Reduced Form Energy Model Elasticities from EIA's Regional Short-Term Energy Model (RSTEM)

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Summary

- This analysis examines the price and weather elasticities derived from EIA's Regional Short-Term Energy Model (RSTEM).

- RSTEM is used to produce forecasts for EIA's monthly Short-Term Energy Outlook (STEO) and to generate information on how domestic energy markets respond to changes in economic growth, world oil prices, weather events, and domestic energy supply disruptions.

- Overall, net price elasticities of demand in RSTEM over a 2-year horizon tend to be small because of the limited substitution possibilities available for most fuels and sectors.

- Substantial shortfalls in supply (such as from a disruption due to natural or man-made causes) generally result in sharp near-term increases in price.

- Natural gas demand tends to be somewhat more price elastic in the short-run than petroleum demand in the United States, mainly because of a larger presence of natural gas in sectors where a moderate range of substitution possibilities exist (i.e. the industrial and power sectors).

- Demand shocks (in particular from weather) can have powerful feedback effects on natural gas demand though domestic natural gas prices, sometimes neutralizing output effects from the demand shock that might otherwise be supposed to ensue (e.g. electric power sector demand for natural gas during the heating season).

- Because near-term domestic natural gas market equilibrium can depend much less on the availability of foreign supplies at the margin compared to petroleum, demand shocks (particularly due to winter weather) will tend to induce sharp natural gas price increases and important offsets in quantity demanded, most notably in the industrial sector.

Overview

This analysis examines the underlying price and weather elasticities in EIA's Regional Short-Term Energy Model (RSTEM) (see Model Documentation for a model summary). RSTEM is used to produce forecasts for EIA's monthly *Short-Term Energy Outlook* (STEO) and to generate information on how domestic energy markets respond to changes in economic growth, world oil prices, weather events, and domestic energy supply disruptions. The focus of this report is on national-level results for demand elasticities with respect to oil prices, natural gas prices, and weather.

In this report, a demand elasticity is defined as the percent change in the quantity consumed during a period divided by the percent change imposed on a particular demand determinant, such as price or weather. These elasticities are recovered from the model by performing a baseline simulation and a series of alternative simulations over a specified forecast horizon. In the alternative scenarios, permanent percentage shifts in key demand determinants (e.g. the crude oil price is increased by 10 percent for every month of the forecast period) are imposed, the model is re-solved and percentage differences in consumption are compared to the baseline to derive the implied elasticities. Note that the denominators in the elasticity calculations are the percentage changes imposed on the primary determinants (e.g., crude oil price or wholesale natural gas price), not the resulting percentage changes in specific demand determinants (e.g. retail gasoline prices or industrial natural prices). This is to allow for simplicity of presentation.

The simulation approach used here (as opposed to a analytical derivation of specific elasticities from estimated demand equation parameters) is a convenient method to provide a sense of how domestic energy consumption will tend to change as various key determinants are allowed to take on alternative ranges. The resulting elasticities from this method, however, have a "net" quality to them because there may be feedback between determinants (e.g. cold weather generally causes higher natural gas prices so that the increase in demand from cold weather may be partially offset by lower demand because of higher prices). In this analysis these feedbacks are allowed to occur. Thus, in some sectors where a positive elasticity might otherwise be expected, a negative net elasticity may be the result because of feedback across determinants. An example is the winter weather elasticity of electric power sector natural gas demand. Colder weather has a positive impact on electricity demand and generation but, with natural gas prices rising, electric generators may substitute other fuels for natural gas and these substitution effects may outweigh power sector demand and generation effects.

Data Considerations

RSTEM utilizes a monthly frequency for the underlying data and projections. For some energy demand concepts used in RSTEM, a discrepancy exists between monthly reported values and (unobserved) values for the calendar month. This applies specifically to natural gas demand and electricity demand where, for the most part, reported consumption (deliveries by distribution companies) are on monthly billing bases which typically straddle months (i.e. the current reported consumption is actually the combination of consumption in the current month and in the previous month). No explicit attempt is made in RSTEM to correct for this but the implications for modeling of demand are handled in the model specifications (e.g. current and lagged degree-days are determinants in many of the natural gas and electricity demand equations). In this analysis, some displays of month-by-month demand elasticities will show cumulative effects that are in part due to this "billing cycle" versus calendar month issue. This is particularly true for the weather elasticities.

Scenarios

Table 1 summarizes the 9 scenarios run using RSTEM (including the baseline). The February 2006 version of RSTEM was used for the analysis. For this version the forecast horizon was from February 2006 through December 2007 (essentially a two-year horizon). The baseline scenario is the base case used in EIA's February 2006 Short-Term Energy Outlook.

Table 1. Scenario Summary for RSTEM Demand Elasticities Analysis

Scenario	Description
1) Baseline	(See EIA's February 2006 Short-Term Energy Outlook on archive)
2) High Oil Prices	+10% West Texas Intermediate Oil Price
3) Low Oil Prices	-10% West Texas Intermediate Oil Price
4) High Natural Gas Prices	+10% Henry Hub Spot Price
5) Low Natural Gas Prices	-10% Henry Hub Spot Price
6) Cold Winter Weather	+10% HDDs (all regions) for the heating season (October through April)
7) Warm Winter Weather	-10% HDDs (all regions) for the heating season (October through April)
8) Hot Summer Weather	+10% CDDs (all regions) for the cooling season (May through September)
9) Cool Summer Weather	-10% CDDs (all regions) for the cooling season (May through September)

Notes: HDDs=heating degree-days; CDDs=cooling degree-days.

The West Texas Intermediate (WTI) oil price is a key variable in the RSTEM system and changes in it affect all petroleum prices in the model, directly or indirectly. The Henry Hub spot price (HH) is also a key RSTEM variable and is a key benchmark price in the U.S. natural gas market. Changes in HH ultimately affect all downstream natural gas prices in RSTEM. Heating and cooling degree-days used here are population-weighted degree-days as reported by the National Oceanic and Atmospheric Administration. Degree-days, including U.S. Census Division-level details, are extensively used in RSTEM demand models as strictly exogenous determinants related to increased heating and cooling demand, particularly in residential and commercial settings. For all of the scenarios, all degree-day inputs are shifted by an identical percentage (+ or – 10 percent) for each month in the forecast.

Demand Elasticity Results

Table 2 summarizes the net elasticity calculations derived from the weather and price scenarios. Demand responses to increases or decreases weather or prices are not significantly different from each other (i.e., are symmetrical). Averages for +/- versions of the different scenarios (also averaged across the entire horizon) are displayed. In the weather cases, only seasonal periods (i.e. cooling season or heating season) are used in the averages. The calculated elasticities are derived from differences in the scenarios from the baseline case. The averages mask lower near-term elasticities and higher medium term elasticities due to lagged effects of price changes on demand.

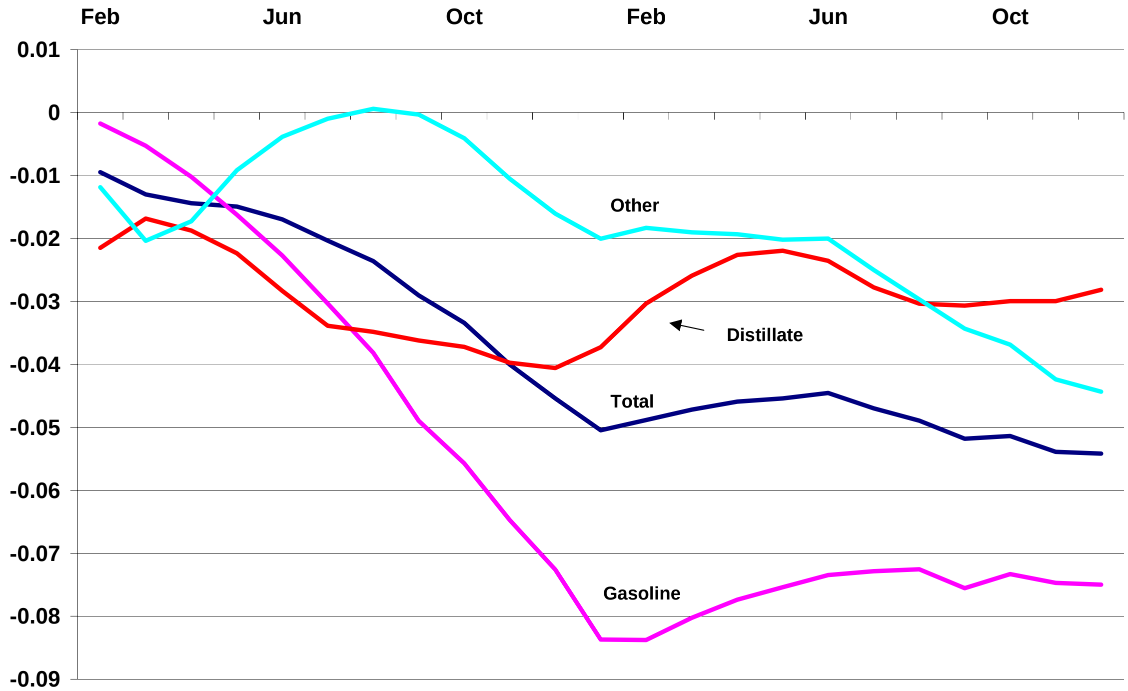
Table 2. Average U.S. Energy Net Elasticities for Price and Weather Scenarios, 2-year Horizon

			Weather Cases	
	Oil Prices (+/-10% WTI)	N. Gas Prices (+/-10% HH)	Fall/Winter (+/-10% HDDs)	Spring/Summer (+/-10% CDDs)
	(Average Elasticities with Respect to Scenario Variables)			
Petroleum				
Total	-0.037	0.008	0.076	0.016
Motor	-0.056	0.000	-0.001	0.000
Gasoline				
Distillate Fuel	-0.029	0.047	0.181	0.025
Other	-0.019	-0.005	0.110	0.032
Natural Gas				
Total	0.036	-0.137	0.236	0.074
Residential	-0.011	-0.042	0.880	-0.010
Commercial	-0.015	-0.055	0.526	-0.017
Industrial	0.078	-0.269	-0.303	-0.052
Electric Power	0.055	-0.138	-0.030	0.247
Coal				
Total	0.002	0.004	0.060	0.125
Electric Power	0.002	0.004	0.062	0.135
Electricity				
Total	-0.002	-0.009	0.064	0.136
Residential	-0.001	-0.006	0.180	0.263
Commercial	-0.002	-0.007	0.015	0.110
Industrial	-0.004	-0.014	-0.019	-0.006

Oil Price Changes. Domestic petroleum consumption would be expected to decline/(increase) by about 0.4 percent for every 10 percent permanent increase/(decrease) in the WTI price (i.e. 10% x -0.037=- 0.4%, approximately) over a 2-year horizon. A change in the crude oil price also leads to a corresponding change in the HH natural gas price. The HH natural gas price moves with the WTI crude oil price at a rate of about 25 percent (i.e. 2.5 percent for every 10 percent change in WTI). Holding HH natural gas prices constant in these scenarios would result in somewhat higher values for petroleum demand own-price elasticities because consumers capable of switching from the relatively more expensive liquid fuels derived from crude oil to natural gas will do so.

Not surprisingly, the short-term petroleum elasticities with respect to the WTI price are small (i.e. demand is inelastic) because of limited substitution possibilities in the short run. Indeed, all of the net price elasticities in RSTEM are small for this reason. Of the major petroleum fuel groups shown, the motor gasoline elasticity is the highest, reflecting changes in the amount and type of discretionary highway travel done in response to higher pump prices. The "Other" petroleum group tends to be very insensitive to price on net partly because of the fact that some of its components are actually derived largely from natural gas and in some cases are substitutes for each other (e.g. oil-based feedstocks versus liquefied petroleum gases used in the petrochemical industry). Figure 1 illustrates the month-by-month pattern of elasticities associated with a permanent upward shift in the WTI price of 10 percent over the entire forecast period.

Figure 1. Monthly Petroleum Net Demand Elasticities with Respect to West Texas Intermediate Oil Price



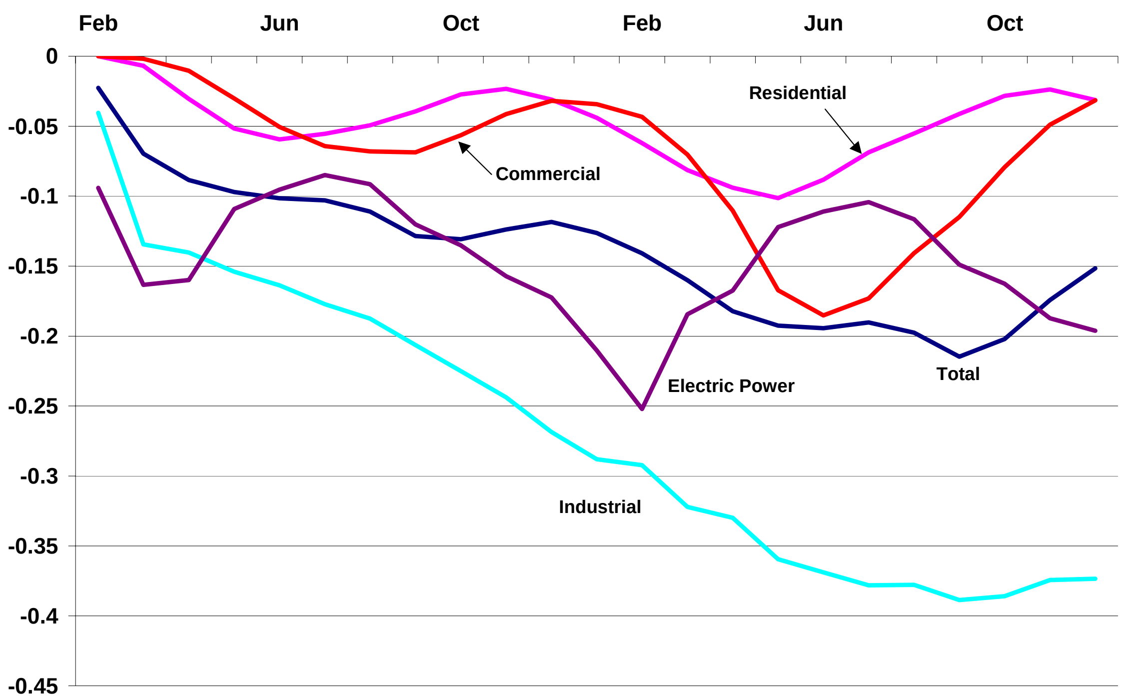
Oil price variations also affect relative prices between natural gas and competing petroleum products. In the WTI scenarios, natural gas demand would tend to move in the opposite direction as petroleum demand (i.e. the overall natural gas demand elasticity is positive with respect to the WTI price). In RSTEM, this effect relates particularly to the industrial and electric power sectors. (The negative signs for the residential and commercial sectors reflect the fact that higher natural gas prices in the WTI scenarios induce consumers in these sectors to conserve fuel use but not significantly switch fuel sources in the short run.)

The oil price elasticities in the electricity demand sector are small and reflect minor effects on electricity costs to consumers due to higher oil (and natural gas) prices.

Natural Gas Price Changes. Net own price elasticities for natural gas demand tend to be larger (in absolute value) than the oil price counterparts. In RSTEM, total domestic natural gas demand would be expected to decline by about 1.4 percent for every 10 percent permanent increase in the HH price (i.e. 10% x -0.137=1.4%(approx)) over a 2-year horizon. The bulk of the responses to the posited natural gas price changes are in the industrial and electric power sector.

In the industrial sector, sustained higher natural gas prices induce industries to substitute other fuels where possible, or to rationalize operations or increase process efficiency in order to reduce gas consumption per unit of output. In the electric power sector, higher natural gas prices tend to induce higher utilization of alternate fuels such as oil or even coal. Figure 2 illustrates the month-by-month net price elasticities for natural gas demand sectors.

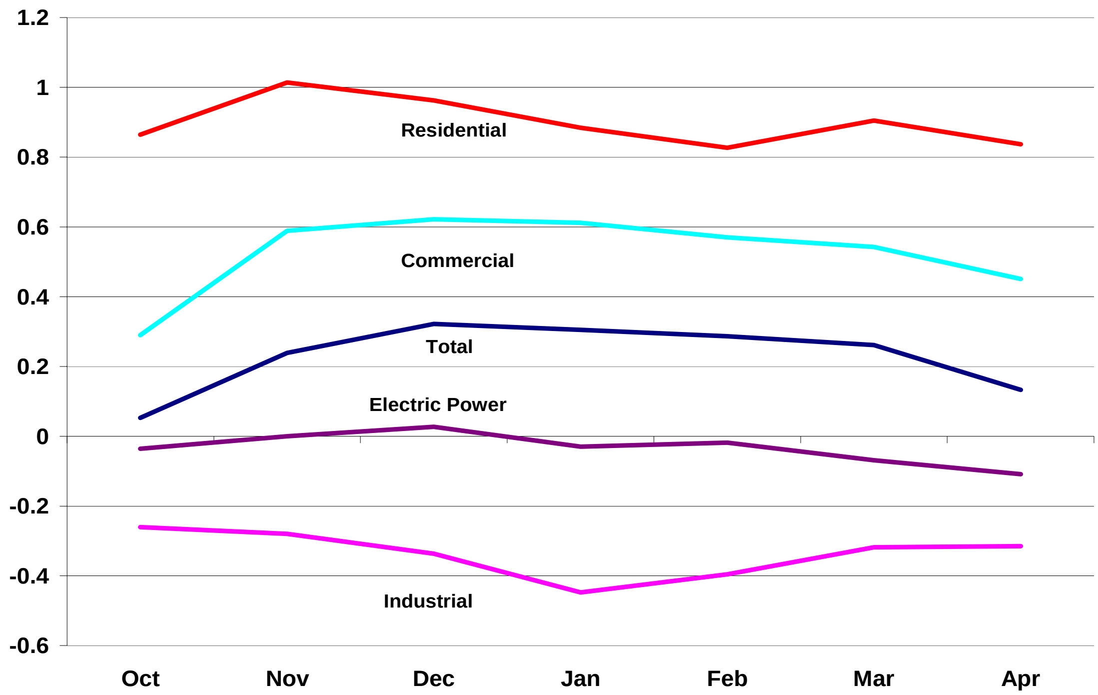
Figure 2. Monthly Natural Gas Net Demand Elasticities with Respect to Henry Hub Spot Price



Net effects on petroleum consumption of changes to HH prices tend to be relatively small due in part to the fact that pressure on crude oil prices from this source is limited by the global nature of oil markets. As with oil price changes, the natural gas price elasticities in the electricity demand sector are small and reflect minor effects on electricity costs to consumers due to higher fuel prices.

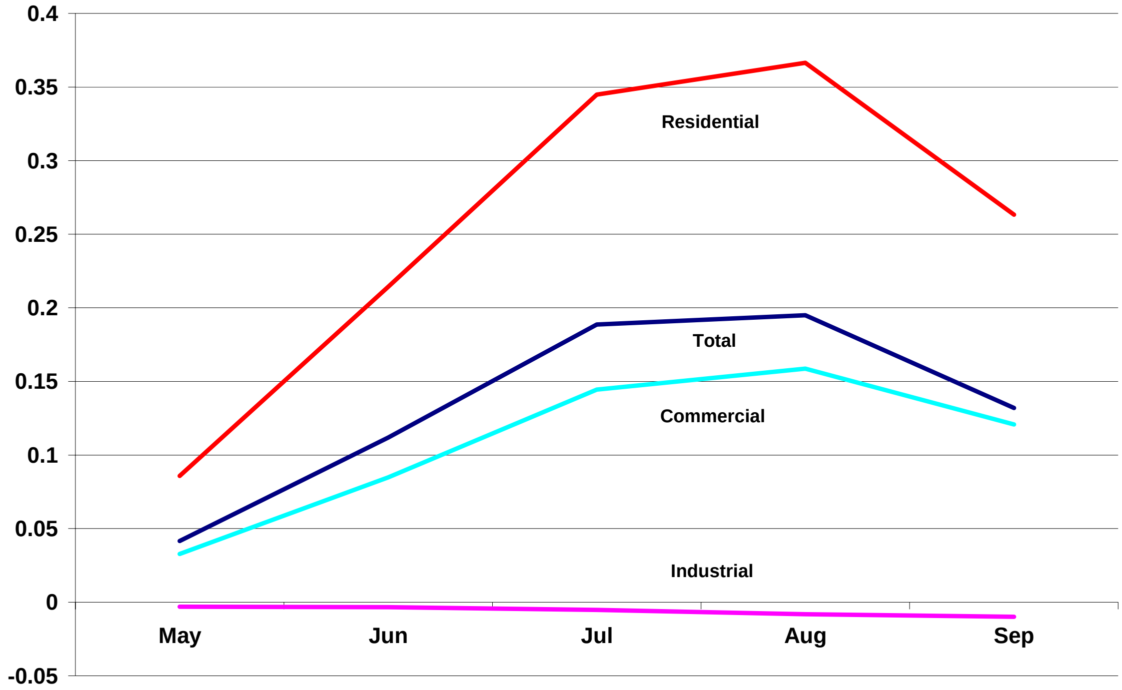
Weather Cases. Not surprisingly, the weather scenarios reveal that impacts from various degree-day assumptions are greatest in the residential and commercial sectors, particularly for residential natural gas and electricity. The dominant weather-related sensitivities for natural gas are of course during the winter or heating season period because of the very large role that natural gas plays in the U.S. heating market. A 10 percent across-the-board increase in heating degree-days would tend to increase residential natural gas demand in the United States by about 9 percent (i.e. 10% x 0.880=8.8%) during the heating season. Figure 3 illustrates the net heating degree-day elasticities for U.S. natural gas markets during the heating season. (As suggested in the Data Considerations section above, parts of the initially increasing pattern in the degree-day elasticities shown in the Figure are due to the issues related to the billing cycle.)

Figure 3. Monthly Natural Gas Net Demand Elasticities with Respect to Heating Degree-Days



With respect to electricity demand, a 10-percent shift in degree-days tends to have its largest effect in summer because of the importance of air conditioning in electricity markets. Figure 4 provides a month-by-month view of the net cooling degree-day elasticities associated with U.S. electricity demand.

Figure 4. Monthly Electricity Net Demand Elasticities with Respect to Cooling Degree-Days



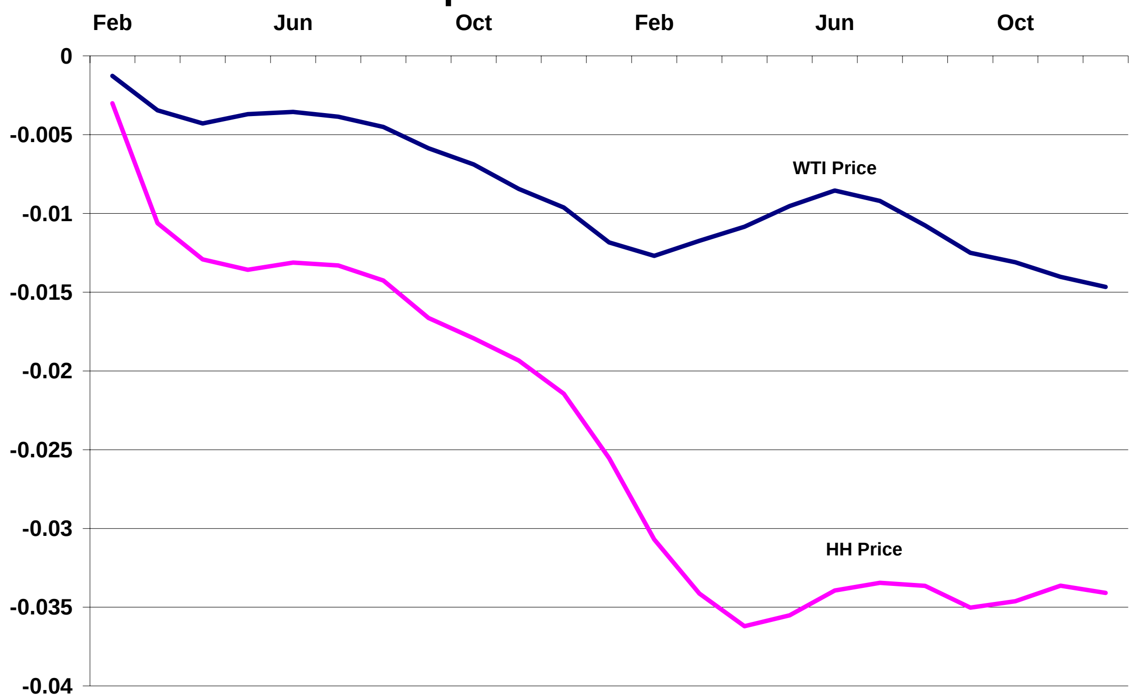
In petroleum markets, the principal sensitivities to weather have to do with residential and commercial heating oil and propane demand during the winter and to a lesser extent with residual fuel oil demand in the electric power sector during the heating and cooling seasons.

Summary on Demand Elasticities

Overall, net price elasticities of demand in RSTEM over a 2-year horizon tend to be small because of the limited substitution possibilities available for most fuels and sectors. This analysis focuses on oil and natural gas price shifts, and no explicit electricity or coal price scenarios are considered.) Thus, substantial shortfalls in supply (say from a disruption due to natural or man-made causes) generally result in sharp near-term increases in price. This has been very clearly evident in domestic fuel markets over the last few years. Natural gas demand tends to be somewhat more price elastic in the short-run than petroleum demand in the United States, mainly because of a larger presence of natural gas in sectors where a moderate range of substitution possibilities exist (i.e. the industrial and power sectors). Nevertheless, demand shocks (in particular from weather) can have powerful feedback effects on natural gas demand through domestic natural gas prices, sometimes neutralizing output effects from the demand shock that might otherwise be supposed to ensue (e.g. electric power sector demand for natural gas during the heating season). Also, because near-term domestic natural gas market equilibrium can depend much less on the availability of foreign supplies at the margin compared to petroleum, demand shocks (particularly due to winter weather) will tend to induce sharp natural gas price increases and important offsets in quantity demanded, most notably in the industrial sector.

While examination of these elasticities by fuel is informative about the properties of RSTEM, one does not get an overall view of the sensitivity of total domestic energy demand to the shifts posited in the scenarios. Figures 5, 6 and 7 provide a broad perspective on price and weather elasticities for total energy demand in the United States.

Figure 5. Monthly Total Energy Net Demand Elasticities with Respect to Oil and Gas Prices



WTI Price= West Texas Intermediate Oil Price; HH price=Henry Hub Spot Natural Gas Price.

Figure 6. Monthly Total Energy Net Demand Elasticities with Respect to Heating Degree-Days

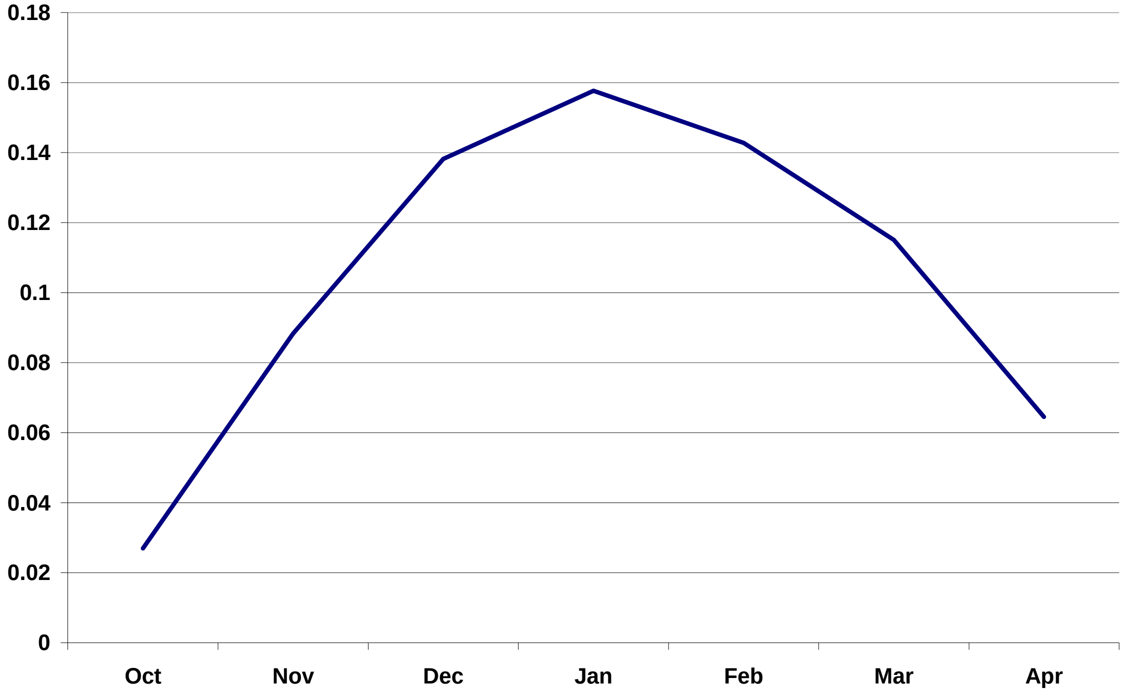


Figure 7. Monthly Total Energy Net Demand Elasticities with Respect to Cooling Degree-Days