Energy Economics 64 (2017) 63–76

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

Setting the standard? A framework for evaluating the cost-effectiveness of building energy standards☆

Maya Papineau

Department of Economics, Carleton University, 1125 Colonel By Drive, Ottawa K1Z 1C1, Canada

ARTICLE INFO

Article history:
Received 5 January 2016
Received in revised form 23 February 2017
Accepted 27 February 2017
Available online 12 March 2017

JEL classification:
Q20
Q42
Q48

Keywords:
Energy efficiency
Energy consumption
Regulation

ABSTRACT

The adoption rate and stringency of building energy standards in the U.S. have been increasing since the mid-1990s as a result of the Energy Policy Act mandate of 1992 (EPAct). Current evidence on the energy savings that accrue from commercial building energy standards is based on engineering simulations, which do not account for realized behaviour once a standard is actually adopted. This paper uses quasi-experimental variation in commercial building energy standard adoptions to estimate their effect on realized electricity consumption and cost-effectiveness. In states induced by EPAct to adopt an energy standard where all new nonresidential construction was erected under a commercial standard, electricity consumption per service worker is lower by about 12%, and total commercial electricity consumption is lower by 10%. Including early adopters and never-adopters to the analysis leads to a downward bias in the treatment effect. The realized electricity savings in the EPAct states represent three quarters of predicted simulated savings, and electricity saved in 2010 came at a cost of approximately 7.7 cents per kWh.

1. Introduction

Direct or "command-and-control" regulations to improve energy efficiency are politically popular policy instruments, and several recent environmental legislation efforts in the U.S. incorporate regulations to increase energy efficiency in buildings. These include the Environmental Protection Agency's Clean Power Plan (EPA, 2015a,b), the American Clean Energy and Security Act (H.R. 2454, 2009), and California's Global Warming Solutions Act (A.B. 32, 2006).[1] The persistent popularity of standards to reduce energy consumption contrasts with a large body of economic literature that argues that market-based instruments are typically first-best responses to address the external costs of energy use (Hahn and Stavins, 1992; Jaffe and Stavins, 1995; Linares and Labandeira, 2010; Anderson et al., 2011). Recently, however, work based on the behavioural economics literature has not found such a clear-cut preference for pricing policies over standards. Standards could in theory be complementary to pricing when consumers either misperceive product costs or give in to temptation to buy products with low first costs (Small, 2012; Tsvetanov and Segerson, 2013; Parry et al., 2014).

A number of studies have attempted to quantify the realized electricity impact and cost-effectiveness of energy efficiency investments induced from utility demand-side management (DSM) programs, which include free energy audits, subsidized financing and other similar incentives for the purchase of energy efficient equipment (Joskow and Marron, 1992; Horowitz, 2004; Loughran and Kulick, 2004; Auffhammer et al., 2008; Arimura et al., 2012; Alberini and Bigano, 2015). Over time, the energy efficiency evaluation literature has shifted from early work based on "ex-ante" engineering predictions of savings (Fickett et al., 1990; Nadel, 1992) to methods based on realized, or "ex-post", energy consumption (Parformak and Lave, 1996; Metcalf and Hassett, 1999; Anderson and Newell, 2004). This impetus towards ex-post analysis was motivated by the desirability of focusing on practical achievements and accounting for actual consumer and institutional behaviour (Joskow, 1994).

☆ Financial support from the Canadian Social Sciences and Humanities Research Council is gratefully acknowledged. I thank Joel Bruneau, Kenneth Gillingham, Sumeet Gulati, Chuck Mason, Martino Pelli, David Rapson, Nic Rivers, Brandon Scheifele, and two anonymous referees for their helpful comments and suggestions. The paper also benefitted from comments at presentations at the University of Ottawa, the Canadian Resource and Environmental Economists' Study Group, and the Association of Environmental and Resource Economists conference in San Diego. Any errors are my own.

E-mail address: maya.papineau@carleton.ca.

[1] The Clean Power Plan includes a "Clean Energy Incentive Program" that rewards energy efficiency investments, and both the Clean Energy and Security Act and Global Warming Solutions Act include provisions to strengthen building energy standards.

http://dx.doi.org/10.1016/j.eneco.2017.02.011
0140-9883/

Given the large literature evaluating energy efficiency programs and the ongoing popularity of standards in the regulatory toolbox, it's somewhat surprising that work assessing the effect of building energy standards on realized energy consumption is quite sparse. Three recent studies estimate the impact of building energy standards on residential energy consumption (Levinson, 2016; Aroonruengsawat et al., 2012; Jacobsen and Kotchen, 2013), and another study by Arimura et al. (2012) controls for an aggregate index of commercial and residential building energy standards in order to analyze the cost-effectiveness of DSM, but thus far no studies have assessed the effect of commercial building energy standards on realized commercial sector energy use, not to mention their cost-effectiveness.[2] As was pointed out over twenty years ago in a highly cited set of papers (Joskow and Marron, 1992; Joskow and Marron, 1993), commercial sector efficiency programs may face considerably lower average costs relative to the residential sector.[3] In addition, recent evidence suggests that commercial and industrial customers exhibit relatively inelastic demand when exposed to price interventions (Jessoe and Rapson, 2015), a result consistent with two early studies on the topic (Aigner and Hirschberg, 1985; Aigner et al., 1994). These distinct commercial sector outcomes bolster the importance of evaluating the effectiveness of commercial energy efficiency regulations.

A more recent area of focus in the environmental economics literature has been to improve the reliability of empirical inference by using experimental and quasi-experimental methods, as articulated by Greenstone and Gayer (2008). Examples in the energy context include Allcott (2011a), Allcott (2011b), Gans et al. (2013), and Jessoe and Rapson (2014), among others. Randomized experiments are considered the gold standard for unbiased inference, yet in many settings and for many important questions, data from randomized trials are unavailable, or too costly to obtain. In such cases, quasi-experimental approaches, in which treatment status is determined effectively by random assignment due to a number of potential circumstances, such as a natural disaster or a political outcome, can approximate experimental outcomes (Angrist and Krueger, 1999). In these settings causal inference requires that assignment to treatment is exogenous, or in other words not related to other unobserved variables that affect the outcome of interest.

Evaluating the realized cost-effectiveness of building energy standards, particularly at the state or federal level, is one area where experimental data are not available, and very unlikely to become available due to a combination of high costs and legal/institutional constraints. However, as I argue in this paper, passage of the Energy Policy Act (EPAct) of 1992 and the building energy standard mandate included in it makes it possible to exploit plausibly exogenous variation in energy standard adoptions, to identify their impact on commercial electricity consumption.

The paper makes three distinct contributions to the existing literature. First, I implement a quasi-experimental approach that uses variation in commercial building energy standard adoptions as a result of the EPAct mandate to identify the impact of energy standards on commercial electricity consumption. Exploiting the variation in building energy code stringency in states that complied with EPAct results in a sample in which states are almost indistinguishable on the basis of observable covariates, both overall and in the pre-treatment period. On the other hand, as discussed below, states that were early movers in undertaking voluntary policies to adopt building energy standards (before the EPAct mandate came into effect), as well as states that have never adopted a commercial building energy standard, differ significantly from states that were induced to adopt a standard as a result of the mandate.[4]

Second, the analysis focuses on the effect of commercial building energy standards on realized commercial sector electricity consumption in the U.S., and estimates their realized cost-effectiveness in this sector, the only study to do so thus far. The framework I present estimates the cost-effectiveness of commercial building energy standards by putting together a novel dataset that utilizes the annual state-level value of commercial construction, together with aggregate commercial square footage added between 1993 and 2010, to proxy for the annual share square of footage erected under a building standard in the EPAct timeframe.[5] These data are combined with two other data sources: estimates of the incremental cost per square foot of building energy standard vintages that have been implemented in the post-EPAct period, compiled from a number of technical studies produced by the Department of Energy (DOE), and estimated electricity savings from EPAct-induced building standards in 2010.

Third, I use this new data set to estimate total realized savings per square foot per year and then assess the reliability of ex-ante engineering predictions, by comparing these realized savings to predicted savings obtained from studies produced before the standards were implemented.

Several results emerge. First, in states with the most post-EPAct new construction under a code, commercial electricity consumption per worker is lower by approximately 12%, and aggregate electricity consumption is lower by about 10%, relative to no standard in place. Second, after accounting for both the share of construction under a standard and standard stringency, in 2010 energy standards reduced aggregate electricity consumption by approximately 15%. These estimates increase further in a robustness check based on the propensity score.

Third, the realized electricity savings of moving from no standard to the most stringent in-sample standard represent roughly three quarters of predicted simulated savings. Fourth, building energy standards came at a cost of approximately 7.7 cents per kWh saved (in 2009 dollars), about 2.5 cents lower than the average national commercial electricity rate in 2009, but at the high end of previous energy efficiency cost-effectiveness estimates. Fifth, including the early adopters and never-adopters in the estimating sample mitigates the treatment effect, causing a downward bias of approximately two percentage points. In a sample that includes only the early and never-adopters, the share of construction under a standard is statistically insignificant at the 5% level. Finally, I implement a robustness check evaluating whether, between states with high and low intensity of adoption, differential changes in average operating hours, square foot per worker, or average service sector worker hours can account for part of the treatment effect. The available data suggest that changes in these variables do not explain the results.

[2] Another study, Jaffe and Stavins (1995), compares the effect of taxes, building standards and technology subsidies on the state-level diffusion of home insulation. It finds a small effect of standards on insulation levels, but the authors note that over the time frame of the data (1979–1988), there were very few energy standard adoptions observed, and thus limited time variation. This may have affected inference on the standards variable.

[3] Referring to engineering predictions in the early literature, Joskow and Marron (1992) note that "results for both cost per kWh saved and total kWh saved indicate that the potential for large economic and environmental benefits from energy conservation lies not in the residential sector, but in the Commercial & Industrial sectors."

[4] For example, early adopter states had significantly lower pre-existing per worker electricity consumption levels and higher electricity prices than states that never adopted a building standard.

[5] Comparable residential data are not collected by the Census Bureau. Residential construction data are limited to the number of building permits. Since building permit data do not reflect variations in building size, they are a noisy proxy for building square footage.