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The misuse of net present value in energy efficiency standards

Syed Abul Basher[a,*], David G. Raboy[b]

[a] Department of Economics, East West University, Aftabnagar Main Road, Dhaka 1212, Bangladesh
[b] Department of Economics, Northern Virginia Community College, Manassas Campus, VA 20109, United States

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ABSTRACT

Consumers are often blamed for not making necessary investments in energy-efficient durables despite that these investments have positive net present value (NPV). Several papers have argued that when investments have option-like characteristics (e.g., irreversibility, uncertainty, flexible timing, and lumpiness), the aphorism "invest if the net present value of investing exceeds zero" isn't the best advice. Yet, curiously, the Department of Energy (DOE) in the United States proposes new regulations mandating higher energy efficiency standards for consumer durables on the basis of non-negative NPV over an investment's lifetime. In this paper, we provide a step-by-step deconstruction of DOE's NPV methodology and show that DOE's method purges volatility, volatility persistence, and nonstationarity that are otherwise present in energy prices. As a result, DOE's projections of future energy prices are artificially smooth and statistically biased, casting serious doubt on the reliability of the magnitude of energy savings from energy-efficient durables.

1. Introduction

The rule, "invest if the net present value of investing exceeds zero" is still widely popular among managers and taught to students in business schools. Ross [46] remarks that NPV "is the meat of most textbook and lies at the core of what financial academics think they have to offer CFOs, corporate treasurers, investment bankers, and practitioners of all stripes" (p. 96). Excel spreadsheets and financial calculators include an "NPV" function, which makes it very easy to calculate the net present value (NPV). Harvard Business Review sells a guide for businesses which includes an easy-to-use pre-filled spreadsheets for NPV and the other return on investment methods [48].

However, when investments have option-like characteristics (e.g., irreversibility, uncertainty, flexible timing, and lumpiness), simple NPV rules must be modified [37,43,44]. The concept of NPV is built on the assumption that "the variance of the present value of future benefits and costs is zero" [37, p. 708]. But when investment decisions involve real options, variance "matter very much, so that an investment decision based on a mean-reverting process could turn out to be quite different from one based on a random walk" [44, p. 2].

To appreciate the significance of irreversibility and option value of an investment, let us consider the evidence of underinvestment in energy-efficient technologies. Despite the considerable promise for reducing the costs and environmental damages associated with energy use, consumers and businesses are not investing in energy-efficient technologies to the extent they should, a paradox that has come to be known as the "energy-efficiency gap" [25]. Over the last several decades, a burgeoning literature has emerged to explain the apparent market failures (and behavioral biases) associated with a suboptimal use of energy-efficient technologies – see Gerarden et al. [25] for an excellent survey of this literature.

However, when viewing through the lens of irreversibility and option to wait, such underinvestment in energy-efficient technologies may not appear to be a paradox [4]. Uncertainty regarding future energy price or future benefits from technological change coupled with little resale value, among other unobserved costs, may cause consumers and firms to delay or postpone investment in energy efficient durable goods. Put differently, the presence of market imperfections, uncertainty, risk, and a host of other factors cause the implicit discount rate to be higher making expected present discounted value of the energy savings lower than is typically assumed. Numerous empirical studies have revealed that implicit discount rates substantially exceeding market interest rates – see Kim and Sims [33] for an overview of the implicit discount rate from 19 energy-efficiency studies.

Over the years, the Department of Energy (DOE) in the United

* Corresponding author.
E-mail addresses: syed.basher@ewubd.edu (S.A. Basher), draboy@nvcc.edu (D.G. Raboy).

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States has promulgated a set of new regulations mandating higher energy efficiency standards for consumer durables. These regulations are derived from the Energy Policy and Conservation Act of 1975[1] (EPCA) and the DOE is delegated to monitor the standards set by the EPCA over time. When considering amending a standard, the DOE follows the guidelines stipulated in the EPCA that the new standard must: "achieve the maximum improvement in energy efficiency … which the Secretary determines is technologically feasible and economically justifiable." In determining whether a standard is "economically justifiable" or not, the DOE depends on a set of techniques such as simple payback period, NPV and life cycle costing to evaluate potential savings from investment in energy efficient equipment.[2] What is required for the regulation to proceed is to show that the NPV is non-negative; that is it provides net benefits to consumers, or at least does not make them worse off. In so doing, however, the DOE neglects other relevant costs or benefits, as highlighted above, that can drive the investment decision.

The primary goal of this paper is to deconstruct DOE's methodology in evaluating potential saving from purchasing or investing in energy efficient durables. We provide a step-by-step description of the nature of DOE projections to highlight the underlying limitations in DOE's methodology such that the empirical validity of the future projections about saving is in serious question. The results of our analysis reveal new insights that have subsequent implications for other areas of research and policy undertakings.[3]

The rest of the paper is organized as follows. Section 2 briefly reviews the empirical literature on irreversibility, option value and the relevance of discount rates. Section 3 discusses the data and presents preliminary empirical evidence supporting the volatility and uncertainty in energy prices. Section 4 discusses DOE's predictive methodology in defense of the energy-efficient consumer-durable regulations. Section 5 offers a discussion of the main findings. Section 6 concludes the paper.

2. Literature review

This section briefly summarizes the findings of previous research concerning the use of NPV for evaluating energy-efficient durables. Purchase of energy-efficient durable is often framed as akin to investments in safe financial instruments like perfectly liquid and insured bank account. However, numerous studies have pointed out that the implicit discount rates for purchases of energy-related durables are well above the market discount rate. Hausman [29] finds a discount rate of 20% for purchases of energy-efficient durables. In commenting on Hausman's paper, Gately [24] provides discount rates in the range of 45–300%.

Hasset and Metcalf [28] have made an interesting and useful contribution by conducting an option value analysis of energy-efficient investments. They find an implicit discount rate of around 20% due to a high option value to waiting, resulting in the slow diffusion of energy saving technologies. The model of Hassett and Metcalf has been extended in several directions. Sanstad et al. [47] include the costs of delaying purchases that offset the value of the option to delay and find a hurdle rate (implicit discount rate) of only 6.8%. Likewise, Baker [4] argues that when consumers care more about *which* products to choose (rather than *when*), uncertainty and irreversibility (or the "option value") play little role in explaining the slow diffusion of energy efficient technologies. Further, Kim and Sims [33] update the option value analysis of Hasset and Metcalf [28] using more recent fuel price data and find that the option value multiplier is lower than Hassett and Metcalf's results.

However, when investors' anticipation of future technological advance is incorporated in Hasset and Metcalf's model [28], Ansar and Sparks [3] find a higher implicit discount rate than is generally observed in the literature. Bauner and Crago [7] extend the analysis by Ansar and Sparks [3] for solar PV system and find an option value multiplier of 1.6, implying that the discounted benefits from solar PV need to exceed installation costs by 60% for investment to occur.

It is instructive to review the contributions that highlight the limitations of the *ex-ante engineering* studies which tend to overestimate energy savings from investment in energy-efficient durables (see, e.g., [27]). The reason for overestimation is because ex-ante engineering analyses rely on predicted energy savings, whereas most impact evaluations are conducted on actual energy usage, among other explanations (see [25]). Nadel and Keating [39] compare nine residential appliance and lighting programs and find that, except for two programs, the magnitude of energy saving ranged from negative to 74% in the engineering estimates. Likewise, in a randomized controlled experiment in Florida, Dubin et al. [15] find that actual conservation is as much as 13% below engineering estimates for cooling and 8–12% below for heating. Recent studies that provide evidence that predicted savings from certain energy-efficiency programs are overstated include Allcott and Greenstone [1], Davis et al. [13], Fowlie et al. [20], Gillingham and Palmer [26], Houde and Aldy [30], and Levinson [34], to cite just a few contributions.

We contribute to this voluminous literature of energy-efficiency gap in two ways. First, we apply recent advances in time series econometrics to test whether energy price evolves as a random-walk process (or unit root process) or can be described as a mean-reverting process. As uncertainty about future energy prices is often used as a non-market failure explanation of the energy-efficiency gap [32], identifying the stochastic nature of prices is importing for consumers and firms making investment decisions. Second, and already stated in the Introduction, we provide a step-by-step analysis of the NPV methodology that informs ex-ante engineering analyses such as the influential analysis of Granade et al. [27].

3. Empirics of energy prices

3.1. Data

We employ one basic data set. The Energy Information Agency (EIA) provides data on the retail residential prices of gas and electricity, disaggregated by month and state. We acquired these data for the period spanning January 2001 through December 2013. For each state plus the District of Columbia, then, our data comprise 156 observations. That these data are volatile is apparent from even cursory observation. But the results of our inquiry depend crucially on whether the data are mean reverting or are stationary.

3.2. Unit roots tests

Stationary data are mean-reverting (a price shock is temporary, and data naturally revert to trend). Non-stationary data are not mean-reverting, and a price shock will appear to be permanent.

[1] Public Law 94–163 (42 U.S.C. 6291–6309, as codified) Authority and details are codified in Title 10 of the Code of Federal Regulations Parts 429 and 430 (10 CFR Parts 429, 430).

[2] 42 U.S.C. 6295(o)(2)(B)(i)(II).

[3] The regulatory approach in the Energy Policy and Conservation Act (EPCA) is one of a command and control system applied to producers, but which should impact consumers and alter consumer choices. But in the presence of nonstationary electricity and gas retail prices (ambiguous data) consumers, who cannot assess the probability of future outcomes on savings on energy, may not resound as intended. Policy research on other ways to affect consumer behavior should be explored. Examples include tax incentives but these may face hurdles due to budget implications. Government efforts to accelerate technology to lessen up-front cost would alter incentives in an NPV test, rendering random-walk data less problematic.