Estimating an energy consumer price index from establishment survey data

Residential price and consumption estimates from the Energy Information Administration's establishment surveys can be used to estimate a consumer price index for energy at national and State levels; at the national level, the index is comparable to the energy component of the BLS Chained CPI and is more timely

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Over the past few decades, technological and societal changes have made household survey data collection increasingly difficult. Concerned about privacy and the possibility of identity theft, many Americans hesitate to disclose personal information to survey interviewers, in spite of the strict confidentiality protections government statistical agencies provide.

Household expenditure information has always been expensive and time-consuming to collect. Conducted by the Census Bureau for the Bureau of Labor Statistics (BLS), the Consumer Expenditure Survey (CE) is a comprehensive survey of household purchases that is seen by some as placing a heavy burden on responding households. Moreover, nonresponse and the potential for underreporting of purchases by respondents (partial response) present serious challenges for data collectors. In addition, CE data require several months of processing time after collection. The lag creates timeliness issues for data users including the BLS, which uses CE data to estimate relative importance weights for the Consumer Price Index (CPI).

Data collected through establishment surveys can be used to estimate some types of consumer expenditures. For many establishment surveys, such as those conducted by the Energy Information Administration (EIA), response is mandated by law, ensuring a high response rate. Establishment survey data can often be collected online or via automatic electronic data transfer, making the data less costly to collect and more timely than household survey data.

This article presents a new monthly Energy Consumer Price Index (ECPI) based primarily on establishment data collected through EIA surveys.[1] The ECPI estimation method, detailed in the Appendix, is also used to estimate regional and State-level energy CPI series. Targeting the Fisher index formula, the ECPI is conceptually similar to the energy component of the BLS Chained CPI (C-CPI-U), which targets a Törnqvist formula. For the period from 2005 to mid-2010, the ECPI tended to run below the energy components of both the CPI-U and the C-CPI-U. In this article, the similarities and differences among the three measures are examined by comparing the underlying data series using the data that were available as of September 2010. The analysis indicates that EIA establishment survey data are useful for estimating consumer expenditure weights for some energy products and services.

The ECPI and the BLS CPI

All data needed for computing the ECPI are available 6 to 7 weeks after the end of the reference month. Although the CPI-U and initial value of the C-CPI-U are published 2 to 3 weeks after the end of the reference month, the C-CPI-U undergoes two revisions—interim and final—and its final value is published 1 to 2 years after the reference month. Historically, the initial values of the C-CPI-U energy component have been relatively close to those of the CPI-U. The final C-CPI-U series, however, ran below the CPI-U for the 2005–2008 period.

Chart 1 shows the ECPI along with the CPI-U and C-CPI-U energy component series, based to December 1999. The ECPI series runs to April 2010. The final C-CPI-U extends to December 2008; interim C-CPI-U values are shown for 2009, and initial values for January through July 2010. The ECPI series tended to run below the other two series for months following mid-2005. Although the EPCI and final C-CPI-U values were very close for most months, the ECPI showed deeper troughs. The ECPI also ran substantially below the initial and interim values of the C-CPI-U for 2009 and 2010.

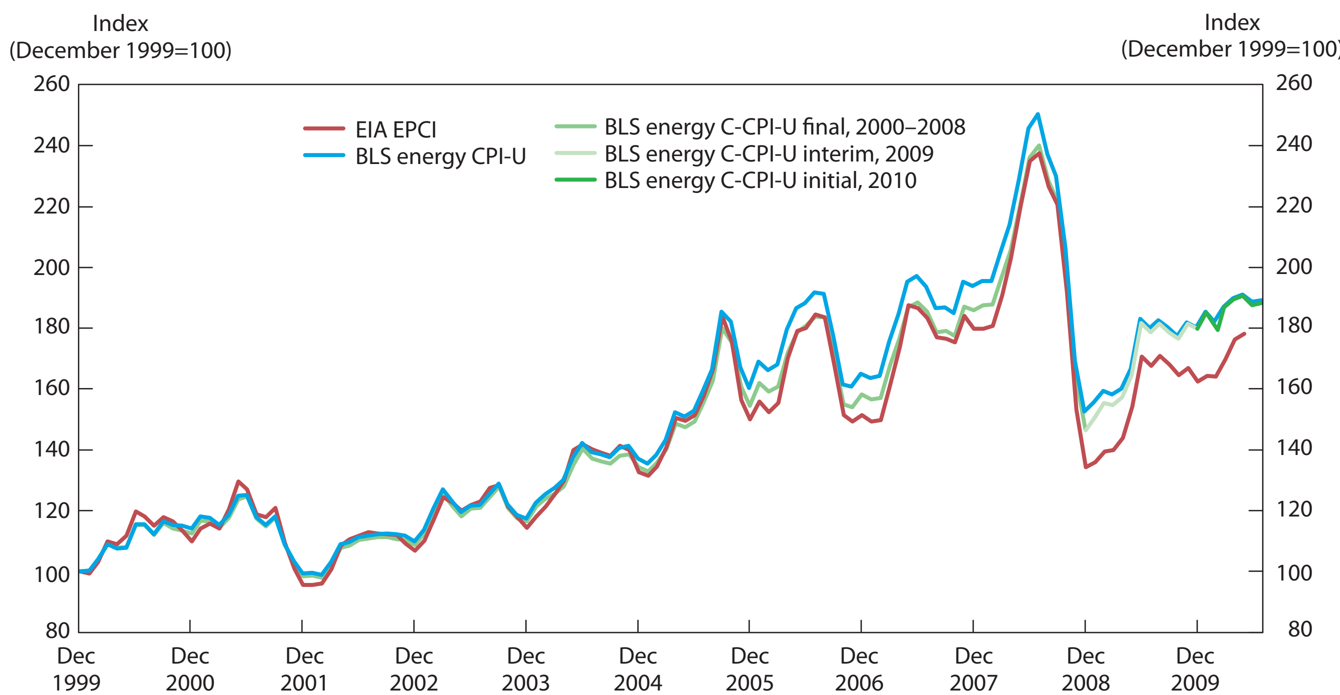
Energy prices and expenditure weights

The ECPI and the C-CPI-U both target "superlative" index formulas.[2] The reasons for the differences between the series can be found in the underlying data values. Both BLS and EIA publish average price estimates for energy products (e.g., gasoline, piped natural gas, electricity). The BLS average price estimates are computed from price quotes gathered monthly through the CPI price survey. The target population for this survey is "all urban consumers."

EIA average price estimates, however, are designed to cover both urban and rural populations. In addition to its monthly sample surveys, EIA conducts regular censuses of electricity and natural gas distributors and gathers data on residential, commercial, and industrial sales. With the exception of heating oil prices, the EIA residential prices collected include all taxes and distribution costs paid by residential customers.

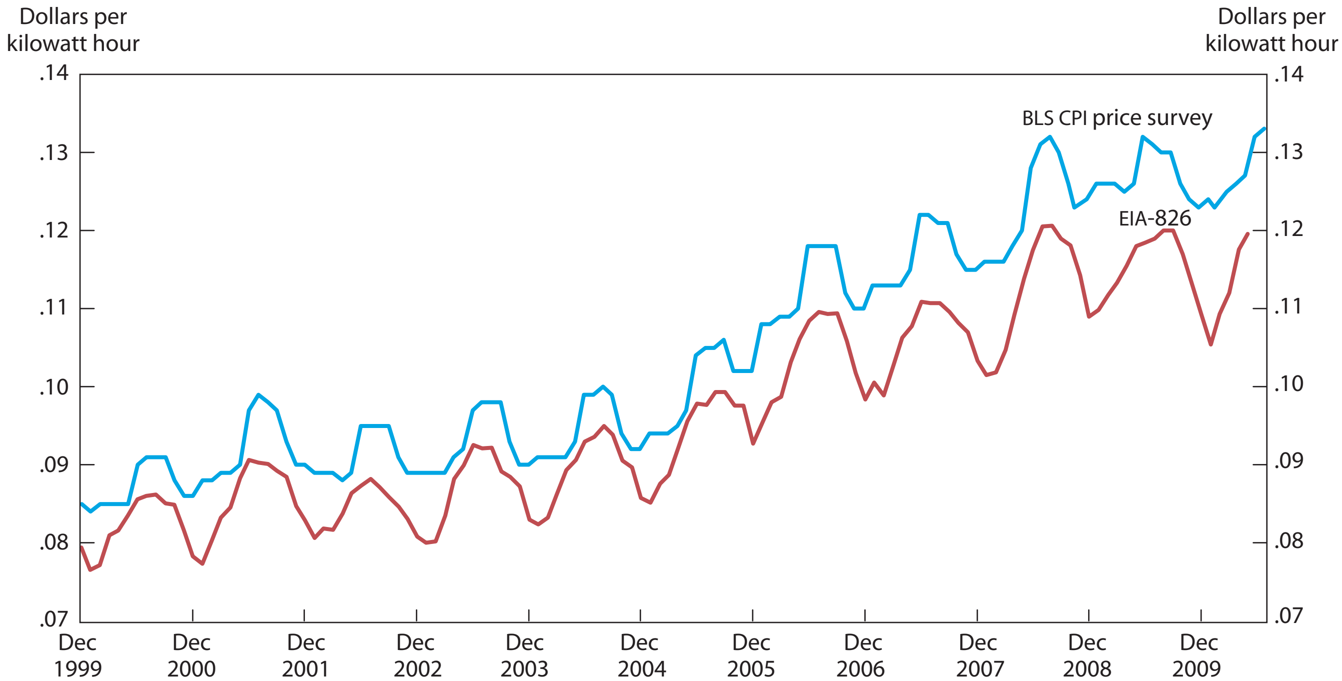
As illustrated in charts 2 through 5, the EIA national average price estimates tend to run below average price estimates published from the BLS CPI price survey. The differences may be due, in part, to the different target

Chart 1. EIA energy CPI (ECPI) and the BLS energy CPI-U and C-CPI-U series indexes, December 1999–June 2010



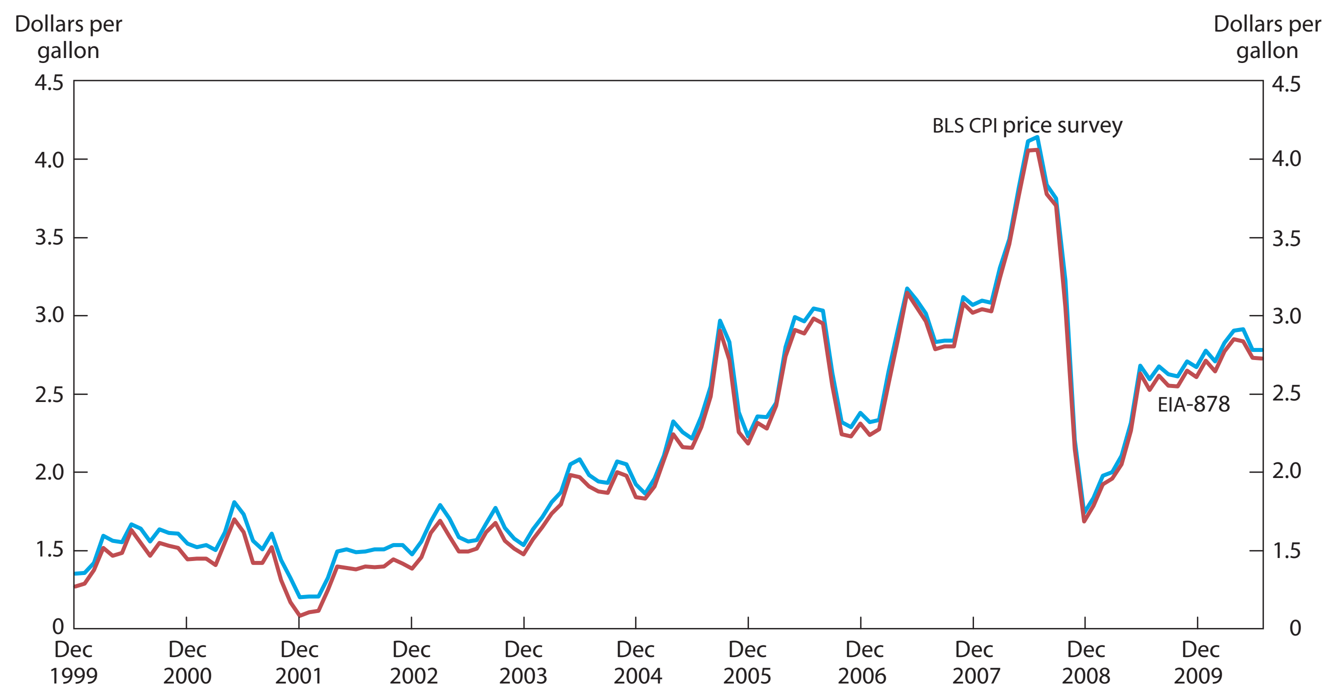
SOURCES: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 2. Average residential electricity prices from BLS and EIA, December 1999–July 2010



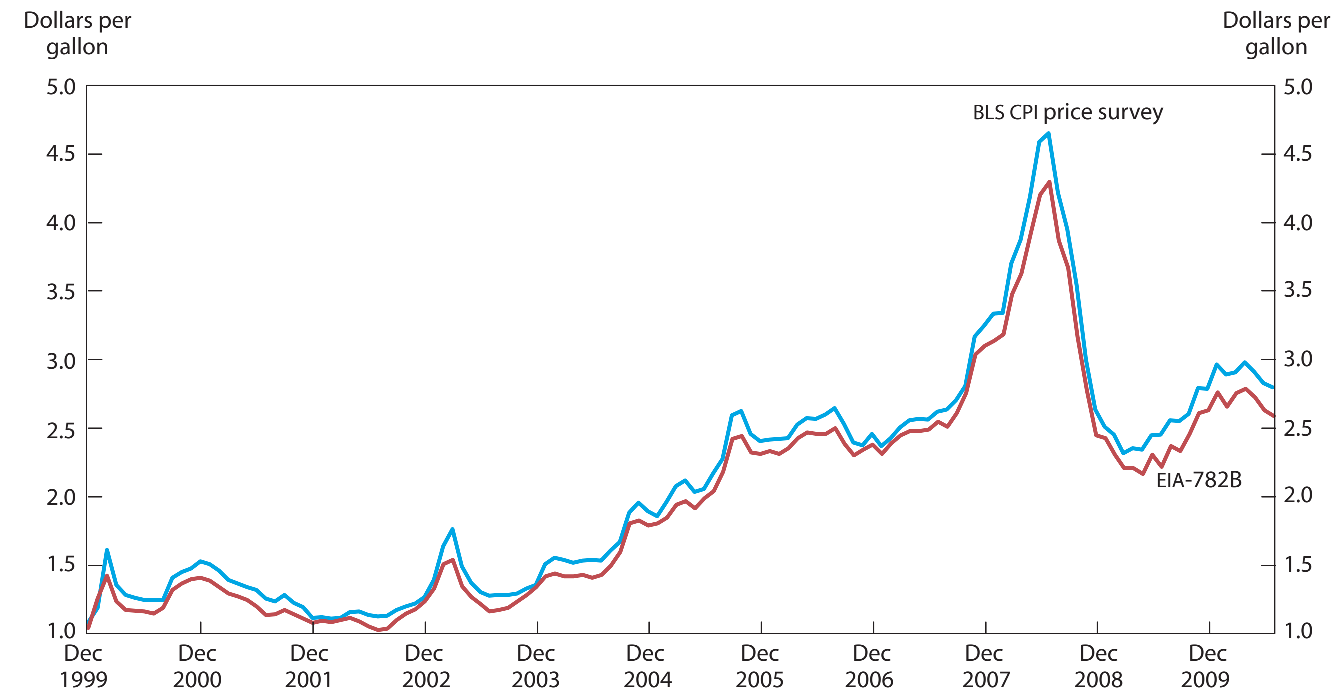
NOTE: EIA-826 is derived from the Energy Information Administration's "Monthly Electric Utility Sales and Revenue Report with State Distributions."
SOURCES: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 3. Average retail gasoline prices from BLS and EIA, December 1999–July 2010



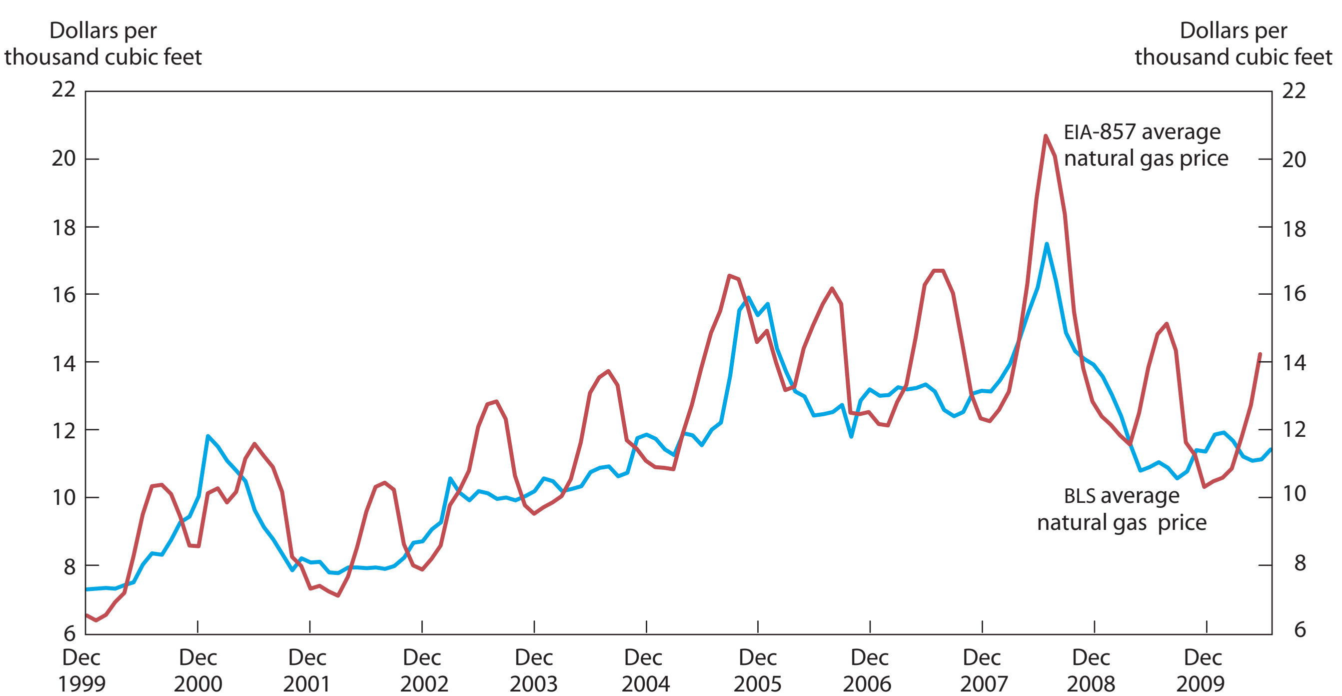
NOTE: Series include all gasoline grades and formulas. EIA-878 is derived from the Energy Information Agency's Motor Gasoline Price Survey.
SOURCES: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 4. Average heating oil prices from BLS and EIA, December 1999–July 2010



NOTE: EIA-782B is derived from the Energy Information Administration's "Resellers'/Retailers' Monthly Petroleum Product Sales Report."
SOURCES: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 5. Average residential natural gas prices from BLS and EIA, December 1999–July 2010



NOTE: EIA-857 is derived from the Energy Information Administration's "Monthly Report of Natural Gas Purchases and Deliveries to Consumers."
SOURCES: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

populations, as well as to differences in the survey methods and sample sizes used. The EIA price data for electricity, gasoline, and heating oil (charts 2 through 4) show deeper troughs than those observed for the BLS CPI prices. A comparison of the residential natural gas prices from the two sources (chart 5) shows a much more pronounced and regular seasonal pattern in the EIA series.

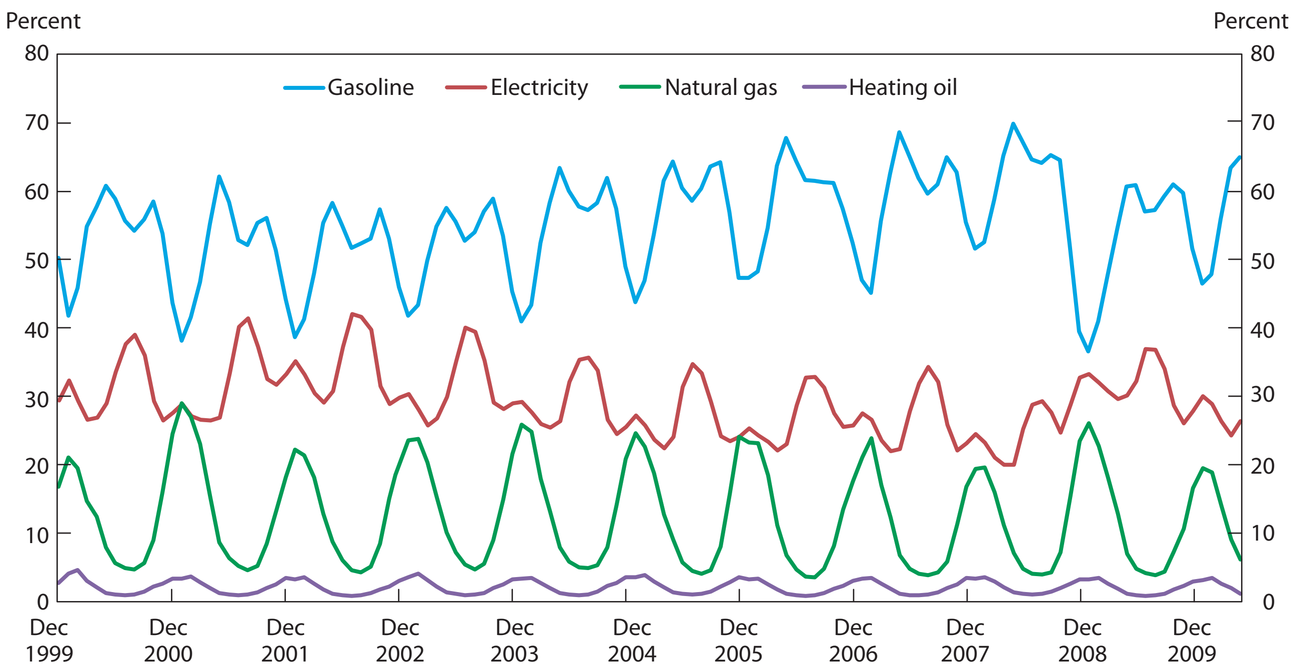
Differences in estimated expenditure share weights, as well as in price data, contribute to the differences between the ECPI and the C-CPI-U. The ECPI series relies on monthly weights. The weight series (in percentages) for the four largest energy components are shown in chart 6. The monthly weights are highly seasonal, with the summer peaks for the gasoline weights being regularly "bitten off" by the simultaneous peaks in electricity expenditure shares. The gasoline weights trend upward during 2004–2008, reflecting the rise in gasoline prices relative to prices of other energy sources. Expenditure estimates from the CE survey tend to be less seasonal, perhaps because of the 3-month recall period employed in CE data collection.

In the BLS CPI-U and C-CPI-U, the gasoline component relies on expenditure data collected through the Point of Purchase Survey (POPS), the CPI price survey, and the CE survey; the other energy components rely on expenditure data from the CE and supplementary data collected through the CPI program ("non-POPS" sources).

The 2009 CE energy expenditure share data for the Northeast and Midwest census regions are shown in charts 7 and 8, along with the shares for those census regions computed from State-level data used in the ECPI. The relative importance weights used in the BLS price indexes are based on CE data from urban areas only and thus differ somewhat from the published CE expenditure shares. In the 2009 CPI calculations, for example, motor fuel accounted for roughly 53 percent of household energy expenditures, compared with about 56 percent in the all-areas CE, indicating that urban households spend a smaller portion of their energy expenditures on motor fuel. Chart 9 shows the CPI-U relative importance weights for energy categories in 2009.

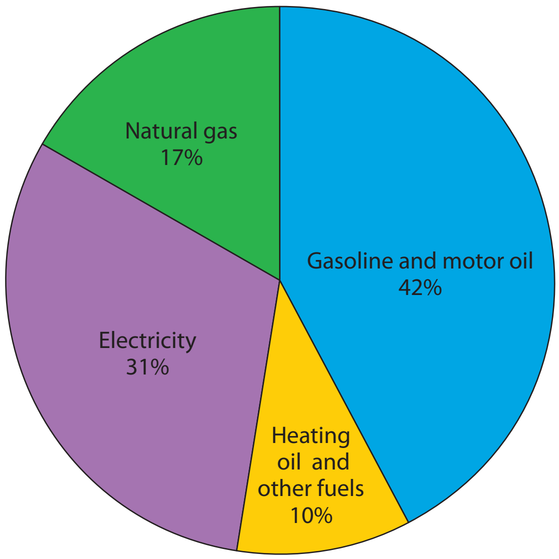
Charts 10 through 12 show the pattern of change over time in the CE weights for the three largest energy components, while charts 13 through 15 display the corresponding data for the weights used in the ECPI. The ECPI and CE expenditure share weights are not

Chart 6. ECPI national monthly energy expenditure shares by type of energy, December 1999–June 2010

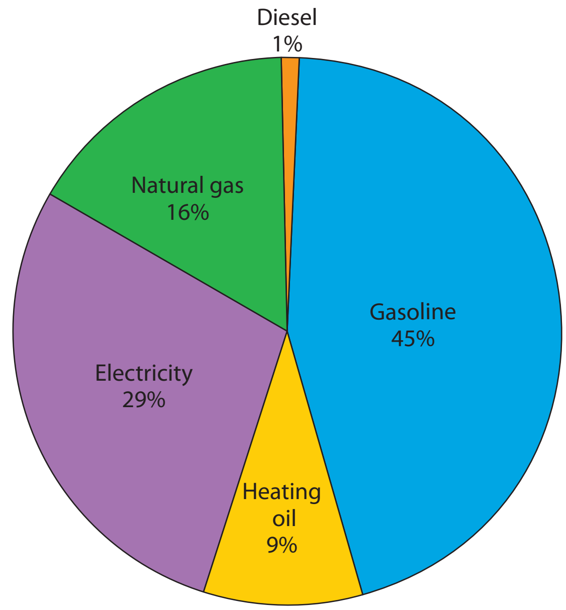


SOURCES: U.S. Bureau of Labor Statistics using data from the Energy Information Administration.

Chart 7. **Energy expenditure shares for the Northeast, 2009 annual averages**



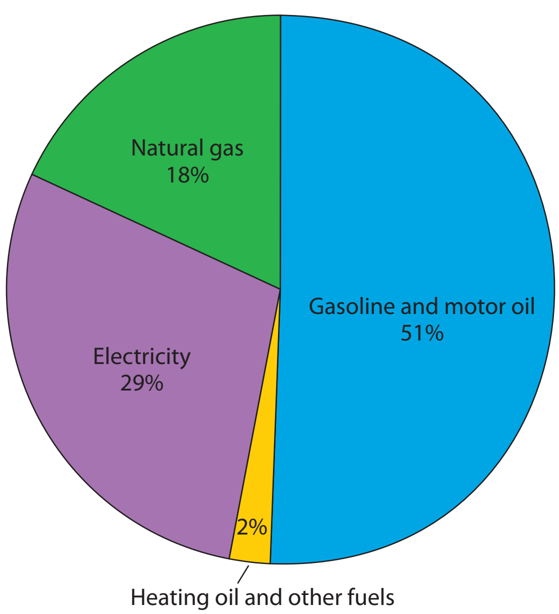
Consumer Expenditure Survey



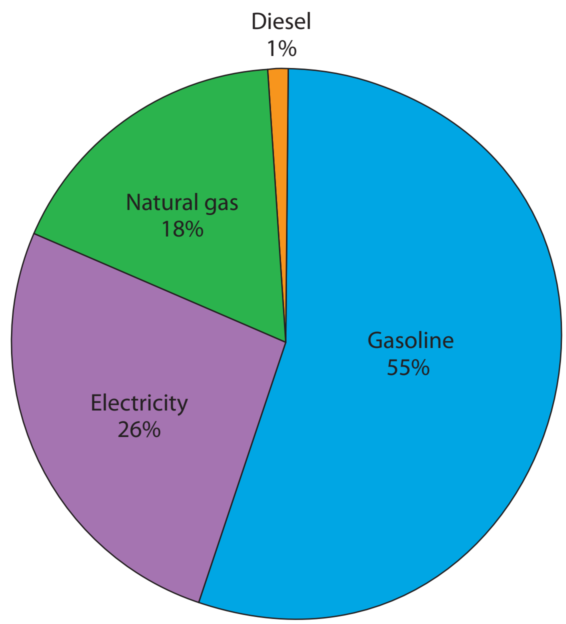
ECPI

SOURCE: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 8. **Energy expenditure shares for the Midwest, 2009 annual averages**



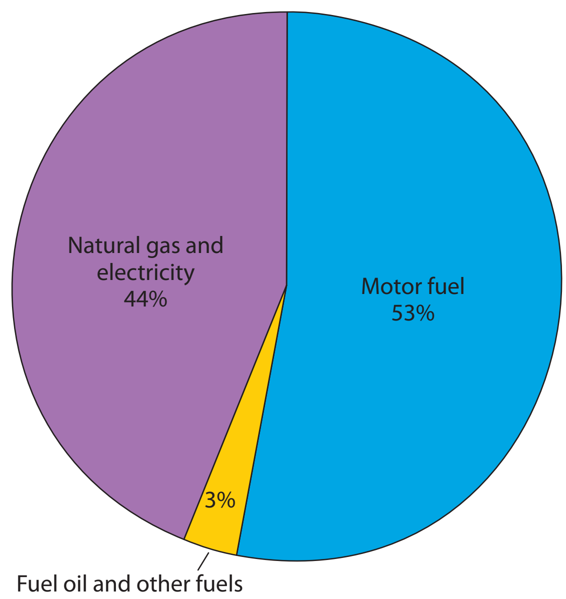
Consumer Expenditure Survey



ECPI

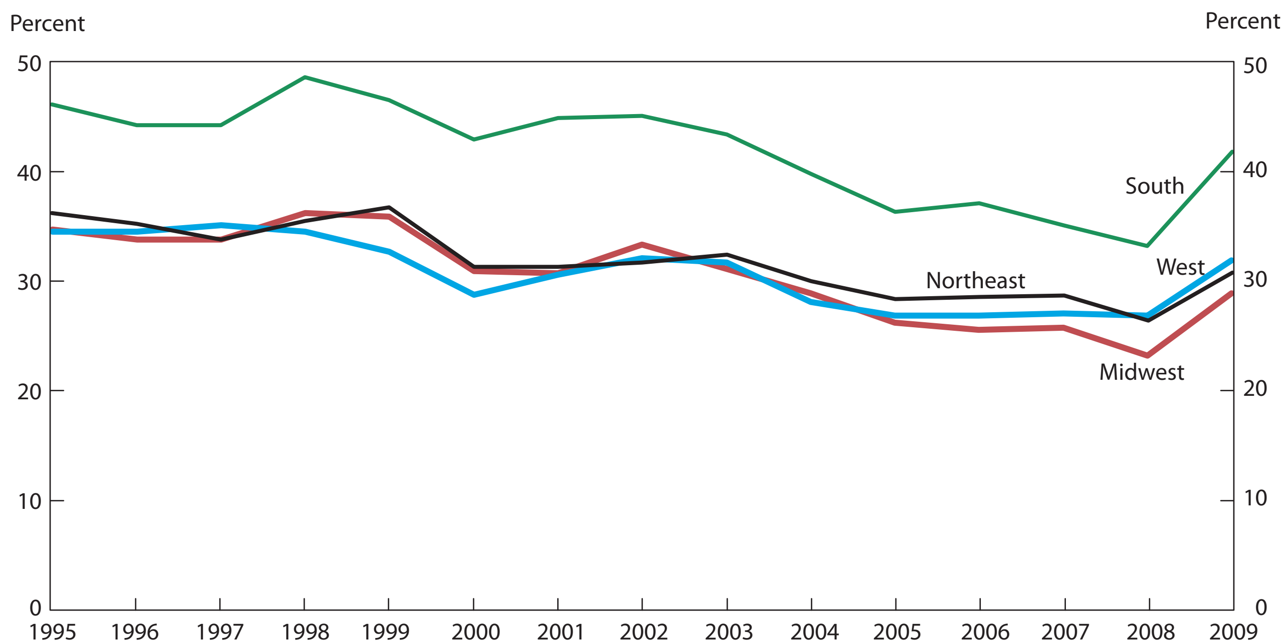
SOURCE: U.S. Bureau of Labor Statistics using data from BLS and the Energy Information Administration.

Chart 9. **Energy expenditure shares for urban areas from the CPI-U relative importance weights, 2009 annual averages**



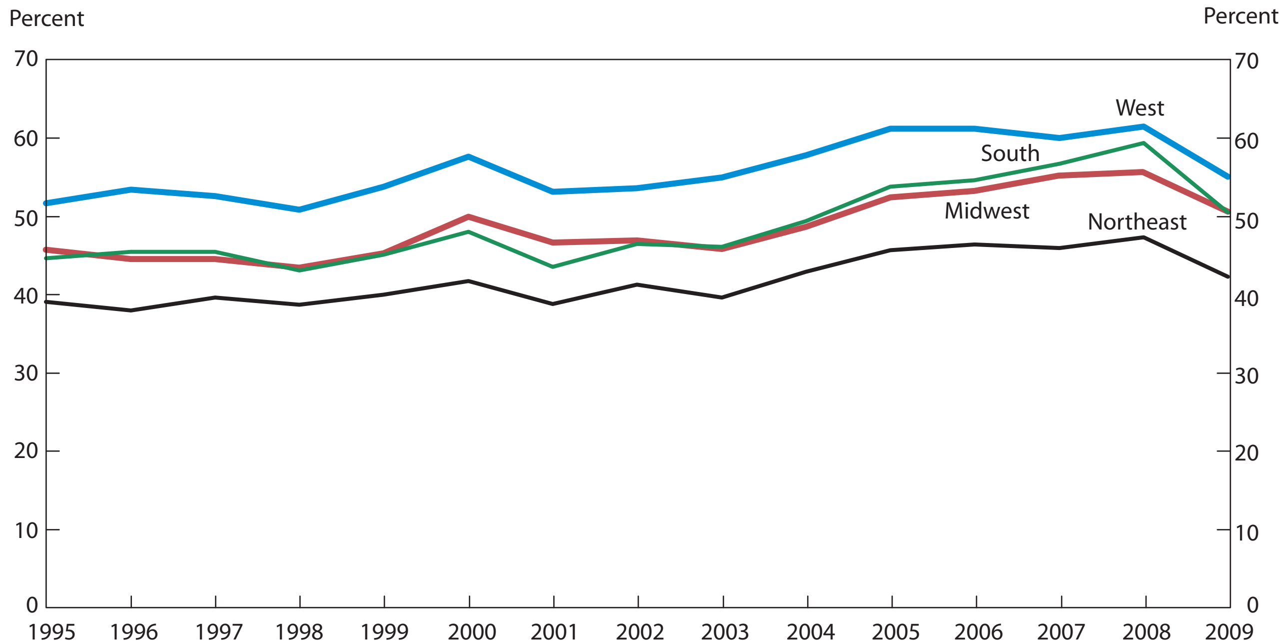
SOURCE: U.S. Bureau of Labor Statistics.

Chart 10. **Electricity expenditures as a percentage of energy expenditures, by region, from the Consumer Expenditure Survey, 1995–2009**



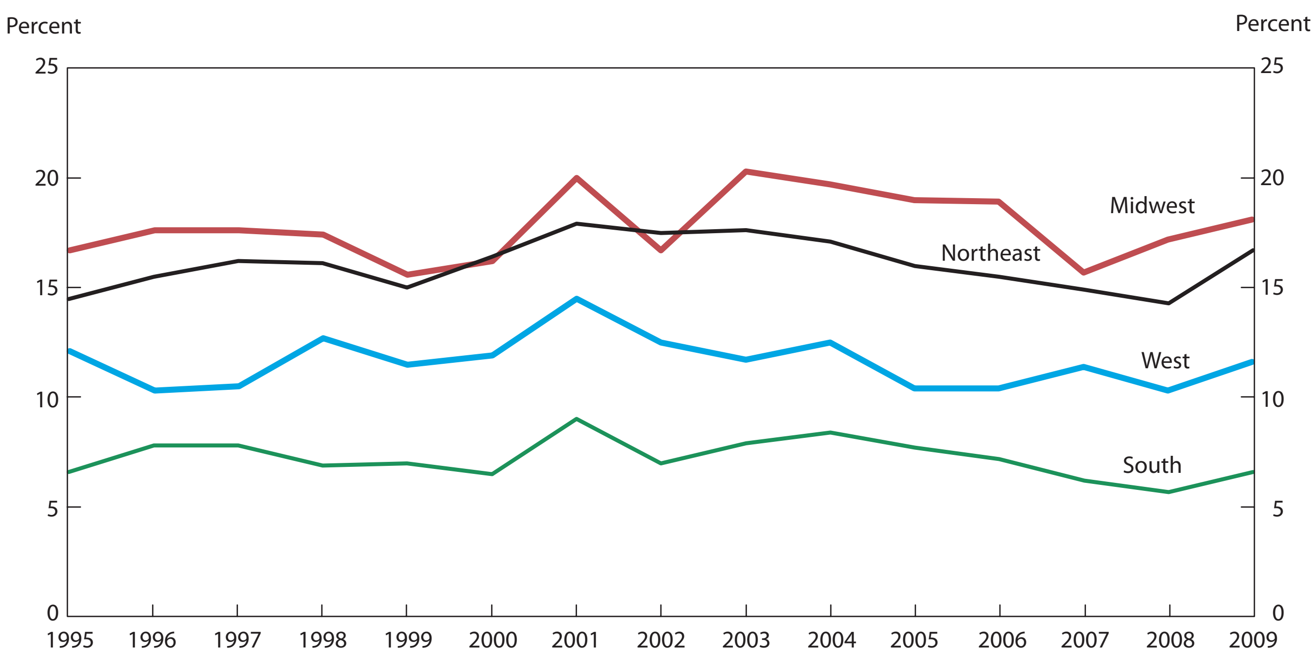
SOURCE: U.S. Bureau of Labor Statistics.

Chart 11. **Gasoline expenditures as a percentage of energy expenditures, by region, from the Consumer Expenditure Survey, 1995–2009**



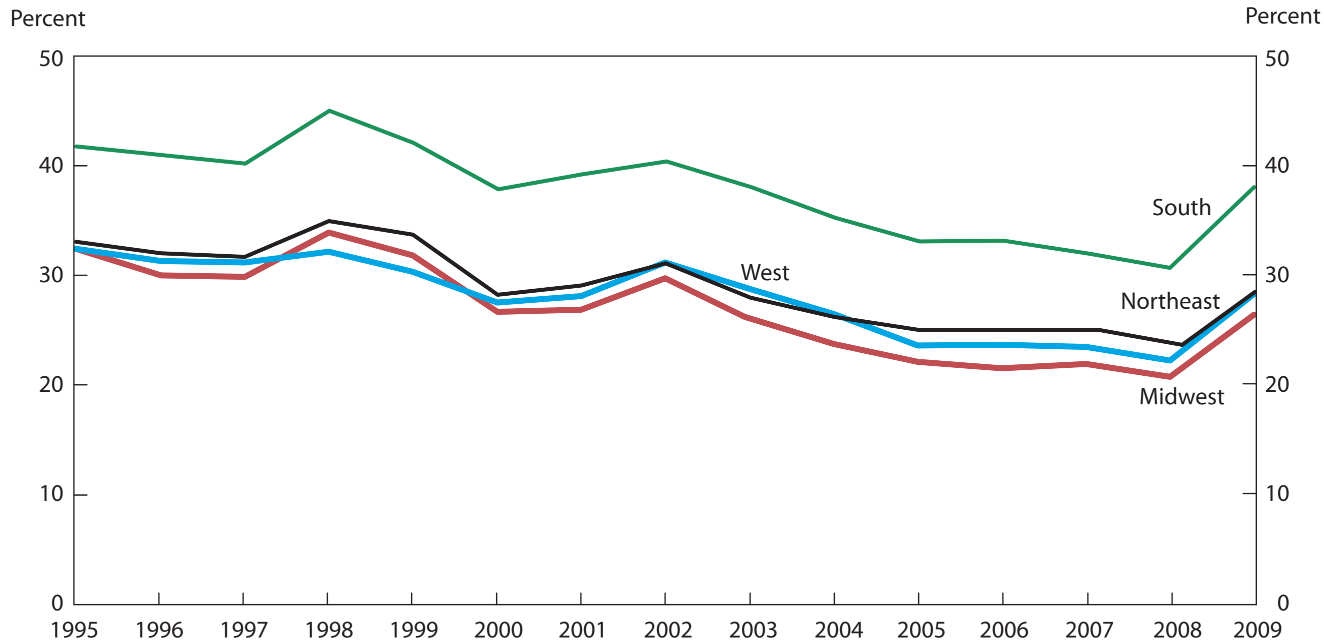
SOURCE: U.S. Bureau of Labor Statistics.

Chart 12. **Natural gas expenditures as a percentage of energy expenditures, by region, from the Consumer Expenditure Survey, 1995–2009**



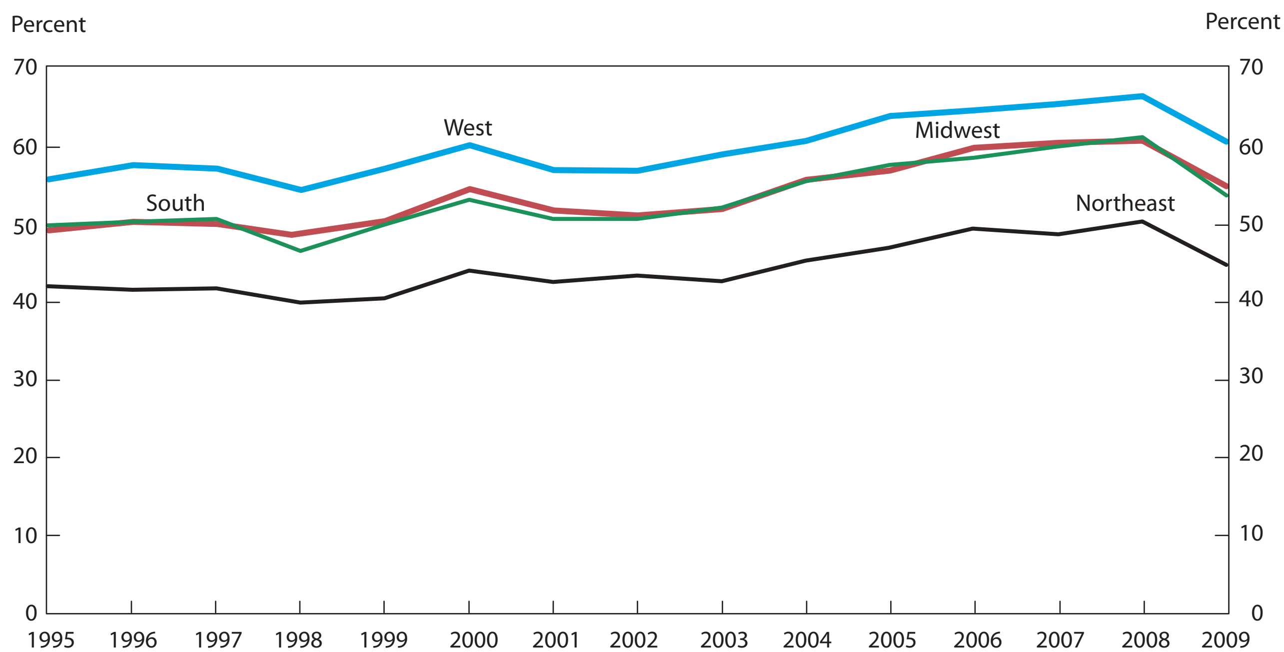
SOURCE: U.S. Bureau of Labor Statistics.

Chart 13. **Electricity expenditures as a percentage of energy expenditures, by region, from EIA ECPI data, 1995–2009**



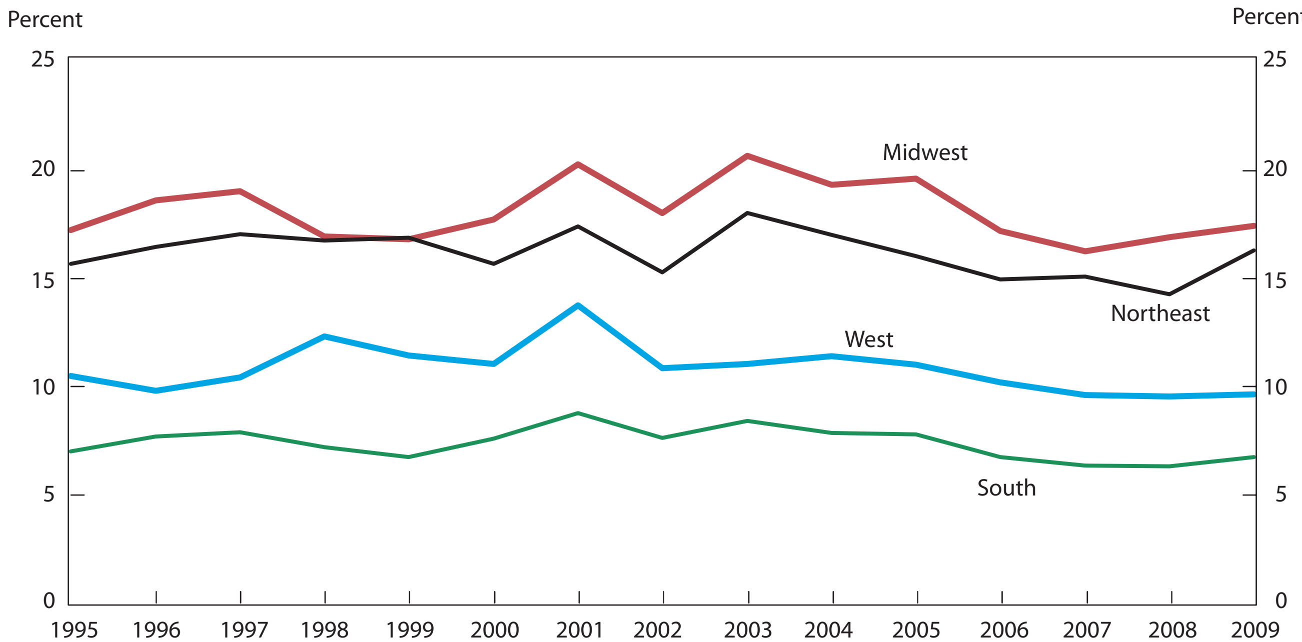
SOURCES: U.S. Bureau of Labor Statistics using data from the Energy Information Administration.

Chart 14. **Gasoline expenditures as a percentage of energy expenditures, by region, from EIA ECPI data, 1995–2009**



SOURCES: U.S. Bureau of Labor Statistics using data from the Energy Information Administration.

Chart 15. Natural gas expenditures as a percentage of energy expenditures, by region, from EIA ECPI data, 1995–2009



SOURCES: U.S. Bureau of Labor Statistics using data from the Energy Information Administration.

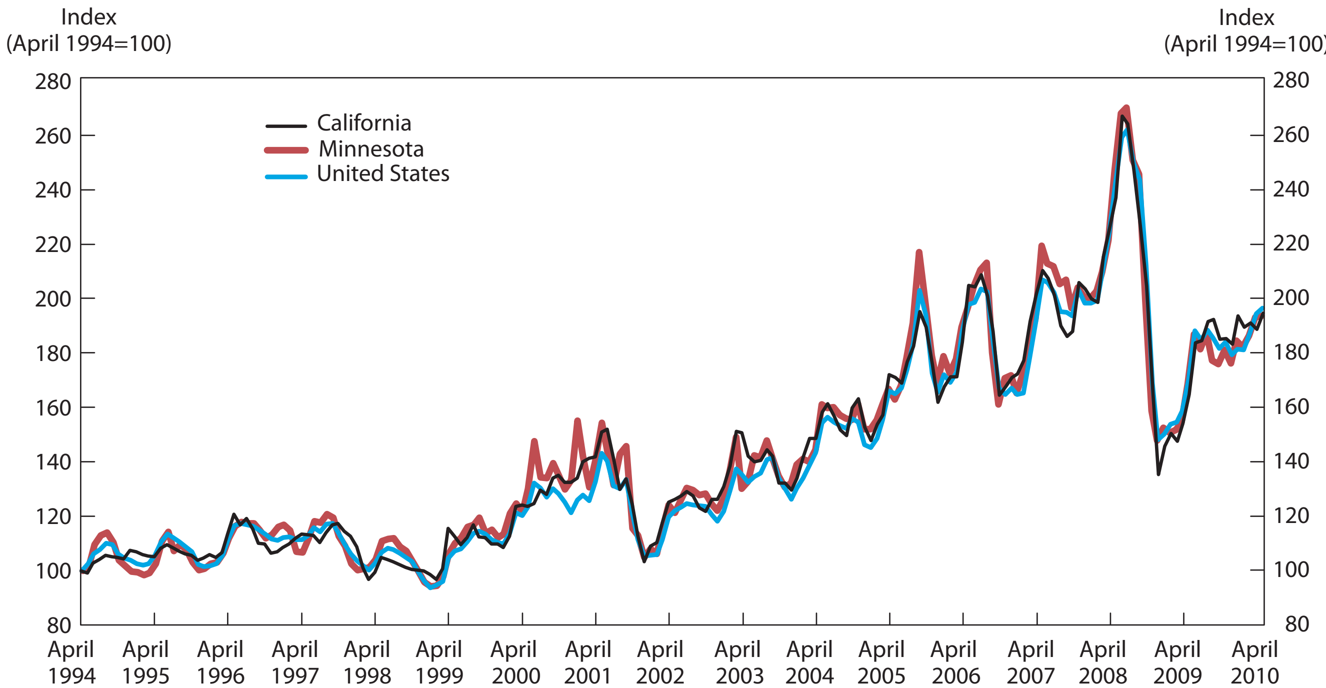
directly comparable, because of definitional differences. The published CE shares for gasoline, for example, also include motor oil. The data nevertheless indicate that the ECPI weights provide reasonable approximations to the CE shares and display the same pattern of regional differences and changes over time.

The primary difference between the ECPI and CE energy expenditure shares is the higher values of the gasoline shares computed for the ECPI. This difference may be due in part to what we believe is respondents' underreporting of gasoline purchases in the CE survey, although additional factors are likely to contribute to the difference. The ECPI motor fuel use estimates rely on model-based estimates computed from mileage data reported in the National Household Travel Survey, and therefore are affected by model assumptions. Improved data on household motor fuel use would be helpful in estimating biases that may be present in both the CE and ECPI expenditures shares. EIA is preparing to launch a Residential Transportation Energy Consumption (RTECS) survey in 2012.

The ECPI estimation method can also be used to estimate energy CPI series for States and census divisions. Chart 16 shows examples of ECPI series for two States, California and Minnesota. Although the State-level series follow national-level trends and long-term cycles, some important differences are evident in chart 16. The Minnesota series, for example, displays a more pronounced seasonal pattern with some erratic behavior during the 2000–2001 period. This behavior is due to volatility in residential natural gas prices experienced in some parts of the country during this period. The deeper troughs and higher peaks in the California series for recent years result from larger gasoline expenditure shares—attributable, in part, to lower than average heating and cooling expenditures for this State.

SUPPLIERS OF ELECTRICITY, HEATING OIL, AND NATURAL GAS maintain records of quantities sold to, and revenues from, residential customers. Through establishment surveys, these suppliers provide aggregate energy consumption data for large numbers of households. Reliable estimates of in-home energy consumption can therefore be computed from establishment survey data. Household motor fuel use is more difficult to estimate, because gas stations don't collect data on their customers' usage (residential or commercial).

Chart 16. **Examples of State-level ECPI series, April 1994–April 2010**



SOURCES: U.S. Bureau of Labor Statistics using data from the Energy Information Administration.

The data presented here demonstrate that an energy consumer price index can be estimated primarily using data collected through EIA's establishment surveys. Energy estimates from the ECPI run close to the final C-CPI-U energy component, except for lower troughs that appear to be due primarily to different target populations and different expenditure share weights for gasoline. In spite of the differences, the evidence suggests that EIA establishment survey data may be useful in estimating the interim C-CPI-U energy component. The State-level ECPI series are also useful for evaluating the impacts of State energy policies on consumers. □

Notes

ACKNOWLEDGMENT: The author gratefully acknowledges the helpful comments provided by Alan Dorfman of BLS on drafts of this paper.

[1] The ECPI is based entirely on data available for download from the EIA public website. SAS programs for computing the indexes (at State, regional, and national levels), along with runtime instructions, are available from the author upon request.

[2] See W. Erwin Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, vol. 4, no. 2 (May 1976), pp. 115–145.

APPENDIX: Estimating the EIA Energy Consumer Price Index (ECPI)

Target price index formulas

A price index measures the change in the purchasing power of a currency between two time periods, either for all purchases or for a specific target category of goods and services. The Energy Consumer Price Index (ECPI) indicates monthly price changes, at the State level, for household energy services and fuels. The ECPI estimator is based on two index formulas, the Fisher index[1] and the unit value index. The Fisher index formula is given by

$$F = \sqrt{LP}, \tag{1.1}$$

where L is the Laspeyres index, and P is the Paasche index. The textbook Laspeyres formula is

$$L = \frac{\sum_{i=1}^{N} q_{i,1} p_{i,2}}{\sum_{i=1}^{N} q_{i,1} p_{i,1}}, \tag{1.2}$$

where N is the number of items in the target population, and, for $t \in \{1, 2\}$, $p_{i,t}$ and $q_{i,t}$ denote the price and quantity purchased, respectively, of item i in time period t, $i = 1, 2, \ldots, N$. In the ECPI series, the time periods are months. We may also write

$$L = \sum_{i=1}^{N} w_{i,1} \left(\frac{p_{i,2}}{p_{i,1}} \right), \tag{1.3}$$

where $w_{i,t} = \dfrac{q_{i,t} p_{i,t}}{\sum_{i=1}^{N} q_{i,t} p_{i,t}}$, the expenditure share associated with item i in time $t \in \{1,2\}$.

The Paasche index P, which also contributes to the Fisher, is similar to the Laspeyres, but P is based on quantity measures from the second time period:

$$P = \frac{\sum_{i=1}^{N} q_{i,2} p_{i,2}}{\sum_{i=1}^{N} q_{i,2} p_{i,1}} = \frac{1}{\sum_{i=1}^{N} w_{i,2} \left(\frac{p_{i,2}}{p_{i,1}} \right)^{-1}}. \tag{1.4}$$

At the State/energy category level in the ECPI, the unit value index[2] is used as an approximation of the Fisher. Simpler than the Fisher, the unit value index is often used for aggregating prices within narrowly-defined categories of items measured in the same units.[3] For such a category c (e.g., residential natural gas purchased in a particular State) and for $t \in \{1,2\}$ let

$$q_{c,t} = \sum_{i \in c} q_{i,t}. \tag{1.5}$$

The unit value index for category c is defined as

$$u_c = \frac{\sum_{i \in c} q_{i,2} p_{i,2} / q_{c,2}}{\sum_{i \in c} p_{i,1} q_{i,1} / q_{c,1}}. \tag{1.6}$$

In words, the unit value index is the average price paid for an item in category c during time period 2 divided by the average price paid for an item in category c during time period 1.

ECPI input data

The ECPI incorporates price and quantity (residential sales or consumption) data from numerous EIA surveys. What follows is a description of the input data for each of the ECPI components. Detailed information about each survey is available on the EIA website at **www.eia.doe.gov**.

Electricity and natural gas components. The electricity and natural gas components are the two simplest energy components in the ECPI. Price and quantity data are drawn from the following surveys:

- Electricity: Residential price and sales data from "Monthly Electric Utility Sales and Revenue Report with State Distributions" (EIA-826)
- Natural gas: Residential price and sales data from "Monthly Report of Natural Gas Purchases and Deliveries to Consumers" (EIA-857)

Where monthly State-level estimates are missing, they are imputed using the method described by Lent.[4] For regulated utilities, many price increases occur in January, and this affects the seasonal pattern of electricity prices.

Motor fuel component (gasoline and diesel fuel). The ECPI motor fuel component incorporates data from the following sources:

- Average gasoline prices (all grades) from the Motor Gasoline Price Survey (EIA-878)
- Average diesel fuel prices from the On-Highway Diesel Fuel Price Survey (EIA-888)
- Residential consumption volumes estimated by combining data from the following sources:

  —"Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption" (EIA-782C)

  —"National Household Travel Survey, 2001," published by the Federal Highway Administration (FHWA)

  —Fuel use data for cars and light trucks published in the *Transportation Energy Data Book,*[5] Edition 29, to estimate the proportion of diesel fuel (versus gasoline) used in household vehicles

For nine States, the State-level average gasoline prices are sufficiently reliable for publication. For the remaining States, we used prices estimated at the Petroleum Administration for Defense District (PADD) level. For diesel fuel, we used PADD-level prices for all States except California. Our research indicates that motor fuel prices in different parts of the country tend to follow the same movements with regard to trends and long-term cycles, in spite of varying price levels and irregular movements. For all States for which we could make comparisons, we found little difference between the ECPI series computed from State-level gasoline prices and those computed from PADD-level gasoline prices.

To estimate household gasoline consumption by State, we computed adjustment factors that could be applied to the State-level EIA estimates of gasoline sales by prime suppliers[6] (including sales to nonresidential customers) to reduce them to levels representative of household sales levels. We used the most recent available household motor fuel consumption estimates, which are based on data from the 2001 National Household Transportation Survey (NHTS).[7] Because the NHTS consumption estimates were published by census division rather than by State, we computed the adjustment factors by census division and applied them to the State-level estimates of gasoline sales by prime suppliers.

From the 2001 NHTS, we obtained estimated numbers of "gasoline equivalents" (gallons of gasoline or diesel fuel) used by households in each census division. For each census division d, we estimated an adjustment factor to convert prime supplier sales volumes for gasoline into gasoline equivalents used by households:

$$f_{d.h,2001} = \frac{g_{d,h,2001}}{g_{d,\,2001}}, \qquad (2.1)$$

where

$g_{d,h,2001} =$ number of gasoline equivalents for households in census division d in 2001;

$g_{d,\,2001} =$ total number of gallons of gasoline sold by prime suppliers in census division d in 2001.

Thus we implicitly assumed that the ratio $f_{d,h,2001}$ of household gasoline consumption to gasoline sales by prime suppliers was constant across the time used in this study and across States within each census division. The ratio will be updated when new data become available.

To estimate household diesel fuel consumption, we used data provided in tables A1 and A5 of the *Transportation Energy Data Book,* Edition 29. These tables give estimated volumes of fuel used in automobiles and light trucks, along with proportions of gasoline and diesel used in each type of vehicle. We estimated the annual proportion of household gasoline equivalents accounted for by diesel fuel as

$$\pi_{D,y} = \frac{\pi_{D,a,y}Q_{a,y} + \pi_{D,l,y}Q_{l,y}}{Q_{a,y} + Q_{l,y}}, \qquad (2.2)$$

where

$\pi_{D,a,y}$ and $\pi_{D,l,y}$ represent gallons of diesel fuel as proportions of the total gallons of fuel used in automobiles and light trucks, respectively, in year *y*; and

$Q_{a,y}$ and $Q_{l,y}$ represent total gallons of fuel used in automobiles and light trucks, respectively, in year *y*.

For the years 1994 to 2008, the annual estimates $\pi_{D,a,y}$, $\pi_{D,l,y}$, $Q_{a,y}$, and $Q_{l,y}$ were obtained from the *Transportation Energy Data Book*. Because 2008 was the most recent year for which these data were available, and there was little change in the diesel proportions for the years 2000 to 2007, we used the 2008 estimates for the years 2009 and 2010.

We then computed monthly State-level estimates of household gasoline and diesel fuel consumption, respectively, for State *s* in month *m* of year *y* as

$$\hat{q}_{G,s,h,m,y} = g_{s,m,y} f_{d,h,2001} (1 - \pi_{D,y}) \tag{2.3}$$

and

$$\hat{q}_{D,s,h,m,y} = g_{s,m,y} f_{d,h,2001} \pi_{D,y}. \tag{2.4}$$

The main contributor to change in both of these estimates is $g_{s,m,y}$, the monthly State-level estimate of prime supplier gasoline sales volumes from the EIA-782C. Thus changes in the volumes are driven by current State-level EIA data. We chose gasoline prime supplier sales volumes over a weighted average of gasoline and diesel sales volumes because diesel sales are dominated by sales to nonresidential customers (e.g., commercial motor carriers). Changes in diesel sales volumes may not reflect changes in household motor fuel consumption patterns. Although the ECPI includes, from a computational standpoint, two motor fuel components (gasoline and diesel fuel), we expect the quantity weights for both to follow essentially the same pattern of change over time.

Heating oil component. The ECPI series for the following 10 States incorporate a component for home heating oil: Connecticut, Maine, New Hampshire, Rhode Island, Vermont, Massachusetts, Maryland, New Jersey, New York, and Pennsylvania. The series for the New England and Middle Atlantic census divisions also include heating oil data. For the remaining States and census divisions, the EIA data on home heating oil were deemed too unstable to use in the ECPI or were missing.

The heating oil component incorporates data from the following sources:

- Residential price data from "Resellers'/Retailers' Monthly Petroleum Product Sales Report" (EIA-782B)
- Residential consumption data from "Annual Fuel Oil and Kerosene Sales Report" (EIA-821). Monthly estimates are extrapolated from the annual data using monthly data from "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption" (EIA-782C).

To estimate monthly residential consumption of No. 2 distillate fuel oil by State, we use the monthly total consumption volumes from the EIA-782C to approximate the seasonal pattern of fuel oil consumption. We expect the seasonal pattern of residential use to be more pronounced than that of industrial use or electric power sector use. Because the proportion of total consumption attributable to residential use has increased over time, the seasonal pattern from a recent year is likely to more accurately reflect residential seasonality than would the seasonal pattern estimated from older data.

We let $q_{y,m}$ be the estimated volume (in gallons) of No. 2 distillate fuel oil sold by prime suppliers in month *m* of year *y* for a particular State.[8] Then

$$q_{y,m} = q_{R,y,m} + q_{N,y,m}, \tag{2.5}$$

where $q_{R,y,m}$ and $q_{N,y,m}$ (both unknown) represent sales volumes to residential and nonresidential customers, respectively. We computed these as

$$q_{R,y} = \sum_{m=1}^{12} q_{R,y,m}, \text{ and } q_y = \sum_{m=1}^{12} q_{y,m}, \tag{2.6}$$

We let $\breve{y}$ be the year having the maximum value of the proportion $\frac{q_{R,y}}{q_y}$ among all the years for which data are available. Because of the increasing proportion of total consumption attributable to residential use, we used the most recent data available to estimate the seasonal ratios $\frac{q_{y,m}}{q_y}$. For the initial ECPI series, we set $\breve{y} = 2008$. From the EIA-821, we have the annual residential sales estimates, $v_{R,y}$; we estimate the monthly State-level residential sales volumes as

$$\hat{q}_{R,y,m} = q_{R,y} \left(\frac{q_{\breve{y},m}}{q_{\breve{y}}} \right). \tag{2.7}$$

Although the use of $\hat{q}_{R,y,m}$ in place of actual monthly State-level data on residential consumption is likely to dampen the seasonal pattern somewhat, the effect should be minimal because, for $\breve{y} = 2008$, we have $\frac{q_{R,\breve{y}}}{q_{\breve{y}}} > 0.8$.

For details on the research underlying the estimation method for the heating oil component, see Lent.[9]

Price index estimators

Using the data described above, we computed price indexes measuring change between two months, t_1 and t_2. Note that the formulas given here are completely general with regard to the two time periods, so that t_1 and t_2 need not be consecutive months.

We first estimated unit value indexes at the State level for each energy component. For $i \in \{1, 2\}$, we let $\hat{\bar{p}}_{c,s,t_i}$ be the average price of one unit of energy in component (or category) c in State s during month t_i (taking the most up-to-date revised price estimate available on the EIA website). Similarly, we let $\hat{q}_{c,s,t_i}$ be the estimated number of units of energy component c purchased by residential customers in State s during month t_i. We estimated the unit value index representing price change from month t_1 to month t_2 as

$$\hat{u}_{c,s,t_1,t_2} = \frac{\hat{\bar{p}}_{c,s,t_2}}{\hat{\bar{p}}_{c,s,t_1}}. \quad (3.1)$$

The State-level Laspeyres and Paasche indexes representing price change from month t_1 to month t_2 may then be estimated as

$$\hat{L}_{s,t_1,t_2} = \sum_c \hat{w}_{c,s,t_1} \hat{u}_{c,s,t_1,t_2} \quad (3.2)$$

and

$$\hat{P}_{s,t_1,t_2} = \frac{1}{\sum_c \frac{\hat{w}_{c,s,t_2}}{\hat{u}_{c,s,t_1,t_2}}}, \quad (3.3)$$

respectively, where, for $i \in \{1, 2\}$,

$$\hat{w}_{c,s,t_i} = \frac{\hat{q}_{c,s,t_i} \hat{\bar{p}}_{c,s,t_i}}{\sum_c \hat{q}_{c,s,t_i} \hat{\bar{p}}_{c,s,t_i}}. \quad (3.4)$$

The State-level Fisher index estimator is simply

$$\hat{F}_{s,t_1,t_2} = \sqrt{\hat{L}_{s,t_1,t_2} \hat{P}_{s,t_1,t_2}} \quad . \quad (3.5)$$

To estimate indexes for census divisions, we aggregated the unit value indexes $\hat{u}_{c,s,t_1,t_2}$ across components and States within each census division d:

$$\hat{L}_{d,t_1,t_2} = \sum_{s \in d} \sum_c \hat{w}_{c,s,t_1,t_2} \hat{u}_{c,s,t_1,t_2}, \quad (3.6)$$

$$\hat{P}_{d,t_1,t_2} = \frac{1}{\sum_{s \in d} \sum_c \frac{\hat{w}_{c,s,t_2}}{\hat{u}_{c,s,t_1,t_2}}}, \quad (3.7)$$

and

$$\hat{F}_{d,t_1,t_2} = \sqrt{\hat{L}_{d,t_1,t_2} \hat{P}_{d,t_1,t_2}}, \quad (3.8)$$

Similarly, we estimated the national-level Fisher index by

$$\hat{F}_{n,t_1,t_2} = \sqrt{\hat{L}_{n,t_1,t_2} \hat{P}_{n,t_1,t_2}}, \quad (3.9)$$

where

$$\hat{L}_{n,t_1,t_2} = \sum_s \sum_c \hat{w}_{c,s,t_1,t_2} \hat{u}_{c,s,t_1,t_2}, \quad (3.10)$$

and

$$\hat{P}_{n,t_1,t_2} = \frac{1}{\sum_s \sum_c \frac{\hat{w}_{c,s,t_2}}{\hat{u}_{c,s,t_1,t_2}}}. \quad (3.11)$$

Index chaining. When the months t_1 and t_2 are not consecutive, two types of indexes may be computed: (a) *direct* indexes, as given above, and (b) *chained* indexes, computed as a product of month-to-month indexes.

The chained Fisher index estimator of price change between periods t_1 and t_2 is a product of $t_2 - t_1$ factors, with each factor a Fisher index estimator measuring change between two consecutive months:

$$\tilde{F}_{t_1,t_2} = \prod_{j=t_1}^{t_2-1} \hat{F}_{j,j+1}. \quad (3.12)$$

Short-term price comparisons are generally more valid than long-term ones, because changes in the quality of goods and services provided are less likely to occur between consecutive time periods than between periods farther apart. Thus the chained index $\tilde{F}_{t_1,t_2}$ is theoretically more desirable than the direct index $\hat{F}_{t_1,t_2}$. Under our estimation procedures, however, the estimator $\tilde{F}_{t_1,t_2}$ is less robust to extreme values than is $\hat{F}_{t_1,t_2}$.

At the national level, $\hat{F}_{n,t_1,t_2}$ displays a slight upward bias relative to $\tilde{F}_{n,t_1,t_2}$. For some States and census divisions, however, the chained series (based on $\tilde{F}_{s,t_1,t_2}$ and $\tilde{F}_{d,t_1,t_2}$) are adversely affected by erratic price movements.[10] We therefore estimate the chained indexes for States and census divisions by adjusting the direct indexes by a ratio computed from the national series. We let t_0 be the base month for the direct indexes (April 1994). Then for a State s and two months t_1 and t_2, where $t_0 \le t_1 \le t_2$, we let

$$\hat{\tilde{F}}_{s,t_1,t_2} = \left(\frac{\hat{F}_{s,t_0,t_2}}{\hat{F}_{s,t_0,t_1}}\right)\left(\frac{\tilde{F}_{n,t_1,t_2}}{\hat{F}_{n,t_1,t_2}}\right). \qquad (3.13)$$

Similarly, for a census division d,

$$\hat{\tilde{F}}_{d,t_1,t_2} = \left(\frac{\hat{F}_{d,t_0,t_2}}{\hat{F}_{d,t_0,t_1}}\right)\left(\frac{\tilde{F}_{n,t_1,t_2}}{\hat{F}_{n,t_1,t_2}}\right). \qquad (3.14)$$

For details on the research underlying the ECPI estimators used for States and census divisions, see Lent[11].

Notes

[1] For information on the theoretical properties of the textbook Fisher index, see Irving Fisher, *The Making of Index Numbers: A Study of Their Varieties, Tests, and Reliability* (New York: Sentry Press, 1922).

[2] Research results indicate that this approximation is reasonable for the electricity and natural gas components of the ECPI. The approximation is most likely also reasonable for gasoline and heating oil; in these cases, use of the unit value index is necessary because of data limitations. For details on the research, see Janice Lent memorandum for Stephanie Brown on *Interim Report on Energy Consumer Price Index (ECPI) Estimation Research*, February 4, 2009. This is an internal EIA memorandum, available from the author upon request.

[3] For a general discussion of the use of unit value indexes, see Bert M. Balk, “On the Use of Unit Value Indices as Consumer Price Subindices,” in W. Lane, ed., *Proceedings of the Fourth Meeting of the International Working Group on Price Indices* (U.S. Bureau of Labor Statistics, 1998).

[4] Janice Lent, memorandum for Stephanie Brown on *Interim Report on Energy Consumer Price Index (ECPI) Estimation Research*.

[5] Estimates published in the *Transportation Energy Data Book* are interpolated from FHWA and EIA sources. The publication is sponsored by the DOE Office of Energy Efficiency and Renewable Energy and is available on the website of Oak Ridge National Laboratories.

[6] Prime suppliers are dealers who sell to other dealers, end-use customers, or both. Prime suppliers include producers, importers, and wholesalers. The prime supplier sales volumes are used here as a proxy for total sales. EIA also publishes estimates of “product supplied,” which is often used as a proxy for total consumption.

[7] The NHTS motor fuel volume estimates were given in “gasoline equivalents;” these are volumes of other fuels used that had been converted into gasoline equivalents. Because no data were available on the volume proportions for gasoline, diesel, and other fuels, in this research we treated the gasoline equivalents as gallons of gasoline. The values of the adjustment factors computed are clearly higher than they would have been if estimates of gasoline consumption alone had been used. For more information on the NHTS, see **http://nhts.ornl.gov/** (visited 12/8/2011).

[8] For cleaner notation, we have suppressed the subscript indicating the State.

[9] Janice Lent, memorandum for Stephanie Brown on “Research on Energy Consumer Price Index (ECPI) No. 2 Distillate Fuel Oil Component,” November 18, 2009. Also Janice Lent, memorandum for Stephanie Brown on “Research on Elasticity-based Forecasts of No. 2 Distillate Fuel Oil Sales,” December 16, 2009. These are internal EIA memoranda, available from the author upon request.

[10] For more information on potential biases associated with index chaining, see Janice Lent, “Chain Drift in Experimental Air Travel Price Index Series,” in *Proceedings of the Section on Survey Research Methods*, 2003 Joint Statistical Meetings, American Statistical Association, Alexandria, VA, **http://www.amstat.org/Sections/Srms/Proceedings/y2003f.html** (visited 12/8/2011).

[11] Janice Lent, memorandum for Stephanie Brown on “Research on Energy Consumer Price Index (ECPI) State-level and Census Division-level estimators,” July 7, 2009. This is an internal EIA memorandum, available from the author upon request.