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How High Are Option Values In Energy-Efficiency Investments?

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Abstract

High implicit discount rates in consumers' energy-efficiency investments have long been a source of controversy. In several recent papers, Hassett and Metcalf (1992,1993,1994) argue that the uncertainty and irreversibility attendant to such investments, and the resulting option value, account for this anomalously high implicit discounting. Using their model and data, we show that, to the contrary, their analysis falls well short of providing an explanation of this pattern.

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Background

Numerous empirical studies have shown that many consumers purchasing energy efficiency reveal implicit discount rates that substantially exceed market interest rates for borrowing or saving, in some cases by an order of magnitude. This pattern has been cited by some analysts as evidence of market "barriers," market failures, or other anomalies, and used to justify a number of policies promoting energy efficiency. Conversely, others have placed a premium on explaining it in terms of efficient markets and rational consumer behavior, thereby obviating such policies.

One such explanation, developed by Hassett and Metcalf in a series of papers in this journal and elsewhere, is based on the concept of an "option value" associated with energy-efficiency investments in a model adapted from the theory of finance (McDonald and Siegel 1986; Hassett and Metcalf 1992, 1993; Metcalf 1994). In this model, the simultaneous presence of uncertainty regarding prices and of irreversibility results in a quantifiable benefit (the option value) of delaying a final decision until some uncertainty is resolved. The implication is that a rational consumer will apply a "hurdle rate" to potential investments that will in general exceed that which is predicted by standard models. Applying this idea to energy-efficiency investments, Hassett and Metcalf find that the rational hurdle rate for such investments exceeds the conventional estimate by approximately a factor of four. They conclude that empirically observed "high" implicit discount rates in fact merely reflect rational consumer behavior under conditions of uncertainty and irreversibility.

While it has been realized for some time that option value might play an important role in understanding consumers' energy-efficiency decisions, Hassett and Metcalf are the first to provide an explicit framework for calculating the magnitude of that role. In this note we show, however, that their analysis falls well short of explaining high discount rates implicit in consumers' energy efficiency investments. The problem with their conclusion does not lie with their computed factor of four, which we do not dispute. Rather, this factor of four occurs in an example that explains an implicit discount rate of only 6.3%. In all examples producing hurdle rates of the magnitudes of the implicit discount rates requiring explanation (25% and above) option values generate considerably smaller factors. Thus, even taking uncertainty and irreversibility into account in the manner they propose, consumers must still be applying anomalously high rates of time discounting to yield implicit discount rates in the range reported in the literature. We also note that, because it does not include *costs* of delaying purchases that would tend to offset the option value, the model as developed to-date is likely to apply only to a--possibly small--subset of consumers in the market for energy efficiency. We conclude that is approach to explaining high implicit discount rates for energy efficiency is of limited value.

Data on implicit discount rates

Consumer decisions regarding energy efficiency are usually seen as requiring evaluation of a trade-off between higher initial purchase price and reduced future operating costs (for a more efficient device). Thus, given data on technology and prices and a model of behavior (as well as data on actual purchases), one can calculate a quantity representing the trade-off between present and future cash flows that is implied by consumers' purchases.[1] This quantity is the implicit discount rate. The adjective "implicit" indicates, in part, the "as if" character of such estimates.

Train (1985) provides a summary of the empirical literature on consumers' implicit discount rates in energy efficiency purchases. Most--though not all--such estimates are obtained using parameterizations of utility functions specified within a discrete choice framework. Table 1 presents some of the results commonly cited; all of these were computed assuming infinite device lifetimes and no real increases in fuel prices.

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[1] Some analysts have argued that this approach omits factors that would tend to corrupt the measurement of implicit discount rates. Whatever the merits of this criticism, we note that it is not at issue in Hassett's and Metcalf's work. See, however, Koomey and Sanstad (1994) for a response to this argument. Howarth and Sanstad (1994) provide an extensive discussion of issues associated with discount rates and the energy efficiency "gap."

Table 1

Average implicit discount rates in energy-efficiency investments

Study	*End-use*	*Average rate*
Arthur D. Little (1984)	Thermal shell measures	32%
Cole and Fuller (national survey, 1980)	Thermal shell measures	26%
Goett (1978)	Space heating system and fuel type	36%
Berkovec, Hausman and Rust (1983)	Space heating system and fuel type	25%
Hausman (1979)	Room air conditioners	29%
Cole and Fuller (1980)	Refrigerators	61-108%
Gately (1980)	Refrigerators	45-300%
Meier and Whittier (1983)	Refrigerators	34-58%
Goett (1983)	Cooking and water heating fuel type	36%
Goett and McFadden (1982)	Water heating fuel type	67%

A conventional rule-of-thumb is that consumers purchasing energy efficiency should be expected to discount future costs and benefits either at the rate-of-return available on investments of comparable risk or at the rate at which the purchase is financed, depending upon the exact model of investment. (In engineering-economic parlance, this criterion takes the familiar form, "invest if the rate-of-return exceeds the discount rate.") Thus, an approximate upper bound for the expected rate of time discounting in energy-efficiency investments is 15% real (for purchases financed at commercial short-term consumer credit rates). As the table indicates, in these studies the *average* implicit discount rate revealed by consumers' choices thus substantially exceeds the *maximum* discount rate that consumers would be expected to employ according to standard criteria. Note also that, because the rates reported here are averages, some consumers reveal implicit discount rates that are considerably higher.[2]

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[2] Sutherland (1991) argues, using the Capital Asset Pricing Model (CAPM) , that high implicit discount rates merely reflect riskiness of energy-efficiency investments. However, Stoft (1993) shows that the

The option value model

Definitions of "hurdle rate" vary, but in general this term refers to a threshold rate-of-return demanded from investments by consumers that *differs* from the rate at which they discount future costs and benefits. A important contribution of Hassett and Metcalf is to provide a clear discussion and precise analytical definition of this term. Before reviewing this, we briefly discuss the structure of the model in order to make clear how and why our conclusions differ from their's.

Mathematically, the key conclusions of the option value model follow from the assumption that the time paths of both the (log) price of energy (denoted by P_t) and the (log) price of capital (denoted by K_t) follow "Brownian motion;" intuitively, this means that they are continuous time random walks. Thus, both series of prices are characterized by two parameters: a "drift" term, indicating the mean trend of increase (or decrease) over time, and a "variance" term, indicating random fluctuations around this trend. Hassett and Metcalf estimate these parameters both for the energy price and capital price series separately and for the combined series P / K using national (US) data spanning the period 1955-1981. The following parameters are empirically estimated: α= the trend in the combined series, σ_0= the variance in the combined series, μ_P = the trend in fuel prices alone, σ_P = the variance in fuel prices alone, μ_K= the trend in capital prices alone, and σ_K = the variance in capital prices alone. Hassett's and Metcalf's estimates for the first two parameters are $\alpha = 0.046$ and $\sigma_0 = 0.093$. They do not report their estimates of the pure fuel and capital price trends or variances.

To study the model, we re-estimated all of these parameters; our results were: $\alpha = 0.046$ and $\sigma_0 = 0.089$, $\mu_P = 0.034$, $\mu_K = -0.12$, $\sigma_P = 0.088$, $\sigma_K = 0.013$ [3]. (We cannot account

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quantitative implications of Sutherland's analysis are negligible. Moreover, Metcalf (1994) re-examines the logic of the CAPM in this case and finds that it implies that rates-of-return demanded by consumers on energy-efficiency investments should be *lower* than market interest rates.

[3] Following Hassett and Metcalf, we obtained data from the *Economic Report of the President, 1991;* the "fuel oil and other household fuel commodities" index (1955-81) was used to measure energy price, while the "durable commodities" index (1955-81) was used to measure capital price. Both series were normalized by the composite "all items" index, and the means and standard deviations of the series of log differences computed, to estimate the drift and uncertainty parameters, respectively. To obtain the parameters for the composite series P / K we applied the formulae given by Hassett and Metcalf (1992, Appendix).

for the discrepancy between our estimate of σ_0 and Hassett's and Metcalf's; we note, however, that it makes no substantive difference to either their conclusions or ours.)

The consumer is assumed to minimize the expected present value of energy costs over an infinite horizon. Solving the model entails finding the threshold at which the consumer should undertake the investment. Let γ be the consumer's discount rate, and δ the expected per-period rate of energy savings. Hassett and Metcalf show that the consumer should invest the first time that

$$\frac{\delta P_t}{K_t} > \Gamma(\gamma - \mu_P), \tag{1}$$

where

$$\Gamma = \frac{b}{b-1} \tag{2}$$

with

$$b = \frac{0.5\sigma_0^2 - \alpha + \sqrt{(0.5\sigma_0^2 - \alpha)^2 + 2(\gamma - \mu_K)\sigma_0^2}}{\sigma_0^2}. \tag{3}$$

Note that in the absence of uncertainty, the criterion in inequality 1 is simply

$$\frac{\delta P_t}{K_t} > \gamma - \mu_P, \tag{4}$$

Comparison of inequalities 1 and 4 gives the basic implication of the model. As indicated in inequality 4, the conventional (or "neo-classical") hurdle rate is $\gamma - \mu_P$. In the option value model, the discount rate γ is presumed to be of the same magnitude as in the conventional view (as described above). Assuming that $\gamma - \mu_K > \alpha$, it follows that $\Gamma > 1$. Thus, the option value multiplier Γ directly measures the degree to which the rational consumer's hurdle rate should exceed the conventional criterion. (With the simplifying assumption of no trend in energy price--i.e., $\mu_P = 0$--inequality 4 takes the more familiar form

$$\frac{\delta P_t}{K_t} > \gamma. \tag{5}$$

That is, the conventional hurdle rate equals the discount rate. We also discuss this case below (cf. Table 3).) For the particular parameter values estimated by Hassett and Metcalf, $\Gamma = 4.23$, which, all else being equal, implies that uncertainty and irreversibility will result in the consumer requiring a rate-of-return on efficiency investments more than four times greater than that dictated by the standard model.

Applying the model

The conceptual link between the option value model and the data in Table 1 arises by equating the empirically estimated implicit discount rates with the model's predicted hurdle rates. The model predicts that consumers' hurdle rates should exceed their "actual" discount rates (represented by γ in the model); if, numerically, the hurdle rates at least roughly correspond to reported implicit discount rates, then the "high" values of the latter may be interpreted as reflecting rational investment behavior.

Table 2 summarizes this comparison for several values; the numbers were derived using the formulae above and our re-estimates of the parameters. The first row represents the case discussed by Hassett and Metcalf. Discounting at 5% and given the presumed fuel price trend of 3.4%, the conventional hurdle rate is 1.6%. The option value multiplier is 4.23, so that the rational hurdle rate is 6.3%. Or, conversely, if a consumer reveals an implicit discount rate of 6.3%, then, interpreting that rate as a hurdle rate in the model, we conclude that his conventional hurdle rate is 1.6%, and his discount rate 5%. From 1.6% to 6.3% is indeed a sizable relative difference, but would appear to have no significance in accounting for the data in Table 1.

We thus examine several other cases. Hassett and Metcalf emphasize the dependence of the option value multiplier on uncertainty regarding future prices, but as the above formulae indicate the multiplier depends not only on uncertainty *but also on the consumer's discount rate.* This dependence and its consequences for the consumer's hurdle rate are clearly illustrated in the table: the magnitude of the multiplier falls

Table 2

Consumer discount rates, option value multipliers, and hurdle rates

Consumer discount rate (γ)	Conventional hurdle rate ($\gamma-\mu_p$)	Option value multiplier (Γ)	Adjusted hurdle rate ($\Gamma(\gamma-\mu_p)$)
0.05	0.016	4.23	0.063
0.1	0.066	1.84	0.121
0.15	0.116	1.5	0.174
0.2	0.166	1.37	0.227
0.3	0.266	1.26	0.335
0.4	0.366	1.2	0.44

off rapidly as γ increases. As a consequence, for example, at 15%, which we noted was an approximate upper bound for the expected consumer discount rate, the option value-adjusted hurdle rate is 17.4%. This is well under the *smallest* of the *average* implicit discount rates reported in Table 1.

This gap between the predictions of the option value model and the data on implicit discount rates can also be seen by working "backward" from right to left in Table 2. That is, suppose we observe an implicit discount rate of, for example, 22.7%. Interpreting this as a hurdle rate in the option value model, we conclude that the consumer's true discount rate is 20%. Similarly, an implicit discount rate of 33.5%, interpreted as a hurdle rate, implies a true discount rate of 30%, and so forth.

These calculations demonstrate clearly that, even taking uncertainty and irreversibility into account in the manner proposed by Hassett and Metcalf, consumers must be employing very high discount rates in order to apply hurdle rates that correspond to implicit discount rates in the range reported in the literature. Equivalently, applied with consumer discount rates in what is commonly perceived as a "normal" range, the model fails to predict hurdle rates, and thus implicit discount rates, that are in this range.

This gap may be even clearer if we simplify the model by including only the uncertainty associated with the energy price, that is, we assume no average increase in either energy price or capital price, and no uncertainty in capital price. This simplification also facilitates comparison with the estimates presented in Table 1 (which were computed under the assumptions of no price trends as well as no uncertainty). The results are shown in Table 3.

Table 3

Consumer discount rates, option value multipliers, and hurdle rates assuming only energy price uncertainty[a]

Consumer discount rate (γ)	Option value multiplier (Γ)	Adjusted hurdle rate ($\Gamma\gamma$)
0.05	1.32	0.066
0.1	1.22	0.12
0.15	1.17	0.176
0.2	1.15	0.23
0.3	1.12	0.336
0.4	1.1	0.44

[a] $\mu_P = \mu_K = \sigma_K = \alpha = 0$, σ_0 re-estimated (and in this case equal to σ_P).

The results closely track those of the full model. Thus, for example, calculating as in Table 3, a consumer revealing the average implicit discount rate in the well-known study by Hausman (29% assuming no fuel price trend and infinite device lifetime) would have to be discounting at a rate of approximately 27%.

We conclude that, while Hassett and Metcalf have made an interesting and useful contribution by applying the option value idea to energy-efficiency investments, their analysis falls well short of explaining the data in question [4].

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[4] We also considered another variation. As implemented, the model essentially incorporates rational expectations of energy and capital prices. Given the calculations reported here, it is natural to ask, what level of uncertainty would consumers have to perceive in order for the hurdle rates predicted by the model to match the implicit discount rates reported in the literature? There are various ways of approaching this question; we proceeded as in Table 3, i.e., we supposed that consumers forecast constant capital prices and no average change in energy prices, but do perceive uncertainty in energy prices. We then determined what standard deviation in energy prices (σ_0) they would need to forecast in order for the resulting option value multiplier to bridge the gap between "low" discount rates and "high" implicit discount rates. Using 25% as the "target" hurdle rate, several examples are: for $\gamma = 0.15$, $\sigma_0 = 0.28$; for $\gamma = 0.10$, $\sigma_0 = 0.42$; for $\gamma = 0.05$, $\sigma_0 = 0.57$. That is, for these discount rates, consumers' estimates of the standard deviation

It should be clear that inattention to the details we have presented here could result in serious misinterpretation of the model's implications. For example, in criticizing the use of a 5.5% real discount rate in an application of the Total Resource Cost (TRC) test of a demand-side management project, Nichols (1994) claims that "[Hassett and Metcalf] estimate that a 5% real discount rate under certainty leads to a real hurdle rate 4.23 times higher, or more than 21%." As we have shown, this statement is incorrect: given a 5% real discount rate, the hurdle rate predicted by Hassett and Metcalf is 6.3%, and the hurdle rate predicted by the model assuming no fuel or capital price trends and no capital price uncertainty is 6.6%, both of which are rather closer to the TRC parameter.

Concluding remarks

Our brief discussion here has focussed only upon the basic option value model of McDonald and Siegel as it is applied by Hassett and Metcalf. This model assumes, among other things, that the only cost of delaying energy-efficiency investments is the foregone energy savings. This not always the case. Jaffe and Stavins (1994) make a useful distinction between decisions *whether* to purchase and decisions *whether and when* to purchase. An example is the difference between incorporation of energy-saving technology in a new vs. in an existing home. In the case of the new home, foregoing the technology at the time of construction typically means that the cost of installation later (if it is undertaken) will be higher; i.e., delay is costly. For example, it is much more costly to replace standard windows with high-performance windows than it is to install high-performance windows in the first place. Many-if not most-consumer decisions regarding energy-efficiency are of this character. That is, the consumer must decide whether to include energy-saving attributes as part of a purchase that is being made primarily for other purposes. (Other examples include appliances and new cars.) These investment decisions do not satisfy the assumptions of the option value model, the scope of which is thus further limited.

There remains the problem of explaining high implicit discount rates for energy efficiency. Jaffe and Stavins (1994) argue that there may simply be no way, using observations of purchase decisions alone and assuming optimizing behavior, of disentangling the effects of

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would have to exceed the "rational" estimate by between 300 and 600 percent in order for them to apply an option value-adjusted hurdle rate of 25%, the lowest estimate in Table 1.

consumer discounting, energy price expectations, and principal-agent problems, each of which could account for high implicit discount rates. This suggests, among other things, the need for closer observation of consumers' actual decision-making including, perhaps, relaxation of the optimization assumption.

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