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ABUSE

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The right way to estimate and forecast energy demand is of course to break consumption into rational sub-groups, each analyzed to separate out the effects of income, price, technology, etc., using either past consumption or "pseudodata" calculated from engineering relationships.

As a check on such estimates, and to get a quick impression of recent developments, we can use two widely quoted relations between aggregate energy consumption, on the one side, and national income (usually gross domestic product) on the other. The average energy-income coefficient states consumption per unit of income, and its change over time. The incremental energy-income coefficient divides the percent change in energy use over any time period by the percent change in income.

The average coefficient is a valid if imprecise measure, but the incremental coefficient should not be used at all. It mixes up four elements, to the point where we cannot make out anything about any of them. These four are: the consumption-income relationship, holding price constant; the consumption-price relationship, holding income constant; the time needed to adjust to a price change; and the rate of economic growth.

INCREMENTAL AND TOTAL ENERGY -INCOME COEFFICIENTS

Let Q = amount demanded, G = gross domestic product, P = price, and E = price elasticity of demand. Let a and b be constant scale factors. We assume the amount demanded is:

$$Q = aG b P^E$$

The exponent of G is taken as unity. This is plausible and strongly supported by the demand work of the World Oil Project.

The total energy-income coefficient is:

$$Q/G = ab P^E \tag{2}$$

For any given price, the coefficient is also the slope of the line relating consumption to income:

$$(\partial Q/\partial G) = a b P^E = Q/G \tag{3}$$

If the price varies, the coefficient varies accordingly: for two prices, P_1 and P_2 :

$$\frac{(Q_1 / G_1)}{(Q_2 / G_2)} = \left(\frac{P_1^E}{P_2^E} \right) \tag{4}$$

Now consider the incremental coefficient, which is the relation of the percent change in energy use to the percent change in income:

$$\frac{\partial Q/Q}{\partial G/G} = \frac{G\partial Q}{Q\partial G} \tag{5}$$

But from (3) and (5), we have:

$$\frac{G\partial Q}{Q\partial G} \frac{GQ}{QG} = 1 = \frac{\partial Q/Q}{\partial G/G} \tag{6}$$

Thus, once we isolate the incremental coefficient we see that no matter what the relation of energy use to income at any moment, and no matter how that relation changes in response to price, the incremental coefficient stays at unity. This follows from the linear or log-linear energy-income relation, with exponent unity.

But the observed incremental coefficient does change, so much as to be inscrutable. In Figure 1, we show the average coefficient under two sets of prices, i.e. with two slopes, the higher for convenience being twice the lower. The true incremental coefficient is the same in both. Suppose, however, that there is an instantaneous change from the higher to the lower line. At 1 and 2a, joined by the dotted line, there is the same income, different consumption. Then the apparent incremental coefficient is minus infinity, for the denominator, percent change in income, is zero. Or suppose that the transition is gradual: the line Q/G moves gradually clockwise, but the amount of energy consumption does not change over the interval G_1 to G_2 , as shown by the dashed line from 1 to 2b. With no change in consumption, the numerator is zero and the incremental coefficient is zero.

In Table 1, we see the average and incremented coefficients for several large consuming countries. The instability of the incremental coefficient makes it useless, and contrasts with the minor and symmetrical variation around the median value of .92. (U.K.).

Let us now address the time necessary for the Q/G relation to change. For convenience, refer to a price ratio (P_1 / P_2) as PR, and a consumption-income ratio $\frac{Q_1/G_1}{Q_2/G_2}$ as QR. Then from equation

$$(4), QR = PR^E, \text{ or } E = \ln QR / \ln PR.$$

Assume now a price change whose effects are felt over time, through change in the capital stock of energy-using equipment. That capital stock will have a certain half-life of h years, such that if c is the percent of the old capital stock still existing at any moment, then $c^h = 0.5$. The effect of a given price change is assumed greatest immediately after it happens, after which it weakens at the rate c^t , where t is time in years. The effect of the price change, therefore, can be measured by the expression $(1-c^t)$. Where $t=0$, nothing has happened and the QR is unchanged: where $t = h$, half of the effect has been accomplished, and so on.

Thus E_∞ is a special case of E_t , or E_t converges finally:

$$E_t = E_\infty (1-c^t) \quad (8)$$

Therefore in any year following a price change, $QR_t = PR^{(1-c^t)} E_\infty$

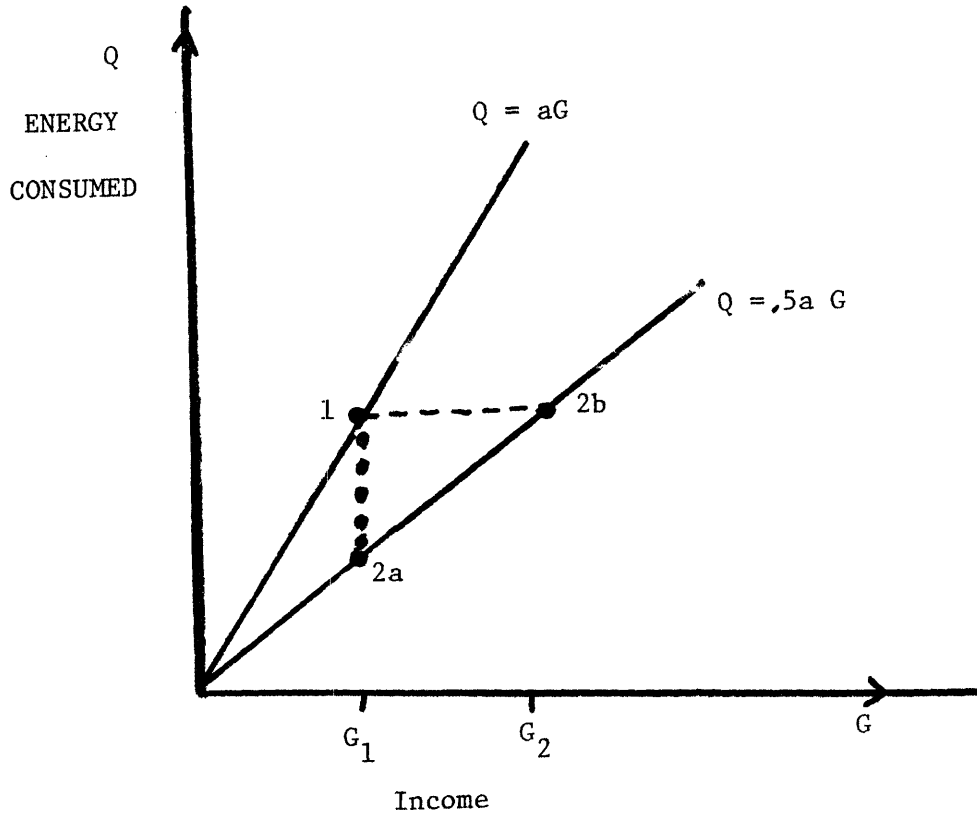
$$\ln QR_t = E_\infty (1-c^t) / \ln PR$$

Let two years be designated as t and T, then:

$$\ln QR_t = \ln QR_T (1-c^t) / (1-c^T) \quad (9)$$

This expression is a reduced form, from which both the price ratio and the elasticity are missing. Let 1972 = 0, 1977 = 5, 1987 = 15 then:

$$\ln QR_{87} = \ln QR_{77} (1 - c^{15}) / (1-c^5).$$



Ratios, 1977: 1972

Energy-GNP Coefficients

<u>Country</u>	<u>Income</u>	<u>Energy</u>	<u>Incremental</u>	<u>Total</u>
U.S.	1.137	1.045	.328	.9191
Canada	1.198	1.162	.818	.9700
France	1.160	1.061	.381	.9146
W. Germany	1.121	1.043	.355	.9304
Italy	1.146	1.067	.459	.9310
U.K.	1.072	.988	-.167	.9216
Japan	1.252	1.123	.488	.8970

Sources: Income, Economic Report of the President, 1978
Energy, BP Annual Statistical Review, 1977

Example: Incremental: U.S., $.045/.137 = .328$
Total: U.S., $1.045/1.137 = .9191$

Then:

	<u>h</u>	<u>c</u>	<u>ln QR₈₇</u>	<u>QR₈₇</u>
(1)	5	.8706	-.1478	.8630
(2)	10	.9330	-.1864	.8296

Let G grow at one, or three, or five percent per year; while h = 10, and $QR_{87} = .8296 QR_{72}$. Then:

	<u>QR₈₇</u>	<u>$\frac{G87}{G72}$</u>	<u>$\frac{Q87}{Q72}$</u>	<u>Incr. coeff., 72 - 87</u>
(1)	.8296	(1.01) ¹⁵	0.963	-.126
(2)	.8296	(1.03) ¹⁵	1.294	.527
(3)	.8296	(1.05) ¹⁵	1.725	.672

These huge variations in the incremental coefficient derive exclusively from the varying rates of growth. Were we to vary h, the capital stock half-life, or the elasticity of demand, the variation would be even greater.

It would be best, therefore, if we heard no more about this confused notion "the incremental energy-income coefficient." But there is reason to expect total energy consumption per unit of income in 1987 to be 80 to 85 percent of what it was in 1972.

TOTAL ENERGY DEMAND ELASTICITY

In Table 2 we have a rough measure of the change in the U.S. consumer energy price, and the producer energy price; assuming energy use divided about equally between the two, and adjusting by the GDP deflator, the real PR is around 1.49. Then the 5 year elasticity is around -.21. If we assume a 10 year half-life, the indefinitely long run elasticity is -.72.

Most of the elasticities in the World Oil Project are in fact in the range -0.5 to -1.0. But if we suppose that after 15 years the consumption pattern will be deflected by new forces, not foreseen now, perhaps the 15-year coefficient, around -.47, should be regarded as the best available approximation to the long run.

Some of the most important biases in this procedure are, first, the assumption that all the price increase came in 1972, when it came mostly in 1974. This tends to understate the elasticity. Second, the slowdown in manufacturing has been proportionately greater than in total economic activity and the energy-manufacturing income coefficient exceeds that for energy-all income. This is an upward bias. Third, the world recession and the limping recovery have been particularly hard on investment, and this has delayed the replacement of less by more energy-efficient capital stock. This is another downward bias.

So far as concerns estimates for 1987, the OPEC increases this year (1979) will add to the response underway since 1972, and cause energy consumption to be lower. If (as the writer guesses) the rate of growth in world income will probably be in the neighborhood of 3 percent, then the growth in energy consumption should not exceed 2 percent. Thus, when linked to an expected growth rate, the total coefficient gives some help in estimation. We badly need some better price indexes, however.

TABLE 2

Consumer energy prices, 1977/1972	1,81
Producer prices, processed fuel, 1977/1972	2,39
Average, equally weighted	2,10
GDP deflator, 1977/72	1,41
Real energy PR, 1977/72	1,49

Source: Economic Report of the President 1978, pp. 241,246, 187.