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The Econometric Submodels of the Energy Policy Socioeconomic Impact Model (EPSIM)

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AVAILABILITY OF COMPUTER SOFTWARE

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Energy Science and Technology Software Center
P.O. Box 1020
Oak Ridge, TN 37831-1020

For information regarding requests for software, call (615) 576-2606.

THE ECONOMETRIC SUBMODELS OF THE ENERGY POLICY SOCIOECONOMIC IMPACT MODEL (EPSIM)

by

J.G. Butler and D.A. Poyer

ABSTRACT

The Energy Policy Socioeconomic Impact Model (EPSIM) is an econometric simulation model that runs on IBM-compatible personal computers. It can be used to assess the economic impact of energy policies and programs, such as utility rate designs and demand-side management programs, on various population groups, such as minority and low-income households. The econometric submodels that constitute the internal structure of EPSIM are described in detail.

1 INTRODUCTION

The Energy Policy Socioeconomic Impact Model (EPSIM) is an econometric simulation model developed by the Socioeconomic Research and Analysis Program, Energy Systems Division, Argonne National Laboratory, under the sponsorship of the Office of Economic Impact and Diversity, U.S. Department of Energy (DOE). The purpose of EPSIM is to assess the economic impact of energy policies and programs, such as utility rate designs and demand-side management programs, on various population groups, such as minority and low-income households. A version of the model that runs on IBM-compatible personal computers is available through the Energy Science and Technology Software Center, Oak Ridge, Tennessee. The user interface for that version is described in the user's guide (Butler and Poyer 1993) that accompanies the software.

This report describes the econometric submodels that constitute the heart of EPSIM. In addition, this report describes the structure of the EPSIM model in detail, starting with representative values for the exogenous variables and working through to the output results. It also develops expressions for calculating the electricity price elasticities for individual households. The calculation of elasticities is not explicitly part of the EPSIM structure, but it reveals how EPSIM generates different responses to energy price changes for households with different demographic characteristics.

Appendix A contains a complete specification of the EPSIM econometric submodels, except for the values of the parameter vectors. It was prepared with Mathcad 4.0 mathematical software (Mathsoft 1993). When run with the Mathcad host program, the calculations presented in Appendix A are a working model of the mathematical equations and

expressions contained in EPSIM. The ":@" symbol denotes variable and function definitions, while the "=" symbol displays the current value of the specified variable or expression. Before any variable can be evaluated (or used in an expression to be evaluated), it must have appeared on the left side of a previous Mathcad definition. A Mathcad document operates in a manner similar to a spreadsheet template, performing its calculations in sequence from top to bottom and from left to right. In EPSIM Version 1.0, the calculations described in Appendix A are performed on each of the 1,606 households that make up the Midwest sample of the 1987 Residential Energy Consumption Survey (RECS) (DOE 1989).

2 EPSIM TECHNICAL SPECIFICATIONS

2.1 EXOGENOUS INPUT VARIABLES

EPSIM requires the following household information as exogenous input data: house vintage (year built); house type (single-family, two to four units multifamily, five or more units multifamily, mobile home); metropolitan location (inner city, suburban/rural); heated house area (square feet); heating degree-days; cooling degree-days; price of electricity; age, gender, and ethnicity of household head; and household size, income, and poverty status. In EPSIM Version 1.0, this information is obtained from the 1987 RECS Midwest sample (DOE 1989). This information is made available to the model equations through the vectors $\mathbf{Xs}$ and $\mathbf{Xe}$ of explanatory variables and expressions.

2.2 ELECTRICITY AND NON-ENERGY PRICES

The composite price of non-energy goods P_c was set equal to 1.44, the level of the consumer price index (1979 = 1.00) in 1987. The electrical appliance share models use the exogenously supplied electricity price P_{el} . For the EPSIM households taken from the 1987 RECS, this price is obtained by dividing the total reported electricity expenditures by the total reported electricity consumption. The equations for electricity and total energy demand specify an endogenously determined two-part electricity tariff consisting of a fixed customer charge M_{elc} plus a consumption-related energy charge P_{elc} . The values of M_{elc} and P_{elc} were estimated to be \$86.50/yr and \$18.66 per million Btu's, respectively. These values were estimated by using non-linear regression techniques and the combined Midwest samples of the 1981, 1982, 1984, and 1987 RECS samples (DOE 1983, 1985, 1987, 1989).

2.3 NON-ELECTRIC ENERGY PRICE

The non-electric energy price P_{nel} was estimated separately from the combined RECS samples by using the demographic variables contained in vector $\mathbf{Xs}$ as instrumental variables. The adjustment variable mr (Mill's ratio) is estimated from a probit model described by Maddala (1983) that compensates for the fact that the sample from which the non-electric energy price model was estimated excludes all-electric households. An important method by which EPSIM generates differential behavioral responses to energy price changes is to allow P_{nel} to vary on demographic factors.

2.4 HOUSEHOLD EXPENDITURES AND DISCRETIONARY EXPENDITURE PARAMETERS

EPSIM budgets fixed portions β_{el} and $(\beta_e - \beta_{el})$ of discretionary household expenditures $(M - P_c * \gamma_c)$ to electricity and non-electric energy consumption. The non-linear "life-cycle" submodel for household expenditures M uses household income and size as well as ethnicity and age of household head as independent variables. This submodel was

specified and estimated on the basis of data from the Consumer Expenditure Survey of 1989 (U.S. Department of Labor 1991). This submodel also generates non-discretionary, non-energy consumption γ_c as a by-product.

2.5 ELECTRICAL APPLIANCE USE PROBABILITIES

EPSIM uses logit models to estimate the probabilities of a household's use of electric space heating, water heating, cooking, and air conditioning equipment. These probabilities, or shares, which depend on the vector $\mathbf{X}$ s of demographic variables and the P_{el}/P_{nel} price ratio (P_{el}/P_c for air conditioning), are major determinants of a household's non-discretionary electric and non-electric energy consumption and responses to price changes. Indeed, EPSIM generates a household's response to price changes primarily by altering the probabilities of the use of major electrical appliances. Separate share models were estimated for black households to correct for observed overestimates of electric appliance use obtained from the all-households share models. While the consumption estimates and elasticities obtained from these two share models may differ substantially for individual households, these differences appear to balance out within the black sample. The use of either share model reveals significant differences between black and non-black households with respect to energy consumption and price elasticities.

2.6 NON-DISCRETIONARY ENERGY CONSUMPTION

Non-discretionary electricity consumption γ_{el} is defined as the dot product of the vector $\mathbf{X}_e$ of explanatory variable expressions and the vector $\mathbf{g}_l$ of parameters. Non-discretionary, non-electric energy consumption γ_{nel} is defined indirectly as the dot product of $\mathbf{X}_e$ and the vector $\mathbf{g}_e$ of parameters. The substitutability between electric and non-electric energy is captured by the dependence of both γ_{el} and γ_{nel} on the probabilities of electric appliance use, which, in turn, depend on the price ratio P_{el}/P_{nel} (P_{el}/P_c for air conditioning).

2.7 ELECTRICITY AND NON-ELECTRIC ENERGY CONSUMPTION AND EXPENDITURES

The final step in EPSIM is to derive electricity consumption Q_{el} , non-electric energy consumption Q_{nel} , and average energy price P_{el} through the simultaneous solution of the energy demand, electricity demand, and average energy price equations shown in Appendix A. The demand equation system solves for total energy consumption Q_e and electricity consumption Q_{el} . The value of Q_{nel} is calculated as the difference between Q_e and Q_{el} . Expenditures on electric and non-electric energy are calculated as simple linear functions of consumption quantities and prices. In the case of electricity, the customer charge M_{elc} is added to the product of P_{elc} and Q_{el} to obtain total electricity expenditures M_{el} .

2.8 PARAMETER ESTIMATION AND MODEL VALIDATION

Values for the 270 parameters used in EPSIM Version 1.0 were estimated by using the MODEL procedure of SAS/ETS Version 6.04 for IBM-compatible personal computers (SAS Institute 1988). These values, along with the FoxPro source code that implements the econometric submodels described in this report, are given in Appendix B. One way to check the validity of the estimated model is to plot the residuals between the observed values for electricity and non-electric energy consumption and the values estimated by EPSIM. Figure 1 plots the electricity residuals. Ideally, these residuals would be distributed normally around a mean value of zero. The cumulative plot in Figure 1 shows that this ideal is nearly achieved. The distribution is only slightly skewed to the right, with little apparent bias.

FIGURE 1 Electricity Consumption Residuals (observed compared with estimated; HHs = households)

3 MANIPULATING THE BASIC MODEL FOR UTILITY RATE DESIGN IMPACT ANALYSIS

EPSIM Version 1.0 provides an interface module (URD) through which users can manipulate the basic model to analyze the differential impacts of various two-part electricity tariff designs on minority and low-income households. The analytical facilities provided by URD are described in detail in the EPSIM user's guide (Butler and Poyer 1993). The URD module uses the parameter values for P_{elc} and M_{elc} that were estimated from the combined RECS samples for its base case. The user can specify alternative values for these parameters for the policy case. The URD module then multiplies the exogenous electricity price P_{el} by an amount proportional to the change in P_{elc} and outputs the cumulative distributions of expenditure differences between the base and policy cases by population group.

4 MANIPULATING THE BASIC MODEL FOR DEMAND-SIDE MANAGEMENT PROGRAM ANALYSIS

EPSIM Version 1.0 also provides an interface module (DSM) through which users can manipulate the basic model to analyze the differential impacts of various demand-side management programs. The use of EPSIM in this policy context requires extension of the basic model by the introduction of the concept of the energy service ratio (ESR). The ESR approach views energy as an input to technological processes that generate as output household services, such as heated space and water, illumination, cooked meals, and so on. The ESR is defined as the ratio between a given quantity of service output and the quantity of energy input required to produce that output. An increase in the efficiency of energy use in producing services reduces the implicit price to consumers of these end-use services. Since we are interested only in projecting consumer responses to *changes* in efficiency, it is not necessary to define explicitly units of consumption for the end-use services. An ESR of unity is specified for the base case, and the ESR for the policy case is derived as unity minus the expected change in efficiency resulting from application of the proposed demand-side management measure.

For example, a demand-side management measure that improves efficiency by 15% would have an associated ESR of 0.85 ($1 - [15/100]$). Setting the ESR to unity for the base case equates the price and demand for the end-use service with the price and demand for the energy input. For a specified policy case ESR, the implicit new price P_s of the end-use service is calculated as the product of the ESR and the old energy price (either P_{el} or P_{nel}). The value P_s is then substituted for P_{el} or P_{nel} in the basic model, and a new consumption quantity is calculated. This new consumption quantity Q_s represents units of end-use service demanded. To convert Q_s back into energy units demanded (Q_{el} or Q_{nel}), Q_s is multiplied by ESR. The Oak Ridge National Laboratory Residential Energy Consumption Model uses a similar ESR approach, as described by Cowing and McFadden (1984). The use of the ESR concept in demand-side management program modeling is also discussed by Khazzoom (1986).

5 EXAMINING EPSIM RESPONSE CHARACTERISTICS THROUGH ANALYSIS OF ENERGY PRICE ELASTICITIES

Appendix A contains analytical expressions for calculating electricity and non-electric energy own-price elasticities for individual households. These expressions were obtained by differentiating the electricity and total energy demand equations with respect to P_{el} , P_{elc} , and P_{nel} . Figures 2a, 3a, 4a, and 5a plot the cumulative distributions of electricity price elasticities calculated from these expressions for the EPSIM sample households for various categorization schemes. Figures 2b, 3b, 4b, and 5b plot non-electric price elasticities. Figure 2 categorizes the households by ethnicity and poverty level, Figure 3 by house type, Figure 4 by house vintage, and Figure 5 by observed electric appliance use. The categories in Figures 2 and 5 are not mutually exclusive. For example, a household categorized as majority could also be categorized as poor. A household that uses electricity for space heating can (and probably does) also use electricity for air conditioning, and so on. Figures 2 through 5 are based on the separate appliance share models (Model B) for black households. In addition to plotting the cumulative distributions of elasticities, Figures 2 through 5 also contain distributions of the electrical appliance shares (probabilities) for the respective categorization schemes.

Clearly, house type and vintage, heated area, and climate are important determinants of elasticity differences among different households. Differences in the way ethnicity and poverty groups are distributed across these determining factors result in the group differences revealed in Figure 2. Figure 2a suggests that only 38% of black households would spend more on electricity ($-E_{el} > 1$) as a result of an electricity price decrease, compared with 48% of Hispanic households, 53% of poor households, and 68% of majority (non-black, non-Hispanic) households. The median electricity price elasticity is -0.76 for black households, -1.03 for poor households, -0.96 for Hispanic households, and -1.15 for majority households.

As for non-electric energy own-price elasticity, Figure 2b suggests that fewer than 5% of black households would spend more on non-electric energy ($-E_{nel} > 1$) as a result of a price decrease, compared with 19% of poor households and 31% of majority households. The median non-electric elasticity is less than -0.2 for black households, less than -0.6 for poor and Hispanic households, and about -0.7 for majority households.

a. Electricity Price Elasticity by Ethnicity and Poverty

b. Non-Electric Energy Price Elasticity by Ethnicity and Poverty

FIGURE 2 Price Elasticities and Appliance Shares by Ethnicity and Poverty

c. Electric Water Heating Share by Ethnicity and Poverty

d. Electric Cooking Share by Ethnicity and Poverty

FIGURE 2 (Cont.)

e. Air Conditioning Share by Ethnicity and Poverty

f. Electric Space Heating Share by Ethnicity and Poverty

FIGURE 2 (Cont.)

a. Electricity Price Elasticity by House Type

b. Non-Electric Energy Price Elasticity by House Type

FIGURE 3 Price Elasticities and Appliance Shares by House Type

c. Electric Water Heat Share by House Type

d. Electric Cooking Share by House Type

FIGURE 3 (Cont.)

e. Air Conditioning Share by House Type

f. Electric Space Heating Share by House Type

FIGURE 3 (Cont.)

a. Electricity Price Elasticity by House Vintage

b. Non-Electric Energy Price Elasticity by House Vintage

FIGURE 4 Elasticities and Appliance Shares by House Vintage

c. Electric Water Heating Share by House Vintage

d. Electric Cooking Share by House Vintage

FIGURE 4 (Cont.)

e. Air Conditioning Share by House Vintage

f. Electric Space Heating Share by House Vintage

FIGURE 4 (Cont.)

a. Electricity Price Elasticity by Appliance Use

b. Non-Electric Energy Price Elasticity by Appliance Use

FIGURE 5 Price Elasticities and Appliance Shares by Appliance Use

c. Electric Water Heating Share by Appliance Use

d. Electric Cooking Share by Appliance Use

FIGURE 5 (Cont.)

e. Air Conditioning Share by Appliance Use

f. Electric Space Heating Share by Appliance Use

FIGURE 5 (Cont.)

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APPENDIX A:
EPSIM TECHNICAL SPECIFICATION WITH
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Exogenous Variables:

House Vintage: vnt := 75   Race: black := 0
 House Type: htyp := 1   Latin: hisp := 0
 Metro Location: incity := 0   Household Size: hhsz := 2
 Heated Area: area := 2430   Household Income: hhinc := 62500
 Heat degree-days: hdd65 := 4555   Poverty: poor := 0
 Cool degree-days: cdd65 := 1451   Gender: femhd := 0
 Electricity price: Pel := 23.66   Age of head: agehd := 45

Electricity and Non-energy Prices: Pc := 1.505   Pelc := 18.66   Melc := 86.50

Logit function definition: $\text{logit}(\pi) := \frac{e^{\pi}}{1 + e^{\pi}}$ Vector of Explanatory Variables: $X_s(P_c) :=$

Non-Electric Energy Price:

ne := READPRN(ne)   pn := READPRN(pn)   pn20 := -2.414

$$\alpha := \text{logit}(ne^T \cdot X_s(P_c)) \quad mr := \frac{(1 - \alpha) \cdot \ln(1 - \alpha)}{\alpha} + \ln(\alpha)$$

$$P_{nel} := pn^T \cdot X_s(P_c) + pn20 \cdot mr \quad P_{nel} = 5.38$$

Household Expenditures:

cpiu := 1.505   cpiu89 := cpiu · 1.0851 $\beta := \text{logit}(-1.823 - .561 \cdot \text{black} - .282 \cdot \text{hisp})$

$$K0 := \exp(.283 \cdot \text{hhsz} - .0346 \cdot \text{hhsz}^2 + .345 \cdot \text{agehd} - .00355 \cdot \text{agehd}^2) \quad \gamma_c := \frac{K0}{\text{cpiu89}}$$

$$Yd := 0.961 \cdot \text{hhinc} - 1.087 \cdot 10^{-6} \cdot \text{hhinc}^2 \quad M := ((1 - \beta) \cdot \gamma_c \cdot \text{cpiu} + \beta \cdot Yd) \cdot 4$$

$$M = 51358 \quad \gamma_c = 3918$$

Discretionary Expenditure Parameters: $\beta_e := .007$ $\beta_{el} := .003$

Electrical Appliance Use Probabilities:

Water Heating: wh := if(black, READPRN(whshr2), READPRN(whshr1))

$$\text{whs}(Pel, P_{nel}) := \text{logit}\left(\text{wh}^T \cdot X_s\left(\frac{Pel}{P_{nel}}\right)\right) \quad \text{whs}(Pel, P_{nel}) = 0.196$$

Space Heating: sh := if(black, READPRN(shshr2), READPRN(shshr1))

$$\text{shs}(Pel, P_{nel}) := \text{logit}\left(\text{sh}^T \cdot X_s\left(\frac{Pel}{P_{nel}}\right)\right) \quad \text{shs}(Pel, P_{nel}) = 0.031$$

Cooking: ck := if(black, READPRN(ckshr2), READPRN(ckshr1))

$$\text{cks}(Pel, P_{nel}) := \text{logit}\left(\text{ck}^T \cdot X_s\left(\frac{Pel}{P_{nel}}\right)\right) \quad \text{cks}(Pel, P_{nel}) = 0.730$$

Central A/C: ac := if(black, READPRN(acshr2), READPRN(acshr1))

$$\text{acs}(Pel, P_{nel}) := \text{logit}\left(\text{ac}^T \cdot X_s\left(\frac{Pel}{P_c}\right)\right) \quad \text{acs}(Pel, P_{nel}) = 0.839$$

1
 cdd65
 hdd65
 cdd65·hdd65
 Pc
 hhinc
 area
 if(htyp=2,1,0)
 if(htyp=3,1,0)
 if(htyp=4,1,0)
 if(htyp=0,1,0)
 if(vnt=40,1,0)
 if(vnt=50,1,0)
 if(vnt=75,1,0)
 if(vnt=80,1,0)
 if(vnt=87,1,0)
 incity
 poor
 hisp
 black

Non-discretionary Energy Consumption:

gl := if(black, READPRN(glparm2), READPRN(glparm1))

ge := if(black, READPRN(geparm2), READPRN(geparm1))

Vector of Explanatory Variables: $X\alpha(Pel, Pnel) :=$

$\gamma_{el}(Pel, Pnel) := gl^T \cdot X\alpha(Pel, Pnel)$ $\gamma_{el}(Pel, Pnel) = 28.66$

$\gamma_e(Pel, Pnel) := ge^T \cdot X\alpha(Pel, Pnel) + \gamma_{el}(Pel, Pnel)$ $\gamma_e(Pel, Pnel) = 102.62$

$\gamma_{nel} := \gamma_e(Pel, Pnel) - \gamma_{el}(Pel, Pnel)$ $\gamma_{nel} = 73.97$

Guesses: $Q_e := 100$ $Q_{el} := 50$ $P_e := 10$

Given

1
hhsz
hhsz·femhd
hdd65·area
cdd65
shs(Pel, Pnel)·area·hdd65
acs(Pel, Pnel)·cdd65
cks(Pel, Pnel)
whs(Pel, Pnel)
poor
hisp
black
if(vnt=40) + (vnt=50), 1, 0)
if(vnt=80) + (vnt=87), 1, 0)
if(htyp=2, 1, 0)
if(htyp=3, 1, 0)
if(htyp=4, 1, 0)
incity

Energy Demand: $Q_e = \gamma_e(Pel, Pnel) + \frac{\beta_e}{P_e} \cdot (M - P_e \cdot \gamma_e)$

Electricity Demand: $Q_{el} = \gamma_{el}(Pel, Pnel) + \frac{\beta_{el}}{P_{el}} \cdot (M - P_e \cdot \gamma_e)$

Average Energy Price: $P_e = \frac{M_{elc} + P_{elc} \cdot Q_{el} + P_{nel} \cdot (Q_e - Q_{el})}{Q_e}$

Solve for Q_e , Q_{el} , and P_e : $Q(Pel, Pnel) := \text{find}(Q_e, Q_{el}, P_e)$ $Q(Pel, Pnel) = \begin{pmatrix} 136.038 \\ 35.964 \\ 9.523 \end{pmatrix}$

Energy Consumption: $Q_{el} := Q(Pel, Pnel)_1$ $Q_{nel} := Q(Pel, Pnel)_0 - Q(Pel, Pnel)_1$
 $Q_{el} = 35.96$ $Q_{nel} = 100.07$

Electricity Expenditures: $M_{elc} + P_{elc} \cdot Q_{el} = 758$

Non-Electric Energy Exps: $P_{nel} \cdot Q_{nel} = 538$

Calculation of Electricity Own-Price Elasticity:

Change in GamL with respect to Pel:

$$d_{\text{yel}}_{\text{sh}} := (gl^T)_5 \cdot \text{area} \cdot \text{hdd65} \cdot \frac{(sh^T)_4}{P_{\text{nel}}} \cdot \text{shs}(Pel, P_{\text{nel}}) \cdot (1 - \text{shs}(Pel, P_{\text{nel}})) \quad d_{\text{yel}}_{\text{sh}} = -0.538$$

$$d_{\text{yel}}_{\text{ac}} := (gl^T)_6 \cdot \text{cdd65} \cdot \frac{(ac^T)_4}{P_c} \cdot \text{acs}(Pel, P_{\text{nel}}) \cdot (1 - \text{acs}(Pel, P_{\text{nel}})) \quad d_{\text{yel}}_{\text{ac}} = -0.02$$

$$d_{\text{yel}}_{\text{ck}} := (gl^T)_7 \cdot \frac{(ck^T)_4}{P_{\text{nel}}} \cdot \text{cks}(Pel, P_{\text{nel}}) \cdot (1 - \text{cks}(Pel, P_{\text{nel}})) \quad d_{\text{yel}}_{\text{ck}} = -0.066$$

$$d_{\text{yel}}_{\text{wh}} := (gl^T)_8 \cdot \frac{(wh^T)_4}{P_{\text{nel}}} \cdot \text{whs}(Pel, P_{\text{nel}}) \cdot (1 - \text{whs}(Pel, P_{\text{nel}})) \quad d_{\text{yel}}_{\text{wh}} = -0.988$$

$$d_{\text{yel}} := d_{\text{yel}}_{\text{sh}} + d_{\text{yel}}_{\text{ac}} + d_{\text{yel}}_{\text{ck}} + d_{\text{yel}}_{\text{wh}} \quad d_{\text{yel}} = -1.612$$

Change in Qel with respect to Pel:

$$dQ_{\text{el}} := d_{\text{yel}} \quad dQ_{\text{el}} = -2.004 \quad Q_{\text{el}} = 35.964$$

$$dPel := 1 \quad Pel = 23.66$$

Electricity Own-Price Elasticity:

$$\varepsilon_{\text{el}} := \frac{d_{\text{yel}}}{dPel} \cdot \frac{Pel}{Q_{\text{el}}} \quad \varepsilon_{\text{el}} = -1.06$$

Numerically Calculated Elasticity:

$$dQ_{\text{el}} := Q(Pel, P_{\text{nel}})_1 - Q(.999 \cdot Pel, P_{\text{nel}})_1 \quad dPel := .001 \cdot Pel$$

$$\frac{dQ_{\text{el}}}{dPel} \cdot \frac{Pel}{Q_{\text{el}}} = -1.06$$

Calculation of Non-Electric Energy Own-Price Elasticity:

Change in GamNel with respect to Pnel:

$$d_{\text{nel}}_{\text{sh}} := - \left(ge^T \right)_3 \cdot \text{area} \cdot \text{hdd65} \cdot \left(sh^T \right)_4 \cdot \frac{P_{\text{el}}}{P_{\text{nel}}^2} \cdot \text{shs}(P_{\text{el}}, P_{\text{nel}}) \cdot (1 - \text{shs}(P_{\text{el}}, P_{\text{nel}})) \quad d_{\text{nel}}_{\text{sh}} = -2.075$$

$$d_{\text{nel}}_{\text{ac}} := 0 \quad d_{\text{nel}}_{\text{ac}} = 0$$

$$d_{\text{nel}}_{\text{ck}} := - \left(ge^T \right)_7 \cdot \left(ck^T \right)_4 \cdot \frac{P_{\text{el}}}{P_{\text{nel}}^2} \cdot \text{cks}(P_{\text{el}}, P_{\text{nel}}) \cdot (1 - \text{cks}(P_{\text{el}}, P_{\text{nel}})) \quad d_{\text{nel}}_{\text{ck}} = 0.074$$

$$d_{\text{nel}}_{\text{wh}} := - \left(ge^T \right)_8 \cdot \left(wh^T \right)_4 \cdot \frac{P_{\text{el}}}{P_{\text{nel}}^2} \cdot \text{whs}(P_{\text{el}}, P_{\text{nel}}) \cdot (1 - \text{whs}(P_{\text{el}}, P_{\text{nel}})) \quad d_{\text{nel}}_{\text{wh}} = -10.217$$

$$d_{\text{nel}} := d_{\text{nel}}_{\text{sh}} + d_{\text{nel}}_{\text{ac}} + d_{\text{nel}}_{\text{ck}} + d_{\text{nel}}_{\text{wh}} \quad d_{\text{nel}} = -12.219$$

Change in Qnel with respect to Pnel:

$$dQ_{\text{nel}} := d_{\text{nel}} - \frac{\beta_e - \beta_{\text{el}}}{P_{\text{nel}}^2} \cdot (M - P_c \cdot \gamma_c) \quad dQ_{\text{nel}} = -18.512 \quad Q_{\text{nel}} = 100.074$$

$$dP_{\text{nel}} := 1 \quad P_{\text{nel}} = 5.375$$

Non-Electric Energy Own-Price Elasticity:

$$\epsilon_{\text{nel}} := \frac{dQ_{\text{nel}}}{dP_{\text{nel}}} \cdot \frac{P_{\text{nel}}}{Q_{\text{nel}}} \quad \epsilon_{\text{nel}} = -0.99$$

Numerically Calculated Elasticity:

$$dQ_{\text{nel}} := \left(Q(P_{\text{el}}, P_{\text{nel}})_0 - Q(P_{\text{el}}, P_{\text{nel}})_1 \right) - \left(Q(P_{\text{el}}, .999 \cdot P_{\text{nel}})_0 - Q(P_{\text{el}}, .999 \cdot P_{\text{nel}})_1 \right) \quad dP_{\text{nel}} := .001 \cdot P_{\text{nel}}$$

$$\frac{dQ_{\text{nel}}}{dP_{\text{nel}}} \cdot \frac{P_{\text{nel}}}{Q_{\text{nel}}} = -0.99$$

APPENDIX B:
EPSIM VERSION 1.0 SOURCE CODE
AND PARAMETER VALUES

APPENDIX B:
EPSIM VERSION 1.0 SOURCE CODE
AND PARAMETER VALUES

Values for the 270 parameters used in EPSIM Version 1.0 were estimated by using the MODEL procedure of SAS/ETS Version 6.04 for IBM-compatible personal computers (SAS Institute 1988). These values, along with the FoxPro source code that implements the econometric submodels described in this report, are given in this appendix.

```

* MEAM67.PRG - Initializes MEAM26.DBF for LCP67.PRG
public GLac, GLwh, GLck, GLsh
set talk off
use parms67
scatter memvar
set procedure to lcp67
do Setup26
module = 'INIT'
numit = 0
scan
  repl M with Consume()
  repl GamC with M.GamC  && Defined in Consume()
  repl GamL with 0

  repl shlnk with ShLnkf(), whlnk with WhLnkf(), cklnk with CkLnkf(), ;
    aclnk with AcLnkf()

  repl Be with c.b0
  repl Bel with c.be0

  repl GamL0 with c.g0 +hhsz*(c.g4+c.g5*femhd) +c.g6*10^-6*hdd65*area ;
    +c.g7*10^-2*cdd65 +c.g12*poor +c.g13*latino +c.g14*afro ;
    +c.g15*(vnt40+vnt50) +c.g16*(vnt80+vnt87) +c.g17*sfam2 +c.g18*multil ;
    +c.g19*multi2 +c.g20*incity

  repl GamE0 with c.f0 +hhsz*(c.f4+c.f5*femhd) +c.f6*10^-6*hdd65*area ;
    +c.f7*10^-2*cdd65 +c.f12*poor +c.f13*latino +c.f14*afro ;
    +c.f15*(vnt40+vnt50) +c.f16*(vnt80+vnt87) +c.f17*sfam2 +c.f18*multil ;
    +c.f19*multi2 +c.f20*incity

  repl Pnel with Pnelf()

  repl Melc with c.a0 +c.a1*Pc
  repl Pelc with c.a4 +c.a5*Pc

  *Pix = (Melc/Mbtuel + Pelc)/Pel
  *repl Melc with Melc*Pix, Pelc with Pelc*Pix

do Meam6

Pe = (Pelc*Qell + Pnel*Qnell)/(Qell + Qnell)
repl Qel with Qell, Qnel with Qnell, Mel with Mell, Pec with Pe

repl GamL with GamL1, GamE with GamE1, shs with GLsh/GamL1, ;
  acs with GLac/GamL1, whs with GLwh/GamL1, cks with GLck/GamL1

  numit = numit+1
  @10,20 say 'Number of Records Processed: '+str(numit,4)
endscan
close procedure
sele c
use
sele b
use
sele a
set talk on

```

* LCPPRO67.PRG - PROCEDURE FILE FOR MEAM/LCP Version 6.7

PROCEDURE MEAM6

public Qell, Qnell, Mell, Mel, Bell, GamEl, GamLl, shs1, acs1, whs1, cks1

do case

case module='URD'.or. module='INIT'

Pelcl = Pelc

Melcl = Melc

Pnell = Pnel

facS = Pel

facW = facS

facC = facS

facA = facS

case module='TAX'

facS = Pelcl/Pelc*Pel

facW = facS

facC = facS

facA = facS

case module='DSM'

facS = Pelcl/Pelc*Pel*iif(targfuel='ElHeat',1-sav/100,1)

facW = Pelcl/Pelc*Pel*iif(targfuel='ElH2o',1-sav/100,1)

facC = Pelcl/Pelc*Pel*iif(targfuel='ElCook',1-sav/100,1)

facA = Pelcl/Pelc*Pel*iif(targfuel='AirCon',1-sav/100,1)

Pelcl = esr*Pelcl

endcase

shs1 = logit(shlnk + b.sh4*facS/Pnell)

whs1 = logit(whlnk + b.wh4*facW/Pnell)

cks1 = logit(cklnk + b.ck4*facC/Pnell)

acs1 = logit(aclnk + b.ac4*facA/Pc)

Bell = Bel

GLsh = c.g8*10^-6*shs1*area*hdd65

GLac = c.g9*10^-2*acs1*cdd65

GLck = c.g10*cks1

GLwh = c.g11*whs1

GamLl = GamL0 +GLsh +GLac +GLck +GLwh

GamEl = GamE0 +c.f8*10^-6*shs1*area*hdd65 + c.f9*10^-2*acs1*cdd65 ;
+c.f10*cks1 +c.f11*whs1 +GamLl

Qell = GamLl + Bell*(M-Pc*GamC)/Pelcl

Mell = Melcl + Pelcl*Qell

b = ((Be-Bell)*(M-Pc*GamC)-Pelcl*GamLl)/GamEl + ;
((Pelcl*GamLl+Bell*(M-Pc*GamC))*Pnell)/(Pelcl*GamEl)-Pnell

c = -(Be*(M-Pc*GamC))*Pnell/GamEl

Pec1 = (-b + (b^2-4*c)^.5)/2

Qel = GamEl + Be*(M-Pc*GamC)/Pec1

Pel = Melcl/Qel + Pec1

Mel = Pel*Qel

Qnell = Qel - Qell

RETURN


```

FUNCTION Kwh
public _Kwh, _dKwh, Qell, Qnell, GamEl, Bell, Mel, Pelcl, Melcl, Pnell

Pnell = Pnel

fac1 = Pel*EnChg/EnChg0

shs1 = logit(shlnk + b.sh4*fac1/Pnell)
whs1 = logit(whlnk + b.wh4*fac1/Pnell)
cks1 = logit(cklnk + b.ck4*fac1/Pnell)
acs1 = logit(aclnk + b.ac4*fac1/Pc)

Pelcl = Pelc*EnChg/EnChg0
Melcl = Melc + (CusChg-CusChg0)*12

*Pelcl = Pelc
*Melcl = Melc

Bell = Bel

GamL1 = GamL0 + c.g8*10^-6*shs1*area*hdd65 + c.g9*10^-2*acs1*cdd65 ;
      + c.g10*cks1 + c.g11*whs1

GamEl = GamE0 + c.f8*10^-6*shs1*area*hdd65 + c.f9*10^-2*acs1*cdd65 ;
      + c.f10*cks1 + c.f11*whs1 + GamL1

Qell = GamL1 + Bell*(M-Pc*GamC)/Pelcl

b = ((Be-Bell)*(M-Pc*GamC)-Pelcl*GamL1)/GamEl + ;
    ((Pelcl*GamL1+Bell*(M-Pc*GamC))*Pnell)/(Pelcl*GamEl)-Pnell

c = -(Be*(M-Pc*GamC))*Pnell/GamEl

Pec1 = (-b + (b^2-4*c)^.5)/2
Qe = GamEl + Be*(M-Pc*GamC)/Pec1
Pe = Melcl/Qe + Pec1
Mel = Pe*Qe
Mel1 = Melcl + Pelcl*Qell
Qnell = Qe - Qell
_dKwh = (Qell-Qel)/.00341
_Kwh = Qell/.00341
RETURN _Kwh

PROCEDURE CUMPLOT      && Writes Cum Dist of Xval to CUMPLOT.PRN
parameter graphno
declare md(4), mn(4)
set safety off
use cumplot
zap
append from meam26
index on xval to t1
cum1 = 0
cum2 = 0
cum3 = 0
cum4 = 0
sum nweight, xval*nweight to sum1, mn(1) for '1'$ycat && majority
sum nweight, xval*nweight to sum2, mn(2) for '2'$ycat && black
sum nweight, xval*nweight to sum3, mn(3) for '3'$ycat && hispanic
sum nweight, xval*nweight to sum4, mn(4) for '4'$ycat && poor125
recnum = 0

```

```

scan all
  if '1'$ycat
    cum1 = cum1 + nweight
  endif
  if '2'$ycat
    cum2 = cum2 + nweight
  endif
  if '3'$ycat
    cum3 = cum3 + nweight
  endif
  if '4'$ycat
    cum4 = cum4 + nweight
  endif
  repl cumdis1 with cum1/sum1
  repl cumdis2 with cum2/sum2
  repl cumdis3 with cum3/sum3
  repl cumdis4 with cum4/sum4
  if cumdis1<=.5
    md(1) = xval
  endif
  if cumdis2<=.5
    md(2) = xval
  endif
  if cumdis3<=.5
    md(3) = xval
  endif
  if cumdis4<=.5
    md(4) = xval
  endif
  if module = 'URD'.or.module = 'ENTX'
    recnum = recnum + 1
    @11,17 say ' Records Done: '+str(recnum,4)+' '
  endif
endscan
mn(1) = mn(1)/sum1
mn(2) = mn(2)/sum2
mn(3) = mn(3)/sum3
mn(4) = mn(4)/sum4
outfile = trim(graphno)+'.prn'
copy fields xval,cumdis1,cumdis2,cumdis3,cumdis4 to &outfile delim ;
  for mod(recno(),16)=7
close data
titfile = trim(graphno)+'.tit'
fl = fcreate(titfile)
do case
  case module = 'URD'
    title = " CusChg "+str(CusChg,5,2)+" , EnChg "+str(EnChg,6,3) ;
      +", Qel "+str(KwhBar,4)+" , MarCost "+str(MarCst,6,3) ;
      +", BasCost "+str(NetRev,4)
  case module = 'DSM'
    title = trim(targfuel)+" Savgs "+str(sav,4,2)+"%, dRate "+str(cost,4,2) ;
      +", Ptr "+str(pr(1),4,2)+" , Group "+ltrim(rtrim(g(1)))
  case module = 'TAX'
    title = "Elec tax "+str(taxL,4,2)+"/MBtu Non-Elec tax
      "+str(taxN,4,2)+"/MBtu"
  otherwise
    title = "N/A"
endcase
a = fputs(fl, title)
a = fclose(fl)

```

```

mndfile = trim(graphno)+'.mnd'
f1 = fcreate(mndfile)
for i = 1 to 4
    mnd = str(md(i),8,3)+' ',''+str(mn(i),8,3)
    a = fputs(f1, mnd)
endfor
a = fclose(f1)
set safety on
RETURN

```

```

FUNCTION Consume
public GamC
private Mtot, beta, cpiu, cpiu89, Yd, K0
cpiu = 1.505
cpiu89 = cpiu*1.0851
beta = exp(-1.823-.561*afro-.281*latino)
beta = beta/(1+beta)
Yd = 0.961*hhinc-(1.0872*10^-6)*hhinc^2
K0 = exp(.283*hhsz-.0346*hhsz^2+.345*agehd-.00355*agehd^2)
Mtot = (1-beta)*cpiu*(K0/cpiu89)+beta*Yd
Mtot = 4*Mtot
GamC = K0/cpiu89
RETURN Mtot

```

```

FUNCTION ShLnkf
Pi = b.sh0 +b.sh1*10^-2*cdd65 +b.sh2*10^-5*hdd65 ;
    +b.sh3*10^-8*cdd65*hdd65 +b.sh5*10^-5*hhinc +b.sh6*10^-4*area ;
    +b.sh7*sfam2 +b.sh8*multi1 +b.sh9*multi2 +b.sh10*mobile +b.sh11*vnt40 ;
    +b.sh12*vnt50 +b.sh13*vnt75 +b.sh14*vnt80 +b.sh15*vnt87 ;
    +b.sh16*incity +b.sh17*poor +b.sh18*latino +b.sh19*afro
RETURN Pi

```

```

FUNCTION WhLnkf
Pi = b.wh0 +b.wh1*10^-2*cdd65 +b.wh2*10^-5*hdd65 ;
    +b.wh3*10^-8*cdd65*hdd65 +b.wh5*10^-6*hhinc +b.wh6*10^-4*area ;
    +b.wh7*sfam2 +b.wh8*multi1 +b.wh9*multi2 +b.wh10*mobile +b.wh11*vnt40 ;
    +b.wh12*vnt50 +b.wh13*vnt75 +b.wh14*vnt80 +b.wh15*vnt87 ;
    +b.wh16*incity +b.wh17*poor +b.wh18*latino +b.wh19*afro
RETURN Pi

```

```

FUNCTION CkLnkf
Pi = b.ck0 +b.ck1*10^-2*cdd65 +b.ck2*10^-5*hdd65 ;
    +b.ck3*10^-8*cdd65*hdd65 +b.ck5*10^-6*hhinc +b.ck6*10^-4*area ;
    +b.ck7*sfam2 +b.ck8*multi1 +b.ck9*multi2 +b.ck10*mobile +b.ck11*vnt40 ;
    +b.ck12*vnt50 +b.ck13*vnt75 +b.ck14*vnt80 +b.ck15*vnt87 ;
    +b.ck16*incity +b.ck17*poor +b.ck18*latino +b.ck19*afro
RETURN Pi

```

```

FUNCTION AcLnkf
Pi = b.ac0 +b.ac1*10^-2*cdd65 +b.ac2*10^-5*hdd65 ;
    +b.ac3*10^-8*cdd65*hdd65 +b.ac5*10^-6*hhinc +b.ac6*10^-4*area ;
    +b.ac7*sfam2 +b.ac8*multi1 +b.ac9*multi2 +b.ac10*mobile +b.ac11*vnt40 ;
    +b.ac12*vnt50 +b.ac13*vnt75 +b.ac14*vnt80 +b.ac15*vnt87 ;
    +b.ac16*incity +b.ac17*poor +b.ac18*latino +b.ac19*afro
RETURN Pi

```

```

FUNCTION Logit
parameter Pi
RETURN exp(Pi)/(1+exp(Pi))

```

FUNCTION PnelF

```

Pi = ne0 +ne4*10^-2*cdd65 +ne5*10^-2*hdd65 +ne6*10^-6*cdd65*hdd65 ;
    +ne7*10^-2*area +ne8*sfam2 +ne9*multi1 +ne10*multi2 +ne11*mobile ;
    +ne12*vnt40 +ne13*vnt50 +ne14*vnt75 +ne15*vnt80 +ne16*vnt87 ;
    +ne17*incity +ne18*poor +ne19*latino +ne20*afro
sh = logit(Pi)
mr = (1 - sh)*log(1 - sh)/sh + log(sh)
Pnel = p0 +p3*Pc +p4*10^-5*hdd65 +p5*10^-4*cdd65 +p6*vnt40 +p7*vnt50 ;
    +p8*vnt75 +p9*vnt80 +p10*vnt87 +p11*incity +p12*sfam2 +p13*multi1 ;
    +p14*multi2 +p15*mobile +p16*afro +p17*latino +p18*poor +p19*10^-5*area
;
    +p20*mr
RETURN m.Pnel

```

FUNCTION CVf

```

CV = Pc*GamC + Pelc1*GamL + Pnel1*(GamE-GamL) ;
    + Uex*Pelc1^Bel*Pnel1^(Be-Bel)*Pc^(1-Be)
RETURN. CV

```

PROCEDURE Setup26

```

clear
close data
select c
use parms67c index shrcatc
select b
use parms67b index shrcatb
select a
use meam26
set relation to shrcat into b, shrcat into c
RETURN

```

EPSIM Parameters

From PARMS67.DBF

NE0	NE4	NE5	NE6	NE7	NE8	NE9	NE10	NE11	NE12	NE13	NE14	NE15	NE16	NE17
1.800	-0.211	-0.017	0.558	0.023	-0.069	0.429	0.135	1.366	0.144	0.024	-0.467	-1.461	-1.357	-0.154
NE18	NE19	NE20	P0	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
0.115	1.455	1.804	0.345	2.946	-5.272	-3.220	0.108	0.183	-0.022	-1.052	-0.456	-0.256	0.018	0.078
P14	P15	P16	P17	P18	P19	P20								
-0.169	1.588	0.599	0.670	0.227	5.466	-2.414								

From PARMS67B.DBF

SHRCAT	SH0	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	SH11	SH12	SH13	SH14	
1	4.18	-0.24	-46.90	80.20	-1.87	-0.47	-0.03	1.04	2.65	1.57	-0.83	-0.32	0.00	1.24	1.64	
SH15	SH16	SH17	SH18	SH19	WHO	WH1	WH2	WH3	WH4	WH5	WH6	WH7	WH8	WH9	WH10	WH11
0.54	0.14	-1.00	0.00	0.00	3.83	0.03	-0.08	-10.43	-1.07	-0.81	-0.55	-0.24	-0.13	-0.86	-0.10	0.56
WH12	WH13	WH14	WH15	WH16	WH17	WH18	WH19	CK0	CK1	CK2	CK3	CK4	CK5	CK6	CK7	
0.46	-0.09	0.67	0.95	-0.62	0.00	0.00	0.00	1.46	0.00	8.00	3.59	-0.43	5.72	0.60	-0.13	
CK8	CK9	CK10	CK11	CK12	CK13	CK14	CK15	CK16	CK17	CK18	CK19	AC0	AC1	AC2	AC3	AC4
-0.15	0.61	-2.50	-0.53	-0.23	0.32	0.61	0.48	-0.26	-0.33	0.00	0.00	-3.49	0.11	-2.20	21.30	-0.03
AC5	AC6	AC7	AC8	AC9	AC10	AC11	AC12	AC13	AC14	AC15	AC16	AC17	AC18	AC19		
20.00	4.20	0.49	-0.05	0.11	0.02	-1.22	-0.56	0.44	0.77	0.83	0.25	-0.76	0.00	0.00		

SHRCAT	SH0	SH1	SH2	SH3	SH4	SH5	SH6	SH7	SH8	SH9	SH10	SH11	SH12	SH13	SH14	
2	8.64	0.49	67.00	-67.90	-2.82	-14.50	-27.10	2.04	-3.12	0.69	0.00	-2.97	0.00	3.05	2.73	
SH15	SH16	SH17	SH18	SH19	WHO	WH1	WH2	WH3	WH4	WH5	WH6	WH7	WH8	WH9	WH10	WH11
0.00	1.31	-2.83	0.00	0.00	1.71	0.25	35.00	-73.66	-1.28	-32.00	0.60	0.50	-0.92	0.55	0.00	0.00
WH12	WH13	WH14	WH15	WH16	WH17	WH18	WH19	CK0	CK1	CK2	CK3	CK4	CK5	CK6	CK7	
0.38	1.67	1.78	2.10	0.55	-1.28	0.00	0.00	3.31	-0.39	-34.90	90.10	-0.79	-3.37	-0.13	-0.02	
CK8	CK9	CK10	CK11	CK12	CK13	CK14	CK15	CK16	CK17	CK18	CK19	AC0	AC1	AC2	AC3	AC4
0.89	2.11	0.00	-0.72	-0.07	0.37	1.61	2.66	0.44	-0.76	0.00	0.00	-12.11	0.93	74.00	-88.00	0.00
AC5	AC6	AC7	AC8	AC9	AC10	AC11	AC12	AC13	AC14	AC15	AC16	AC17	AC18	AC19		
3.22	1.50	0.56	-1.22	1.57	0.00	-0.98	-0.75	0.98	1.48	-2.13	0.30	-1.55	0.00	0.00		

From PARMS67C.DBF

SHRCAT	A0	A1	A4	A5	B0	BEO	F0	F4	F5	F6	F7	F8	F9	F10	F11
1	389	-201	-28	31	0.0069	0.0034	55.91	2.60	4.30	2.81	0.96	-4.03	-1.40	1.06	-74.01
F12	F13	F14	F15	F16	F17	F18	F19	F20	G0	G4	G5	G6	G7	G8	G9
2.03	-1.46	29.24	16.47	-3.13	-11.51	-11.93	-31.25	0.50	-5.4	2.0	-0.5	0.4	0.6	4.6	0.5
G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20					
4.2	31.5	1.8	1.2	5.0	-0.2	-4.5	-4.1	-4.2	-0.9	2.4					

SHRCAT	A0	A1	A4	A5	B0	BEO	F0	F4	F5	F6	F7	F8	F9	F10	F11
2	389	-201	-28	31	0.0062	0.0031	107.22	2.96	2.36	4.44	-0.05	-4.88	-1.79	-52.06	-151.70
F12	F13	F14	F15	F16	F17	F18	F19	F20	G0	G4	G5	G6	G7	G8	G9
-0.12	0.00	0.00	28.54	-13.56	-53.94	-31.29	-54.58	3.99	6.1	2.4	-0.6	-0.1	-0.1	1.6	0.7
G10	G11	G12	G13	G14	G15	G16	G17	G18	G19	G20					
40.3	24.3	1.9	0.0	0.0	-0.7	1.4	1.7	-3.7	-9.0	2.6					

DATE

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END