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Modeling North America Energy Demand by sectors (Residential-Commercial and Transportation)

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Abstract

The aggregate model of North America includes residential-commercial and transportation sectors. The residential-commercial sector equation is Constant Elasticity Model (CEM) and in this paper we used it for Almon polynomial distributed lag model. This model gives the long run price elasticity of demand. The price elasticity compete the income elasticity in the sense that moderate increase in energy demand. The real price elasticity of demand is –0.19 while the income elasticity of demand is high considerably estimated as 0.59.

Like price elasticity in the transportation sector (with the same method) is -0.1 delineating an inelastic demand to price. Also the income elasticity is rather considerable. Income elasticity in this sector is 0.67 that shows the driving force in energy demand in the North America is the transportation sector. The R&D efforts along with other non-price policies contribute in lower energy demand growth. The coefficient of filter variable to cover the asymmetric response of demand to price changes (as a proxy variable for technology improvement) is estimated as -0.037.

Although technology improvements could relax the demand in this sector, but the demand growth still will be considerable.

Key words: Energy demand, Price Elasticity, Income Elasticity, ALMON METHOD.

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I-Theoretical Literature on Energy Demand

Energy demand implies to sum of demands for kinds of energies produced over a period of time (i.e. oil, gas, coal and solids and electricity). It is a dynamic concept and consumer response to a price change lags by a couple of years due to technological and other barriers.

Energy demand equation, generally is determined by economic activity, relative energy- prices, and, if necessary, average winter temperatures, time trends representing energy-saving, technical and institutional change.

For example we can assume that oil consumption behavior can be explained by a simple static model. This can be specified as follows:

$E_t = a + bY_t + mP_t + V_t$

where:

E = total oil consumption

Y = Gross domestic product

a = a constant

v = an error term

If the variables are expressed in natural logarithms, so b is the income elasticity and m is the short-run price elasticity. Unless stated otherwise, we assumes that the error term is normally distributed, independent of the explanatory variables, and neither serially correlated nor heteroscedastic.

Above Equation is a static specification of oil consumption and, therefore, may not allow for any long-run reaction to price changes. Oil demand is then assumed to be a function of income and price, according to the following double-logarithmic equation:

$Et = a + bYt + m0Pt + m1Pt\text{-}l + m2Pt\text{-}2 + \ldots + Vt$

or:

$Et = a + bYt + \sum_{i}^{\infty} m_j p_{t-j} + Vt$

where *a*, b and m are the parameters to be estimated, m0 is the short-run price elasticity and m1, m2 ...are the intermediate price elasticities, because they measure the impact on mean "E" of a unit change in "P" in various periods. But by Almon (1965)[1] polynomial distributed lag model can assumes that m_0 follows the second- degree polynomial the lags weights and result that:

$$Et = a + bYt + \sum_{i=0}^{k} p_{t-i}(a_0 + a_1 i + a_2 i^2) + et$$

Or :

$$Et = a + bYt + a_0 \sum_{i=0}^{k} p_{t-i} + a_1 \sum_{i=0}^{k} i p_{t-i} + a_2 \sum_{i=0}^{k} i^2 p_{t-i} + et$$

And then with substitution ($Zl_t = \sum_{i=1}^{k} p_{t-i}$, $Z2_t = \sum_{i=1}^{k} i p_{t-i}$, $Z3_t = \sum_{i=1}^{k} i^2 p_{t-i}$) may write equation as below :

$$Et = a + bYt + a_0 Zl_t + a_1 Z2_t + a_3 Z3_t + et$$

For energy demand analyses, it is desirable to adopt regression techniques that enable the robust estimation of short- and long-run elasticities. Error Correction Models (ECM) are appealing in that they not only include long-term and short-term effects, but also that a co integrated system can always *be*

1- Almon assumes that the lag weights can be specified by a continuous i function, which, in turn, can be approximated by a discrete point in time. Moreover, i the influence of a change in oil price (P) is completed after a finite number of periods: so that there is a finite maximum lag.

Almon ingeniously makes use of a mathematical theorem. She assumes that a suitable degree polynomial in "i", the length of the lag, can approximate the coefficient. For example, if the lag scheme is a quadratic or second-degree polynomial in i, we can write:

$m_i = a_0 + a_1 i + a_2 i^2$ or , more generally, we may write:

$m_i = a_0 + a_1 i + a_2 i^2 + ... + a_m i^m$

Which the m^{th} is degree polynomial in i. It is assumed that m < k (the degree of the polynomial "m" is less than "k", the maximum length of lags).

represented by an ECM. The procedure adopted in energy demand is therefore as follows:

a) Each variable is tested for the order of integration, using a Dickey-Fuller unit root test. This is done by running the regression:

$$\Delta z_t = \varphi_0 + \varphi_1 t + \varphi_2 z_{t-1} + \sum_n \Delta z_{t-n}$$

Where t is a time trend, and it is testing for whether φ_2 is significantly negative. The augmented test, including various lags of Δz_t are included to reduce white noise. If φ_2 is not found to be significantly less than zero, the null hypothesis cannot be rejected that Z_t is an I(I) variable (i.e. integrated order one).

b) Of the variables found to be non-stationary, tests for cointegration of the variables are then made. This is done by testing for the stationarity or' the residuals of the proposed long-run relationship. If the residuals are stationary, this implies that the variables cointegrate

Also the high energy prices during 1974-1985 triggered large R&D efforts that improved energy efficiencies of appliances (cars, TV-sets, heating systems. etc.). Although further R&D is hardly economical at present energy prices, today's appliances are all much more efficient than 20 years ago. Due to the irreversibility of knowledge. However, efficiency improvements continue in the market place due to the sluggish process of replacing old and inefficient equipment.

Irreversible technological know-how, which was acquired during the period from 1974-1985, continues to determine present demand behaviour and is responsible for this apparent as asymmetry, i.e. ongoing conservation despite very low energy prices.

However, these technical efficiencies are not laws of nature but the result of economic decisions based on energy prices. It was the unique period of "high" energy prices, from the end of 1973 to the end of 1985, which triggered substantial research and development efforts to engineer more fuel efficient appliances, e.g. the increase in mileage consumption of cars across all different categories of cars, the substantial reduction in electricity consumption for television, computers cleaning, lighting, etc.

A price decline which follows the previous regime of "high" prices will not cause the demand to return to its original equilibrium but to a lower one because of the irreversibility of knowledge. As a consequence, the price level and the historical evolution rather than sign of price changes is here important for an eventua1 asymmetry.

A major implication of this is that it is not price *increases*, as such, that trigger asymmetrical behaviour (in the sense of excessive conservation) but rather only a sufficiently "high" (i.e. high rel3tive to past prices) price, no matter what sign the present price changes have. This asymmetry of energy demand has important consequences on the design of a coherent OPEC pricing strategy: moderate OPEC price increases, say up to S30/b, and induce only a moderate cut in demand, because these price levels are insufficient to trigger an R&D process to improve efficiencies further. The reason is that all adjustments that are economical at such a price level have been already accomplished in the past. However, sufficiently high prices will trigger another round of R&D and will induce other measures that improve efficiencies so that demand behaviour is significantly affected, even if prices are later reduced. A similar reasoning applies to pollution/energy/CO: taxes (or whatever name is chosen): low up to moderate (or unilateral rather than internationally agreed) taxes ~'ill have little impact on demand.

These ideas have been implemented within energy demand at the highest level, just an additional variable, S_t, (as a filter) is needed as a shift parameter in the standard energy demand equations.

In Et=(1-v)*A+ (1-v)*BlnPt+(1-v)*St+ (1-v)*DlnYt + v*lnE_{t-1}

<u>Variables</u>

Et= Energy demand in period t

Yt= Income

Pt= Real priceof aggregate energy

St= Technical efficiency of stock

<u>Parameters</u>

A=Intercept

V=long-run parameter

B= Long run price elasticity (symmetric component)

C= Long run demand elasticity with respect to efficiency

D=Long run income elasticity

The variable St, accounts for the state of the technology of the presently used equipment and shifts aggregate demand. The impact of the price movements upon the technical efficiency of the capital stock is estimated by constructing a filter, Ft. This series, Ft, aggregates the impact on R&D of historical energy prices, i.e. Ft is a non-declining series aggregating historical energy prices. IN estimations a delay of five years is used in most cases to account for the delay time between initializing R&D and final products coming out of the factories. The idea behind this filter is that it captures response of R&D following actual oil price realizations. In the other words this filter must account for the cumulative response in R&D following past oil price. From the irreversibility of knowledge, it follows that this impact must be non-declining even in the case of a sharp decline in energy prices. Furthermore, R&D is a sluggish process so that price spikes have little impact, and high prices work slowly through the system. A simple, yet for our purpose sufficiently flexible formulation, is to modify exponential smoothing formulas to achieve the property of a non-declining series:

$$FILT = vP_t + (1-v)FILT_{t-1} \quad \text{IF} \quad P_t >= FILT_{t-1}$$
$$\text{AND IF} \quad P_t < F_{t-1} \Rightarrow F_t = F_{t-1}$$

Ft= filter of proper aggregate of historical energy prices.

Pt= real price of aggregate energy.

V= a constant parameter 0<v<1

From this definition, it follows that Ft is non-declining such that it captures the irreversibility of technological knowledge. This has, however, been modified to capture long-term declines in costs that cause the trigger point for asymmetric reactions to gradually decline. Hence, a 1% per annum fall in Ft is applied, similar to assumption typically used for autonomous efficiency improvements.

II- Equations for Aggregate-Energy Demand

As mentioned, the following equation is suitable for energy demand:

$Ei = F (GDP, P_E, FILT, T)$

Where Ei is aggregate energy consumption by sector i (Residential-Commercial and Transportation) in North America.

GDP is real GDP at factor cost (1990)

P_E is relative and aggregate price of energy for sector i

FILT is a filter constructed from the aggregate energy prices, used to capture asymmetry in the response to price movements (only for transportation sector)

T is the time trend

Aggregate-energy demand is related to output, relative prices, and a filter which constructed from the aggregate energy prices, used to capture asymmetry in the response to price movements. A double-log-form is chosen so that constant elasticities with respect to output and prices are estimated.

In this equation aggregate energy consumption has been calculated as below for two sectors:

Residential-Commercial: ER=OR+SR+GR+ER

Transportation: OT+GT+ET

Which O is oil, S is solids fuels (coal), G is gas and E is electricity. Also filter variable has been calculated as below for transportation sector:

FILT= (if P_E greater of .FILT(-1))[then] (0.2* P_E + (0.987-0.2)*FILT(-1)) and (if P_E littler of .FILT(-1))[then].(FILT(-1))* (0.987*FILT(-1))

Quantities of 0.2 and 0.987 are technical coefficients which calculate for adjustment effects of efficiency on the energy price.

The results are consistent across the regions and all the output and price elasticities are correctly signed. The temperature variables perform as expected, with the lower the average winter temperature the higher the energy consumption. Oil demand for marine bunkers is related to total trade (exports plus imports) rather than output.

There is evidence of a structural break in energy use after 1973.'74. To allow for the lower energy intensities in later years (apart from any effects which can be directly attributed to relative energy prices) a time trend beginning in 1975 has been introduced into some of the equations.

III- Estimating aggregate energy demand

For North America (Residential-Commercial and Transportation sectors), in period of 1970-2001 several equations were examined, using different combinations of explanatory variables. The results reported in this section are those the best fit, in terms of coefficient, sign, statistical significance and relevance to economic theory.

At first we tested stationery and non stationery in variables. For it we used unit root test (ADF and Philips-Perron statistics). Table (1) shows results these tests:

Table (1): test of unit root (critical value 5%)

Variables	**Transportation Sector**			**Residential-Commercial Sector**		
	ADF	PP	critical value	ADF	PP	critical value
Energy Consumption	-3.09	-3.04	-3.5	-2.33	-2.11	-3.5
GDP	-4.6	-3.6	-3.5	-4.6	-3.6	-3.5
Energy Price	-2.1	-1.6	-3.5	-1.09	0.9	-3.5
Filt	-2.66	-0.92	-3.5	-	-	-

All of variable in each sector is detected in the table (1). As results show all of variables except of GDP and to include trend and intercept in two sectors aren't stationery then we cannot reject null hypothesis that energy consumption aren't integrated variables order one (ρ=1).

Then there is not any restriction for use of these variables in estimating model because degree of integrate variables are not similar, then there isn't any problem to estimate model.

As we told for estimating has used from Almon polynomial distributed lag model that in Residential-Commercial we consider 4 lags where the lag coefficients of P_E lie on a 3rd degree polynomial with no endpoint constraints.[1] As similar in transportation sector we considered 2 lags where the lag coefficients of P_E lie on a 1st degree polynomial with no endpoint constraints and for FILTR variable has used from 3 lag where the lag coefficients lie on a 2nd degree polynomial with no endpoint constraints. The estimate results by PDL method (this method in eviwes package is used to estimate Almon polynomial distributed lag model) are as below:

1- Residential-Commercial sector

$$LN(ER)=2.02 + 0.59*LN(GDP) - 0.19*LN(P_E)$$

(5.5) (11) (-9.2)

0.86=Adjusted R-squared

Results show that all of coefficients are significant and coefficient or elasticity of energy price (P_E) is sum of P_E lags. Then it shows long run coefficient or elasticity of energy price (P_E) in Residential-Commercial sector, it is equal of -0.19. Figure (6) shows trend of residual actual and fitted regression for Residential-Commercial sector.

1- This specification allows you to estimate a model with k lags of x using only p parameters (if you choose p>k, Eviews returns a "Near Singular Matrix" error).

If we restrict either the near or far end of the lag, the number of parameters estimated is reduced by one to account for the restriction; if we restrict both the near and far end of the lag, the number of parameters is reduced by two.

By default, Eviews does not impose any constraints.

The specification of a polynomial distributed lag has three elements: the length of the lag k, the degree of the polynomial (the highest power in the polynomial) p, and the constraints that you want to apply. A near end constraint restricts the one-period lead effect of x on y to be zero:

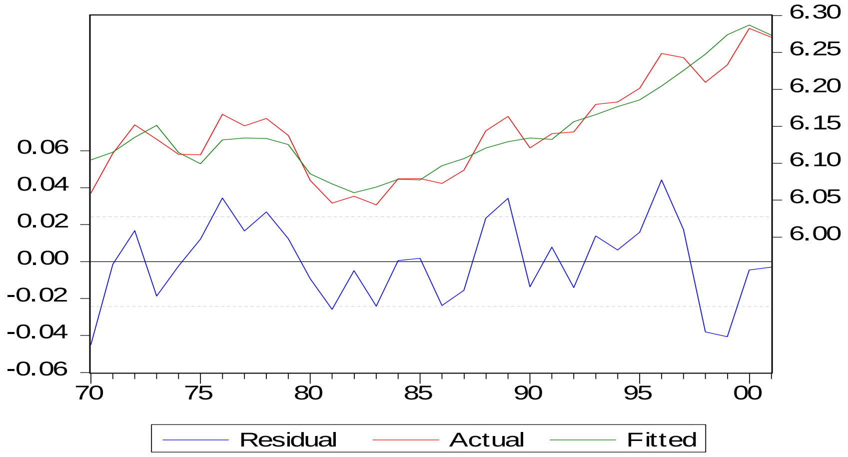

FIGURE 6

2-Transportation sector

LN(ET)=1.07 + 0.67*LN(GDP)-0.1*LN(P_E)-0.04*LN(FILTT(-3))

(7.8) (32) (-8.17) (-2.6)

0.99=Adjusted R-squared

As similar results show that all of coefficients are significant and coefficient or elasticity of energy price (P_E) is sum of P_E lags. Then it shows long run coefficient or elasticity of energy price (P_E) in transportation sector, that is -0.1. As similar elasticity of asymmetry effects in the response to price movements is sum of FILTT lags. Then it shows long run coefficient or elasticity of FILTT in transportation sector, it is equal of -0.04. This coefficient shows efficiency of energy consumption. Figure(7) shows trend of residual actual and fitted regression for transportation sector.

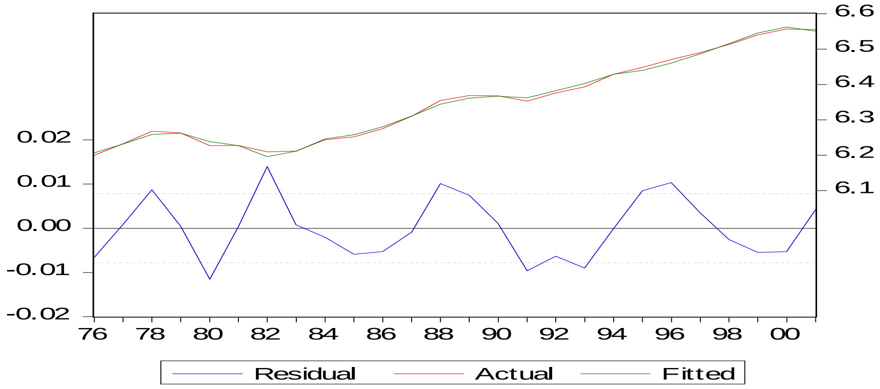

FIGURE 7

IV) Result

Almon (1965) polynomial distributed lag model is suitable method to detect lags. This method shows effects of per lags on dependent variable. In this paper we used from this method for estimate of relation energy demand and energy price in North America Residential-Commercial and transportation sectors. In Residential-Commercial sector the coefficient of GDP is positive and statistically significant at the 86 percent level of confidence. This further validates our hypothesis and qualitative analysis that energy consumption is directly correlated with GDP. The income elasticity is 0.59, which suggests that, if income increases by one per cent, energy consumption increases respectively by 0.59, percent, if other things remain constant.

The long-run Coefficient of energy price by PDL method is negative and statistically significant at the 86 percent level of confidence. The price elasticity is -0.19, which suggests that, if price increases by one per cent, energy consumption decreases respectively by 0.19, percent, if other things remain constant.

The long-run coefficient of filter variable in North America that be used to cover the asymmetric response of demand to price changes, in this sector wasn't statistically significant and wasn't entered in model.

Similarly in transportation sector coefficient all of variables are significant and there are the same interpretations for it. Long-run coefficient of filter variable in this sector is significant and is equal of -0.04 then show 0.04 of effects asymmetric response of demand to price changes is relation to factors such as improvement of efficiency.

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