian, P.L. (2007) Do Transportation and Communications Tend to Be Substitutes, Complements, or Neither? U.S. Consumer Expenditures Perspective, 1984-2002. *Transportation Research Record*, 2010, 121-132.

Cooper, M. (2005) The Impact of Rising Prices on Household Gasoline Expenditures. Consumer Federation of America, www.consumerfed.org/.

Engel, E. (1857) Die Production und Consumptions Verhaltnisse Des Konigreichs Sachsen. Zeitschrift Des Statischen Bureaus Des Koniglich Sachsischen Ministerium Des Inheren, Nos. 8 and 9. Reprinted in Bull de l'Institute Int. de Statistique , 9, 1895.

Fetters, E., and Writer, H. (2008) Gas, Grocery Prices Drive Cost of Living Up. MSNBC News, http://www.msnbc.msn.com/id/25168646/.

FHWA (2008) Traffic Volume Trends. Federal Highway Administration, US Department of Transportation, Office of Highway Policy Information, Washington, D.C. http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.htm

Gicheva, D., Hastings, J., and Villas-Boas, S. (2007) Revisiting the Income Effect: Gasoline Prices and Grocery Purchases. NBER Working Paper Series, No. 13614.

Harris, E., and Sabelhaus, J. (2000) Consumer Expenditure Survey Family-Level Extracts, 1980:1 - 1998:2. http://www.nber.org/data/ces_cbo.html.

Hughes, J.E., Knittel, C.R., and Sperling, D. (2006) Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand. *The Energy Journal*, 29(1), 93-114.

Jones, P. (1979) New Approaches to Understanding Travel Behaviour: the Human Activity Approach. In Hensher, D.A., and Stopher, P.R. (eds.) *Behavioral Travel Modeling*. Redwood Burn Ltd., London, 55-80.

Jones, P. M., Koppelman, F.S., and Orfeuil, J.P. (1993) Activity Analysis: State-of-the-Art and Future Directions. *Developments in Dynamic and Activity-Based Approaches to Travel Analysis*, Gower, Aldershot, England, 34-55.

Krisher, T. (2008) Toyota Takes World Sales Lead from General Motors. *USA Today*, April 23, 2008. http://www.usatoday.com/money/autos/2008-04-23-toyota-gm-sales_N.htm

Linn, A. (2008) Rising Gas Costs Crimping Budgets. MSNBC News, http://www.msnbc.msn.com/id/23637018/.

Moriarty, P. (2002) Household Travel Time and Money Expenditures. *Road & Transport Research: A Journal of Australian and New Zealand Research and Practice*, 11(4), 14-23.

MSNBC News (2008a) Why Now is a Good Time to Buy a Car: Cost of a New Vehicle is Lower Than It Has Been in Years. MSNBC News, June 24, 2008, http://www.msnbc.msn.com/id/25287252/.

MSNBC News (2008b) Poll: Fuel Spike Curbs Vacations, Dining Out. MSNBC News, June 8, 2008, http://www.msnbc.msn.com/id/25237798/.

MSNBC News (2008c) Average Cost of Gas Nationwide Hits $4. Associated Press, MSNBC News, June 8, 2008, http://www.msnbc.msn.com/id/25045979/.

MSNBC News (2008d) Gas Prices Gouge Eating, Shopping Habits, Too - Americans Cutting Back on Other Expenses to Keep Tanks Full. MSNBC News, March 19, 2008, http://www.msnbc.msn.com/id/23636538/.

NBER (1980-2003) The National Bureau of Economic Research (NBER) Archive of Consumer Expenditure Survey microdata extracts. Available at http://www.nber.org/data/ces_cbo.html.

Nicholson, A.J., and Lim, Y.H. (1987) Household Expenditure on Transport in New Zealand. *Australian Road Research*, 17(1), 28-39.

Nicol, C. (2003) Elasticities of Demand for Gasoline in Canada and the United States. *Energy Economics*, 25(2), 201-214.

Oi, W.Y., and Shuldiner, P.Q. (1962) *An Analysis of Urban Travel Demands*. Northwestern University Press, Evanston, Illinois.

Olvera, L.D., Plat, D., and Pochet, P. (2008) Household Transport Expenditure in Sub-Saharan African Cities: Measurement and Analysis. *Journal of Transport Geography*, 16(1), 1-13.

Pendyala, R.M. (2008) Travel Trends and Conditions in an Era of High Gas Prices. Presentation at the Gas Price Summit, Arizona House of Representatives, Phoenix, AZ, June 24.

Pendyala R.M., and Goulias, K.G. (2002) Time Use and Activity Perspectives in Travel Behavior Research. *Transportation*, 29(1), 1-4.

Peterson, J. (2006) The Economic Effects of Recent Increases in Energy Prices. Congressional Budget Office, No. 2835, Washington, D.C.

Pinjari, A.R., and Bhat, C.R. (2008) A Multiple Discrete Continuous Nested Extreme Value Model: Formulation and Application to Activity Time-use and Timing Decisions. Working Paper, Department of Civil, Architectural and Environmental Engineering, The University of Texas at Austin.

Prais, S.J., and Houthakker, H.S. (1955) *The Analysis of Family Budgets*. Second Ed 1961, Cambridge University Press, Cambridge.

Puller, S.L., and Greening, L.A. (1999) Household Adjustment to Gasoline Price Change: An Analysis Using 9 Years of US Survey Data. *Energy Economics*, 21(1), 37-52.

Sanchez, T.W., Makarewicz, C., Hasa, P.M., and Dawkins, C.J. (2006) Transportation Costs, Inequities, and Trade-Offs. Presented at the 85th Annual Meeting of the Transportation Research Board, Washington, D.C., January.

Thakuriah, P., and Liao, Y. (2005) An Analysis of Variations in Vehicle-Ownership Expenditures. *Transportation Research Record: Journal of the Transportation Research Board*, 1926, 1-9.

Thakuriah, P., and Liao, Y. (2006) Transportation Expenditures and Ability to Pay. Evidence from Consumer Expenditure Survey. *Transportation Research Record*, 1985, 257-265.

APPENDIX A

For $r_\delta = 1$, $X_{r\delta} = \{1\}$.

For $r_\delta = 2$, $X_{r\delta} = \left\{ \frac{(q_\delta - 1)(1-\theta_\delta)}{\theta_\delta} + \frac{(q_\delta - 2)(1-\theta_\delta)}{\theta_\delta} + \ldots + \frac{2(1-\theta_\delta)}{\theta_\delta} + \frac{1(1-\theta_\delta)}{\theta_\delta} \right\}$.

For $r_\delta = 3, 4, \ldots, q_\delta$, $X_{r\delta}$ is a matrix of size $\begin{bmatrix} q_\delta - 2 \\ r - 2 \end{bmatrix}$ which is formed as described below:

Consider the following row matrices A_{q_δ} and $A_{r\delta}$ (with the elements arranged in the descending order, and of size $q_\delta - 1$ and $r_\delta - 2$, respectively):

$$A_{q_\delta} = \left\{ \frac{(q_\delta - 1)(1-\theta_\delta)}{\theta_\delta}, \frac{(q_\delta - 2)(1-\theta_\delta)}{\theta_\delta}, \frac{(q_\delta - 3)(1-\theta_\delta)}{\theta_\delta}, \ldots, \frac{3(1-\theta_\delta)}{\theta_\delta}, \frac{2(1-\theta_\delta)}{\theta_\delta}, \frac{1(1-\theta_\delta)}{\theta_\delta} \right\}$$

$$A_{r\delta} = \{r_\delta - 2, r_\delta - 3, r_\delta - 4, \ldots, 3, 2, 1\}.$$

Choose any $r_\delta - 2$ elements (other than the last element, $\frac{1-\theta_\delta}{\theta_\delta}$) of the matrix A_{q_δ} and arrange them in the descending order into another matrix A_{iq_δ}. Note that we can form $\begin{bmatrix} q_\delta - 2 \\ r_\delta - 2 \end{bmatrix}$ number of such matrices. Subsequently, form another matrix $A_{irq_\delta} = A_{iq_\delta} + A_{r\delta}$. Of the remaining elements in the A_{q_δ} matrix, discard the elements that are larger than or equal to the smallest element of the A_{iq_δ} matrix, and store the remaining elements into another matrix labeled B_{irq_δ}. Now, an element of $X_{r\delta}$ (*i.e.,* x_{irq_δ}) is formed by performing the following operation:

$x_{irq_\delta} = \text{Product}(A_{irq_\delta}) \times \text{Sum}(B_{irq_\delta})$; that is, by multiplying the product of all elements of the matrix A_{irq_δ} with the sum of all elements of the matrix B_{irq_δ}. Note that the number of such elements of the matrix $X_{r\delta}$ is equal to $\begin{bmatrix} q_\delta - 2 \\ r_\delta - 2 \end{bmatrix}$.

LIST OF TABLES

Table 1. Descriptive Statistics of Household Expenditures and Savings

Expenditure Category	Number (%) of Households (HHs) Spending In	Average Household Expenditure ($/yr)		Number of Households Who Spent ONLY in This Category and Housing/Food /Utilities
		for all HHs	for HHs spending in this category	
Housing (rent, property taxes, payments on mortgage principal, interest payments on property loan)	4084 (100%)	8691 (19.0%)	8691	0
Utilities (electricity, gas, water, sanitary services, fuel oil, coal, telephone and telegraph bills)	4084 (100%)	2866 (7.5%)	2866	0
Food (food and non-alcoholic product purchases at grocery stores and at restaurants)	4084 (100%)	5297 (13.2%)	5297	0
Alcohol and Tobacco Products (all alcohol and tobacco products purchased for home use as well as at restaurants)	2966 (74.6%)	623 (1.6%)	858	0
Clothing and Apparel (clothing, shoes, dry cleaning bills, watches, jewelry *etc.*)	3912 (95.8%)	1252 (2.6%)	1307	0
Personal Care (services such as barber shops, beauty parlors, health clubs)	3766 (92.2%)	257 (0.6%)	279	0
Household Maintenance (household furniture/supplies/ equipment, gardening and other household operation)	3777 (92.5%)	1482 (3.0%)	1602	0
Entertainment and Recreation (club/gym memberships, movies *etc*, recreational trips, recreational/sports equipment)	4016 (98.3%)	2372 (4.9%)	2412	0
Education (cost of books, nursery/ elementary/ secondary education, higher education and other education services)	2595 (63.5%)	867 (1.4%)	1364	0
Health Care (hospital expenses, prescription drugs and medicines, health insurance and other health care expenses)	3899 (95.5%)	3026 (7.6%)	3170	0
Business Services and Welfare Activities (financial/legal/ professional services, political/religious contributions)	3669 (89.8%)	1392 (3.0%)	1549	0
New/Used Vehicle Purchase (Net outlay of vehicle acquisition excluding trade in allowance, if any)	1074 (26.3%)	3499 (6.0%)	13306	0
Gasoline and Motor Oil	3833 (93.9%)	1299 (2.9%)	1384	0
Vehicle Insurance	3289 (80.5%)	955 (2.2%)	1186	0
Vehicle Operating and Maintenance (repair, greasing, tires, tubes, washing, parking, storage, tolls, interest, rental, *etc.*)	3679 (90.1%)	1433 (2.9%)	1591	0
Air Travel	1289 (31.6%)	256 (0.5%)	812	0
Public Transportation (fares on mass transit, taxicab, railway, bus *etc.*)	1443 (35.5%)	125 (0.3%)	354	0
Savings (Income after taxes – total expenditure in above categories, or zero if the difference is negative)	2566 (62.8%)	14215 (20.9%)	22625	0

Table 2. Estimation Results of the MDCNEV Model of Household Consumer Expenditures

	Housing	Utilities	Food	Alcohol and Tobacco Products	Clothing and Apparel	Personal Care	HH Maint-enance	Enterta-inment and Recreat-ion	Educati-on	Health Care	Business Services and Welfare Activities	New/ Used Vehicle Purchase	Gasoline and Motor Oil	Vehicle Insurance	Vehicle Operat-ion Mainten-ance	Air Travel	Public Transp-ortation	Saving
Baseline constants		-0.096 (-1.51)	0.451 (4.97)	-1.870 (-23.83)	-0.362 (-4.54)	-0.754 (-11.75)	-1.189 (-19.92)	-0.163 (-2.14)	-3.345 (-33.68)	-0.146 (-1.85)	-1.228 (-19.20)	-3.909 (-44.27)	-0.812 (-12.80)	-2.501 (-28.42)	-2.034 (-24.95)	-3.689 (-37.29)	-2.586 (-17.66)	-2.305 (-29.79)
Satiation parameters	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)	0 (fixed)
Translation parameters	NA	NA	NA	0.638 (24.63)	0.295 (20.88)	0.116 (24.33)	0.504 (24.57)	0.373 (16.16)	0.206 (26.32)	0.676 (20.37)	0.488 (25.13)	39.472 (12.63)	0.386 (15.82)	0.947 (21.46)	0.619 (19.84)	0.633 (14.95)	0.214 (19.01)	24.656 (16.75)
Impact of household socio-demographic variables on baseline utility																		
Household size	-0.057 (-4.01)	0.097 (6.01)	0.139 (8.13)															
Children present (≤18yr)	0.206 (5.21)			-0.194 (-4.72)	0.395 (10.38)				0.724 (13.78)			0.149 (3.43)						-0.180 (-3.54)
Number of workers in the HH				0.147 (7.61)	0.124 (6.16)				0.235 (10.12)			0.235 (8.28)	0.286 (11.35)	0.215 (8.99)	0.290 (13.12)			0.313 (12.32)
Income 30-70k (base: income ≤30k)		-0.664 (-13.54)	-0.613 (-12.10)			-0.175 (-5.09)				-0.353 (-7.93)		0.294 (5.82)	-0.303 (-7.16)	-0.184 (-5.20)		0.668 (7.52)		
Income >70k	-0.158 (-4.33)	-1.273 (-15.62)	-0.999 (-13.63)			-0.196 (-3.85)				-0.809 (-12.23)	-0.171 (-3.12)		-0.923 (-12.60)	-0.628 (-9.65)	-0.341 (-5.91)	1.120 (10.84)		
HH w/ 2 cars (base: 1 car)												0.176 (3.10)	0.473 (10.37)					
HH ≥ 3 cars												0.531 (8.63)	0.568 (9.65)					
No. of vehicles														0.813 (14.17)	0.624 (12.26)		-0.608 (-12.43)	
NCar2														-0.510 (-7.45)	-0.564 (-10.95)	-0.239 (-3.00)		-0.108 (-6.11)
NCar3														-0.281 (-6.93)		0.232 (2.40)	0.684 (10.45)	
Home owner (base: renter)	-0.856 (-23.22)	0.101 (1.97)	-0.279 (-4.90)	-0.357 (-8.28)	-0.423 (-11.45)		0.474 (11.16)										-0.378 (-5.65)	-0.197 (-3.64)
Impact of the attributes of household head on baseline utility																		
Non-Caucasian (base: Caucasian)				-0.150 (-3.15)				-0.140 (-2.93)									0.313 (4.41)	

	Housing	Utilities	Food	Alcohol and Tobacco Products	Clothing and Apparel	Personal Care	HH Maint-enance	Enterta-inment and Recreat-ion	Educati-on	Health Care	Business Services and Welfare Activities	New/ Used Vehicle Purchase	Gasoline and Motor Oil	Vehicle Insurance	Vehicle Operat-ion Mainten-ance	Air Travel	Public Transp-ortation	Saving
Male (base: female)				0.191 (5.72)	-0.096 (-2.91)				-0.198 (-4.70)									
Age≤50yr (base: age>50yr)	0.425 (13.97)			0.319 (7.62)				0.176 (4.45)	0.147 (2.77)	-0.735 (-18.12)	-0.287 (-8.34)							
Education < bachelors (base: < high school)									0.612 (7.98)		0.272 (6.62)							
Education ≥ bachelors									1.217 (14.96)		0.411 (8.27)							
Married (base: unmarried)				-0.146 (-3.74)						0.651 (11.28)	0.165 (4.90)							
Widowed /divorced/ separated					-0.079 (-2.09)					0.463 (7.94)								
Impact of spatial and regional location variables on baseline utility																		
Urban (base: rural)	0.578 (18.02)																0.465 (3.95)	
Northeast (base: South)	0.382 (10.02)				0.113 (2.55)			0.151 (2.89)									0.624 (8.92)	
Midwest	0.190 (6.04)						0.108 (2.62)	0.165 (3.68)	0.161 (3.068)									
West	0.315 (9.30)	-0.209 (-3.94)			0.077 (1.90)		0.072 (1.65)	0.125 (2.74)	0.317 (6.02)							0.478 (6.58)	0.559 (7.77)	-0.174 (-3.17)

Nesting parameters (θ)

θ_1 for the nest containing housing, utilities, household maintenance, and business services and welfare activities is 0.771, t-statistic for $\theta_1 = 1$ is 29.09.

θ_2 for the nest containing food, alcohol and tobacco products, and entertainment and recreation is 0.707, t-statistic for $\theta_2 = 1$ is 22.19.

θ_3 for the nest containing clothing and apparel and personal care is 0.651, t-statistic for $\theta_3 = 1$ is 26.96.

θ_4 for the nest containing new/ used vehicle purchase, gasoline and motor oil, vehicle insurance, and vehicle operation maintenance is 0.596, t-statistic for $\theta_4 = 1$ is 41.29.

Goodness of fit

Log-likelihood at constants = -150,620; Log-likelihood at convergence (MDCEV model) = -146552.7; Log-likelihood at convergence (MDCNEV model) = -142,821.6

Adjusted $\overline{\rho^2}$ = 0.052; Likelihood ratio between the MDCNEV and MDCEV models = 7462.3 >> 9.49 (χ^2 at 95% confidence level and 4 restrictions)

Table 3. Short-Term and Long Term Impacts of Fuel Price Increase

Expenditure Category	Short-Term Impact			Long-Term Impact		
	Percentage of Total Budget		Drop in the Percentage Points	Percentage of Total Budget		Drop in the Percentage Points
	Base Case	Policy Case		Base Case	Policy Case	
Housing	-	-	-	18.68	18.18	-0.50
Utilities	-	-	-	9.85	9.57	-0.28
Food	16.22	15.54	-0.68	15.40	15.00	-0.40
Alcohol and Tobacco Products	2.59	2.46	-0.13	2.48	2.41	-0.06
Clothing and Apparel	3.88	3.72	-0.16	3.84	3.72	-0.12
Personal Care	1.08	1.03	-0.05	0.96	0.93	-0.03
Household Maintenance	3.05	2.90	-0.15	3.06	2.97	-0.09
Entertainment and Recreation	5.86	5.60	-0.26	5.57	5.41	-0.15
Education	-	-	-	0.79	0.77	-0.02
Health Care	-	-	-	3.99	3.88	-0.11
Business Services and Welfare Activities	2.39	2.28	-0.11	2.43	2.36	-0.06
New/ Used Vehicle Purchase	6.21	5.78	-0.43	8.06	7.69	-0.37
Vehicle Insurance	-	-	-	3.52	3.42	-0.10
Vehicle Operating and Maintenance	3.82	3.64	-0.17	3.75	3.63	-0.12
Air Travel	0.47	0.45	-0.02	0.51	0.50	-0.02
Public Transportation	0.20	0.19	-0.01	0.17	0.17	0.00
Savings	12.37	11.57	-0.79	13.99	13.47	-0.52