A Note on Price Asymmetry As Induced Technical Change (EMF OP56)

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Abstract

This note evaluates whether fixed time effects (yearly dummy variables) are a better instrument than separate price-decomposition terms for representing induced technical change in energy and oil demand. Fixed time effects are a proxy for all omitted variables that change similarly over time for all countries. Many of these omitted variables have little relevance to technical change. Empirically, statistical tests applied to previous studies reject an important premise of the fixed-time-effect model that energy or oil demand responds symmetrically to price increases and decreases. Moreover, when price-decomposition techniques allow for price-asymmetric responses, the estimated income elasticities are not dramatically different from their fixed-time-effect counterparts, as it is sometimes alleged. There are also practical reasons for choosing models that allow for asymmetric responses to price, especially when evaluating the long-run implications of a number of important energy and environmental issues.

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Introduction

Probably no more difficult problem confronts energy economists than how to represent price-induced, energy-efficient technical change (ITC) in long-run studies of international oil markets or of greenhouse gas abatement strategies[1]. In recent years, this journal has published two major empirical studies with very different approaches to this issue. Gately and Huntington (GH, 2002) decompose prices by direction of change (either increases or decreases) or novelty (either exceeding previous historical maximums or not). Griffin and Schulman (GS, 2005) argue that the price decomposition terms used in the GH asymmetric approach and other similar studies (Dargay, 1992, and Dargay and Gately, 1994, 1995) are simply capturing exogenous energy-saving technological progress that could be represented better by a series of dummy variables for each year. They suggest that once yearly dummy variables are inserted into a pooled panel-data analysis of major OECD countries, the asymmetric effects are not very important and that a symmetric form should be adopted on econometric grounds. Not surprisingly, they believe that the symmetric form should be used for forecasting.

Empirical Estimates of Asymmetric Responses

Energy Demand Specification

This note focuses on the results reported by Griffin and Schulman (GS, 2005), who employ a pooled data set for 16 OECD countries for the 1961-99 period (n=39) as well as for the shorter 1971-96 period (n=26) evaluated by GH. GS based their specification upon the previous GH analysis, which tested six different energy demand specifications before choosing their preferred equation for each group of countries, including the OECD nations.[2] GS estimated the following equation:

[1] Ruttan (2002) provides an extensive review of ITC studies in a range of sectors, Nordhaus (2002: p. 190) explains the asymmetric nature of ITC in the energy and environmental sectors, and Clarke and Weyant (2002) describe the critical role of ITC in integrated assessment models of greenhouse gas emissions.

[2] Other functional forms and specifications could be applied to this problem. This note's objective is to compare reasonably similar approaches rather than applying a new functional form to the data.

$$C_{it} = \alpha_i + \gamma_t + \sum_{j=1}^{J} \beta_j P_{itj} + \theta(Y_{it} - \lambda Y_{i,t-1}) + \lambda C_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

where C is per capita energy or oil consumption, P is real end-use[3] energy or oil price (or its components as described below) in the current year, Y is per capita real Gross Domestic Product, i refers to country, t indicates time and ε is the independent and identically distributed residual term. All price, income and consumption variables are expressed in logarithms. Dummy variables shift the intercept across countries (α_i) and over time periods (γ_t).

The current-year price (P_{it}) can be decomposed into J separate terms depending upon its direction and relationship with historical price peaks. Following previous studies on agricultural supply and energy demand,[4] energy analysts commonly use three such price components: the historical peak (P_{max}), cumulative price cuts (P_{cut}), and cumulative price recoveries (P_{rec}) where the price level does not exceed the previous maximum.[5] However, when aggregated, the separate price variables will equal the original price variable. This specification allows one to easily impose full symmetry constraints on the price coefficients by setting:

$$\beta_{\max} = \beta_{cut} = \beta_{rec} \tag{2}$$

or partial symmetry constraints on some subset (e.g., $\beta_{max} = \beta_{rec}$) that allows asymmetric responses only in terms of direction (price increases versus price decreases). Many energy studies separate the historical peak from other price changes, however, because these novel price innovations could potentially encourage the introduction of new technologies in ways that price recoveries would not. In summary, the response will depend upon not only the direction of the price change but upon whether it is novel or not.

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[3] In order to incorporate 96 nations, including many developing economies, GH used crude oil prices rather than delivered prices. This price variable does not seem critical to their OECD results. For the same specification, their results for the OECD were not much different than those estimated by GS.

[4] Gately (1992), Gately and Huntington (2002), and Griffin and Schulman (2005) provide references. Ryan and Plourde (2002) provide an interesting new development where they find that flexible functional forms representing energy systems may demonstrate the advantages of price-asymmetric specifications better than those based upon more rigid, single-equation Koyck approaches. They also include a rather extensive cointegration analysis in developing their estimates.

[5] Please see either GH or GS studies for more definitive explanations of these separate price components.

This specification allows price to have a larger long-run effect (β_j/ (1-λ) with λ<1) than a short-run effect (β_j), as more efficient, new capital vintages replace older vintages and as new more efficient technologies are adopted. Notice that with a common λ, this effect for each price component persists through time at the same rate.[6] Demand adjustments to income, however, are contemporaneous.

GS use three different specifications: price-asymmetric responses without fixed time effects (γ_t=0 for all t) to represent the price decomposition approach, price-symmetric responses with fixed time effects ($\gamma_t \neq$=0 for all t) to represent the exogenous technical-progress approach, and price-asymmetric responses with fixed time effects to represent a joint specification.

Testing for Asymmetry

All income and lagged consumption coefficients in the GS study are statistically significant at the 95% level, as are 23 of the estimated 28 price coefficients.[7] Surprisingly, GS do not conduct formal tests to see if symmetry or fixed time effects are rejected on statistical grounds. Fortunately, they do report sufficient statistics to compute the same tests that GH used to reject symmetric price responses in their study. Since the equation and the constraints are linear, this test reverts to an F-test for the constraints in equation (2) above:

$$F(k, DF_a) = [(SSE_s - SSE_a)/(k)] \,/\, [SSE_a \,/\, DF_a] \qquad (3)$$

where the subscript *a* denotes the unconstrained asymmetric specification with fixed time effects (their equation 3), *s* refers to the same equation with coefficient constraints (either their equation 1 or 2), and k is the number of additional constraints required to set all fixed time effects to zero (k=25 or k=38) or to have the price-decline and the price-recovery terms equal the price-maximum term in the symmetric specification consistent with the constraints shown in equation (2) above (k=2).

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[6] An alternative approach that would allow this persistence rate to vary would be to estimate a distributed-lag equation with different responses over time for price increases and decreases.

[7] Each of four samples produces 7 price coefficients: three price coefficients from each of two asymmetric specifications and a single price coefficient from the symmetric specification.

Before turning to the tests for the price decomposition terms, we should note that statistical F-tests reported in Table 1 confirm the inclusion of fixed time effects. What is left unsaid, however, is whether these fixed time effects represent a useful measure of price-induced energy-efficient technological change or some other omitted variables that change similarly over time for all countries. Most studies recognize that these yearly dummy variables are incorporating a range of unmeasured variables that are affecting all countries simultaneously. Examples include international prices for oil and other competing fuels, global macroeconomic fluctuations that cannot be captured by income changes alone, changes in taste unrelated to income, economic structure, urbanization and exogenous changes in technology (Holtz-Eakin and Selden, 1995; Schmalensee, Stoker, and Judson, 1998). Most demand specifications that include only price and income ignore too many potentially important variables to ascribe all or even most of the effects of yearly dummy variables to induced technical progress. Casual inspection of the erratic behavior exhibited by the effects of yearly dummy variables in GS's Figure 3 or 4 confirm considerable skepticism about whether they have correctly identified many of the factors influencing this set of variables. As a result, the approach provides no option for separating the effect of price-induced technical change from these other factors and thus leaves open the question of whether the nature of the price change or other explanatory variables may play a role.

Table 1 reports that symmetry can be rejected for all equations at the 10% significance level or higher and can be rejected for 3 of the 4 equations at the 1% significance level. The GS symmetric specification for oil over the 1971-1996 period is the one specification where symmetry cannot be rejected at the 1% level[8]. Extending coverage to the period, 1961-1999, the tests reject symmetry for both the energy and oil equations at the 1% level. The inclusion of 13 more years for each country increases the power of the test. These years also include relatively stable prices prior to 1971 and more observations after energy prices have reached their maximum in the early 1980s.

[8] This result is the only symmetry test reported by the authors. The estimates in Table 2 are based upon the rounded estimates of SSE reported by GS and for that reason may differ slightly from those based upon unrounded estimates. Moreover, their SSE reported for the symmetric oil equation over the 1961-99 period appears misreported (compared to their final draft paper), resulting in an incredibly large F-statistic for rejecting their symmetric results. Instead, we have used the originally reported SSE=1.084, which still rejects symmetry in that equation.

Although these tests reject symmetry, one should be reluctant to claim that the GS results in the *energy* demand equations for 1961-99 confirm the type of asymmetry found in the GH study without further statistical tests and specifications. Asymmetry in the GH approach implies $\beta_{max} > \beta_{cut}$ but the first coefficient is in fact statistically insignificant with a smaller magnitude than the others. This finding contrasts with the *oil* equations in which $\beta_{max} > \beta_{cut}$ and $\beta_{max} \geq \beta_{rec.}$

The fact that P_{max}, unlike the other price components, has no significant effect on energy demand is troubling for understanding the GS estimates. If their price series are similar to the price trends reported by GH (2002: p. 33), the GS results imply that energy demand did not respond to the two major price shocks of the 1970s that are incorporated by P_{max}. Since they use unpublished data for energy prices before 1985 and do not evaluate or chart their price series, it seems prudent to test these hypotheses with other data before concluding that symmetry is the preferred approach for this equation.

Income Elasticities

GS also criticize the asymmetric specification because they claim that it dramatically changes the elasticities for other variables, like income. For example, the single *income* elasticity in the oil demand equation could range from 0.367 to 0.651 when symmetric and asymmetric responses to price are estimated over the 1961-99 period. This disparity, however, has nothing to do with whether symmetric or asymmetric forms are used. It results entirely from whether the fixed yearly effects are included or not. When only the symmetry assumption is changed, the income elasticity increases very modestly from 0.367 to 0.386. The higher income elasticity for the asymmetric specification lies well inside the 95% confidence interval of 0.18 to 0.55 for the income elasticity in the symmetric specification.

Each row of Table 2 demonstrates this result for each of the four samples, depending upon whether the data represent energy or oil demand and whether they cover the 1971-96 or 1961-99 period. The income elasticities are virtually unchanged when only the price-symmetry assumption is changed when moving from the first to the second column of estimates. By contrast, the income elasticities increase substantially only when the fixed time effects are removed in the price-asymmetric specification shown in the third column.

Summary

The major implications of statistical tests of the GS findings are that both exogenous and price-dependent technology developments are important for analyzing oil demand behavior. Moreover, allowing for price-asymmetric rather than imposing symmetric responses will not change the income coefficients. There are also practical reasons for choosing models that allow a direct role for ITC through the price variable.[9] They would be particularly useful to evaluate the long-run implications of a number of important energy and environmental issues:

- Countries finally agree to limit carbon dioxide emissions by placing emissions fees on coal primarily but also on other fossil fuels. With carbon moving from being free to having a positive price, the coal price quickly surpasses its previous peak.
- Continued growth in Chinese and Indian oil demand coupled with stabilizing or declining Russian oil supplies exert even higher long-run pressure on oil prices, making that commodity considerably more expensive than it has been in the past.
- Alternatively, a major oil producing country wants to reduce its price because it thinks that it can earn higher net profits over the long run. However, it knows that some of the potential increase in oil demand will not be forthcoming because energy demand reductions achieved through ITC when prices rose in previous years will not disappear as prices fall.

[9] The GS criticism that the asymmetric specification allows continuous price volatility to permanently reduce demand is not as serious as it seems. One approach would be to impose and test a constraint that sets the responses to price cuts and recoveries equal to each other (Traill, Colman and Young, 1978). Another approach would be to allow asymmetries for prices below the historical maximum to operate only over the short run (Vande Kamp and Kaiser, 1999).

Table 1. F-Tests for Parameter Restrictions

		No Fixed Time Effects, H0: $\gamma(t)=0$		Symmetric Price Responses, H0: β max = β cut = β rec	
Oil	1971-1996	4.43	reject (1%)	2.41	reject (10%)
Energy	1971-1996	6.50	reject (1%)	5.08	reject (1%)
Oil	1961-1999	4.14	reject (1%)	10.26	reject (1%)
Energy	1961-1999	5.59	reject (1%)	6.28	reject (1%)

Table 2. Income Elasticities for Different Specifications

		Fixed Time Effects and		No Fixed Time Effects and
		Symmetric Responses to Price	Asymmetric Responses to Price	Asymmetric Responses to Price
Oil				
	1971-1996	0.401	0.430	0.684
	1961-1999	0.367	0.386	0.651
Energy				
	1971-1996	0.425	0.365	0.691
	1961-1999	0.408	0.404	0.658

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