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A credible approach for measuring inframarginal participation in energy efficiency programs☆

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ABSTRACT

Economists have long argued that many recipients of energy-efficiency subsidies may be "non-additional," getting paid to do what they would have done anyway. Demonstrating this empirically has been difficult, however, because of endogeneity concerns and other challenges. In this paper we use a regression discontinuity analysis to examine participation in a large-scale residential energy-efficiency program. Comparing behavior just on either side of several eligibility thresholds, we find that program participation increases with larger subsidy amounts, but that most households would have participated even with much lower subsidy amounts. The large fraction of inframarginal participants means that the larger subsidy amounts are almost certainly not cost-effective. Moreover, the results imply that about half of all participants would have adopted the energy-efficient technology even with no subsidy whatsoever.

1. Introduction

Global energy consumption is forecast to increase 56% by 2040. While the energy mix is becoming somewhat less carbon-intensive, carbon dioxide emissions are still forecast to increase by 45% over the same period.[1] There is a wide agreement among economists that the best policy to reduce carbon dioxide emissions and other negative externalities from energy use would be a Pigouvian tax. Although there has been some recent progress, the vast majority of carbon dioxide emissions worldwide remain untaxed and there are many countries, including the United States, where it seems unlikely that there will be large-scale carbon policy in the near term.

Instead what is receiving much attention is energy efficiency. Electric utilities in the United States, for example, spent $34 billion on energy-efficiency programs between 1994 and 2012.[2] Energy-efficiency measures like appliance replacement, industrial process changes, and weatherization have the potential to greatly reduce energy consumption (National Academy of Sciences et al., 2010). Proponents of energy-efficiency policies argue that these savings are available at very low cost (McKinsey and Company, 2009). Thus, energy-efficiency policies are promoted as "win–win" policies that reduce both private energy expenditures and the externalities associated with energy use.

Despite all of the resources aimed at energy-efficiency programs, there is a surprisingly small amount of direct evidence evaluating their effectiveness. A recent review paper emphasizes this lack of

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[1] These statistics come from the U.S. DOE, EIA, "International Energy Outlook", released July 2013, Figs. 1 and 10. Global energy consumption increased from 350 quadrillion Btu in 1990 to 520 in 2010, and is forecast to increase to 820 by 2040. Energy-related carbon dioxide emissions increased from 20 billion metric tons in 1990 to 30 billion in 2010, and are forecast to increase to 45 billion by 2040.

[2] U.S. Department of Energy, *Electric Power Annual*, 1995–2013. All dollar amounts in the paper are reported in year 2010 dollars. Spending increased every year from 2004 to 2012, with $4.2 billion in 2012.

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evidence and goes on to argue that there is, "great potential for a new body of credible empirical work in this area, both because the questions are so important and because there are significant unexploited opportunities for randomized control trials and quasi-experimental designs that have advanced knowledge in other domains" (Allcott and Greenstone, 2012).

We are particularly interested in the question of additionality. Many energy-efficiency programs work by subsidizing households and firms to adopt energy-efficient technologies. A fundamental question in evaluating the cost-effectiveness of these programs is how many of the participants would have adopted these technologies with a lower subsidy, or even with no subsidy at all. Economists have long argued that many participants in energy-efficiency programs may be non-additional or "free riders" (Joskow and Marron, 1992), but demonstrating this empirically has been difficult.[3]

Determining the causal relationship between subsidies and technology adoption is challenging because one must construct a credible counterfactual for adoption in the absence of the policy. Cross-sectional comparisons are misleading because places with generous subsidies are different from places with less generous subsidies. For example, "green" communities like Berkeley, California have more generous subsidy programs but also more eager adopters. Similarly, although programs change over time, it is difficult to separate the causal effect of these changes from other time-varying factors. Changes over time in energy-efficiency subsidies are correlated with changes in technology, pricing, and consumer preferences.

In this paper we address these challenges using a regression discontinuity (RD) analysis. Many energy-efficiency programs have eligibility cutoffs and our paper illustrates how these thresholds can be used to measure inframarginal participation. We apply this approach to a national appliance replacement program in Mexico. We first examine the eligibility thresholds carefully, demonstrating clear discontinuous changes in subsidy amounts and testing for manipulation of the running variable. We then turn to the main analysis, finding that program participation increases noticeably with larger subsidy amounts. For example, when a refrigerator subsidy increases from \$30 to \$110 (both in U.S. 2010 dollars), the number of participants increases by 34%. Thus, the participation elasticity is substantial. However, it is also evident that there are a large number of inframarginal participants. At this threshold, for example, our estimates indicate that about 75% of households would have participated in the program even with the lower subsidy amount. For the four main thresholds in our analysis we find that 65% + of households are inframarginal. This large fraction of inframarginal households means that the larger subsidy amounts are almost certainly not cost-effective because each actual increased participant costs a large amount in additional program funds.

We next use the observed changes in demand at these four thresholds to infer what fraction of participants would have participated with no subsidy whatsoever. Under reasonable assumptions, the estimates imply that about half of all participants would have replaced their appliances with no subsidy. We then discuss the implications of non-additionality for cost-effectiveness and welfare. These non-additional participants add cost to the program without yielding any actual reductions in energy consumption. When the marginal cost of public funds is larger than one or when there are indirect program costs then it does not make sense to think of these payments as pure transfers. Our results also demonstrate the potential for cost savings if program designers can target subsidies towards groups where the number of likely non-additional participants is low.

Our paper is the first that we are aware of to use RD to study participation in an energy-efficiency program. We see broad potential for applying this approach in evaluating similar programs. Although eligibility requirements vary widely across programs, the desire to simplify program design often results in the kind of discrete thresholds that we exploit here.[4] In addition, energy consumption is typically carefully measured for large numbers of participants and non-participants. Both of these features make RD a natural approach for causal inference in this context. Relative to the alternative of randomized control trials (RCTs), RD is limited by its focus on specific thresholds. However, RD is easier and less expensive. In addition, RD analyses with administrative datasets have more power and thus can measure smaller effects than typical RCTs.

Most previous studies of additionality in similar programs have been of a much smaller scale (see, e.g., Hartman, 1988), or based on stated-choice experiments (Revelt and Train, 1998; Grosche and Vance, 2009; Bennear et al., 2013). Several related papers look at the impact of subsidies on adoption of energy-efficient vehicles (Chandra et al., 2010; Gallagher and Muehlegger, 2011; Sallee, 2011; Mian and Sufi, 2012). There is also a small literature which addresses additionality indirectly by comparing realized aggregate savings at the utility level to engineering estimates (Loughran and Kulick, 2004; Auffhammer et al., 2008; Arimura et al., 2012). Our paper differs from all of these previous studies because of the RD research design. Probably the closest existing study is Ito (2013), which uses an RD analysis to examine a California policy that paid households to reduce their electricity consumption in Summer 2005.

The paper is also related to a broader literature that examines government programs that subsidize socially-beneficial behavior. A key issue with these programs is the need to distinguish between additional and non-additional participants. Examples include tax subsidies for charitable giving (Feldstein and Clotfelter, 1976), subsidies for building low-income housing (Sinai and Waldfogel, 2005), conditional cash transfer programs (De Janvry and Sadoulet, 2006), pollution offset programs (Schneider, 2007), and environmental conservation programs (Sánchez-Azofeifa et al., 2007).[5]

2. Conceptual framework

2.1. Technology adoption with externalities

In this section we propose a simple framework for thinking about the costs and benefits of energy-efficiency subsidies. We illustrate the welfare loss introduced by transfers to inframarginal participants and show how the optimal subsidy amount depends on the relative shares of marginal and inframarginal participants. We focus on the adoption of an energy-efficient technology, but the same basic framework applies to many other types of government programs that subsidize socially-beneficial behavior.

We begin with a simple graphical partial equilibrium analysis. Fig. 1 describes the market for an energy-efficient technology. Along the x-axis is the number of adopters. Demand is given by the

[3] The term "free rider" has long been used in the context of energy-efficiency programs to describe participants who receive a subsidy for doing something they would have done anyway. This is distinct from the use of the term in economics. The well-known "free rider problem" in economics is that individuals underinvest in public goods because they do not internalize the benefits to others. To avoid confusion we use the term "non-additional" throughout the paper.

[4] For instance, the two largest utilities in California offer rebates for energy-efficient heating and cooling equipment that vary across 16 climate zones. These zones were established by California law in 1978 as a function of climate characteristics. Cities can straddle multiple climate zones, and there are large discontinuous changes in rebates at climate zone boundaries. For example, during 2013 Southern California Edison offered three different subsidy amounts (\$550, \$850, and \$1100) for central air conditioners. Other eligibility thresholds that would be amenable to RD analyses include requirements about the vintage of the home, size or characteristics of the households' current equipment, and, for need-based programs, household income.

[5] In this broader literature there are a few studies that use RD. Baum-Snow and Marion (2009) examine the effect of tax credits for building low-income housing, exploiting a discontinuous increase in the credit amount in census tracts where more than 50% of households qualify for means-tested government housing assistance. Filmer and Schady (2011) study a conditional cash transfer program in Cambodia where program eligibility is limited to households scoring below a specified level on a government poverty index.