i. Disclosure Effect: Evidence from Public Building Energy Consumption

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DISCLOSURE EFFECT: EVIDENCE FROM PUBLIC BUILDING ENERGY CONSUMPTION

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Introduction

The topic of information disclosure in economics typically finds traction in market efficiency due to asymmetries (Akerlof, 1970), however recent progress in behavioral economics has opened up the topic for other areas of economic research (Sunstein, et al., 2016). This new horizon places information disclosure into broad and overlapping categories between firm and consumer economics. Those categories are information as currency, as requirement, and as competitive advantage. When examining information as currency, researchers assess ways in which people disclose private information in exchange for use of or access to something, for example a social media platform (Christofides, 2009). For information disclosure as requirement, research findings give new life to policies in consumer economics regarding optimal decision making (Bertrand, 2009). Similar research provides further empirical evidence for producer responses to disclosing their own information (Jin, 2003). Information as competitive advantage has been established for the longest in economic analysis, assuming consumers have perfect information at all times – firms are then implicated as being the suppliers of not only products and services but optimal information about these offerings. Taken together, the theme of information disclosure for both sides of transactions seems to be ideal as policy in that it addresses market failures, aims to protect consumers and does not impinge free market activity. Policies which are heavier handed, such as bans, tend to be less desirable and evoke perverse consequences (Bharadwaj, 2013 and Lueck, 2003) or force producers to produce items with characteristics not desirable to the consumer (Gayer, 2013).

There is ample evidence in psychology, now being imported into the economic domain. It demonstrates, in both supply and demand, that agents in the presence of new information show detectable effects. With proper assessment of these effects, policy-makers can minimize at least some unintended consequences. Therefore, while bans or laws restricting certain measures or behaviors may be undesirable for reasons stated prior, mandates for information to be disclosed become an ideal policy. It maintains, on balance, free market operations thus reducing the risk for perverse, unintended consequences and loss of social welfare. This information disclosure backdrop is important for understanding this research motivation. In this paper, I assess the phenomenon of discloser response to the public after information disclosure occurs. Specifically, the discloser's building energy use.

Commercial and residential buildings in the US consume 40% of the national electricity ledger (USEIA, 2012). As a result of several federal policies and executive orders, energy reduction in commercial buildings has become a recognized area of focus (Novikova and Ürge-Vorsatz, 2008). Several means of reduction have been proposed, one of which is benchmarking policies or disclosure ordinances. These ordinances have been passed in several cities, seven of which will be analyzed in this paper. For buildings meeting certain requirements, mandates state that annual energy consumption be disclosed to the public via an open data portal.

Exploiting a natural experiment, in conditions absent market pressure and competition, I assess the effect of information disclosure on energy use in the period immediately after disclosure. The concept straddles the themes 'information as requirement' (energy benchmarking mandate) and information 'as competitive advantage' (real estate valuation) using panel data from seven cities (n=7,300) and looking for a "disclosure effect". Disclosure effect has been defined explicitly by economists (Hsu, 2016) but I will use a slightly different definition for this paper which does not include market pressure and competition. Building upon research from this same policy where the analysis was isolated to New York City, this paper aggregates all available cities together. Cities are included in the analysis if they have a) adopted a policy mandating building energy benchmarking and b) have published data to a database. This is a slight and ideally more technical addition to the work completed thus far in assessing this policy as it provides a defined treatment (timestamp of publicly viewable data). This research first estimates a psychological effect of public building operators publishing energy use to a database, which the broader public can see and analyze. Second, it assesses whether or not initial (pre-disclosure) levels of energy consumption matter; and third, assesses this policy effect across six more cities to see if it is more generalizable than results found in New York City. Observations were reduced based on select criterion to analyze identical buildings, across various types, in periods before and after the energy disclosure date.

Generalizable results across all seven cities, using a pooled OLS regression, show a 3% decrease in Site EUI. When isolating public buildings as the treatment group in the treatment period and using clustered errors, I find evidence to support the intrinsic disclosure effect estimated at about 6% less. This evidence runs counter to the profit maximizing axiom of private building owners; if there is no market pressure to reduce energy consumption, and thereby increase energy efficiency, which public disclosure makes salient, the intrinsic motivation, as evidenced by the public building stock, appears to be sufficient based on available data and empirical methods employed. Lastly, I calculate a first order difference and regress this over the same set of independent variables as the pooled regression, with the inclusion of energy consumption in the first time period. Results from this model show initial level of consumption is indeed a predictor of energy reduction in the following period and that public buildings use 7 kBtu per square foot (5.5%) less than their private counterparts.

The rest of the paper is ordered as follows: Section II provides a brief overview of information disclosure policy outcomes and literature review, Section III explains the data and empirical method, Section IV provides results and interpretation and Section V concludes with recommendations.

Section II: Information Disclosure Potential Outcomes

The topic of information disclosure is an important area for research, specifically to economics, because it creates environments which can then be analyzed for effect on variables of interest from both supply and demand sides. Information disclosure finds its roots in the seminal work of George Akerlof assessing information asymmetry and its detrimental effect on efficient markets. Canonical economic rationale for information disclosure, as a remediation for market failure, is explained by the private cost being greater than the individual benefit so once more, information disclosure makes sense and should arise out of efficient markets. The second branch of information disclosure can be traced back to microeconomic theory of the firm: firms want to maximize profits. If disclosing information about their firm will aid in maximizing profits, then theory predicts that firms will do this willingly and no government intervention should be necessary. This implicitly assumes that consumers respond favorably (if at all) to information both being disclosed and not being disclosed, which is where psychology begins to assist economists (Sunstein, 2016). Lastly, there is also attribution of utility to just possessing information irrespective of a decision – the benefit is a bundle of socially optimal dissemination and maximum utility for consumers (Morris, 2002).

Disclosure is called targeted-transparency which is celebrated as a non-controversial method of regulation given its low cost of provision. In this way, disclosure still appeals to economists yearning for free-markets, in the presence of information or new information – consumers can still of course make a decision of their own volition. Just because a producer must provide information does not necessarily restrict them or change their means of production. Similarly, consumers having access to information does not impose upon them a new set of preferences. While the evidence of behavior change is sufficient, it is a leap to say information disclosure restricts or imposes its will on producers and consumers.

An illustration by contradiction is the other end is energy efficiency (EE). In attempts to stimulate reduced energy use and close the so called "Energy-Efficiency Gap" (Gerarden, 2015), stronger mandates for energy efficiency minimums for equipment and buildings, a bundle of policies with good aim, have had perverse effects for producers and consumers alike. Producers are strapped with hard costs of meeting the newly proposed standard and consumers must pay for features, seemingly necessary for EE, that are undesirable – freedom of choice has been impinged here. Disclosure about EE, however, should preserve this in that in the face of new information, consumers can trade off features less desirable for those more desirable according to both preference and savings potential.

This desirability of information disclosure as policy has had a laughable effect in how much information is disclosed – think of product warning labels, terms and conditions or website disclaimers: all of which are forms of information disclosure. Once again, this arises out of the asymmetry between producers and consumers. There is also the introduction of "behavioral market failures", put forward by Nobel Laureate

Richard Thaler, which has to do with internalities or costs bore by the individual but not until some time later. As the Sunstein, et al. note, it is rarely the case that sellers disclose information such that these internalities might be addressed. While internalities have much to say in the domain of energy consumption and climate change, the subject falls outside the scope of this paper.

It must be noted that there is a crucial distinction between verifiable and unverifiable information as a result of disclosure. Miles per Gallon (MPG) and Calories are verifiable; misinformation should be punished in some way. Conversely, a doctor's recommendation to a patient is a judgement call with no clear, verifiable outcome. MPG serves as a good metric here in that buildings are typically measured using EUI or energy use intensity, sometimes loosely referred to as 'an MPG for buildings'. Given recent research on MPG's lack of clarity for comparing fuel efficiency in car rating labels and showing that gallons per mile (GPM) is actually a more salient metric (Larrick and Soll, 2008), it is encouraging to note that EUI is energy use per square foot. The form is "units input per unit output"; this is the building analog of the improved automobile gallons per mile measure.

Psychological Responses to Information Disclosure

Psychologists have known for decades, though economists are just catching up, that attention is a scarce resource but people do not optimize it. Certain items capture attention while others fall to the background. They cite product warning labels and the lack of any measurable effect on consumer choice. Sunstein, et al. find specifically that efficacy of information disclosure hangs on certain assumptions which may be surprising. One such assumption is that in the presence of information disclosure as an option, why would the market forces not provide this information provision out of competitive advantage, referring back to firm theory on profit maximization. As they note, this is not the case as producers are more aligned here with respect to incentives. No producer wants to steer consumers away from the product all together, much less their specific product.

If people can only pay so much attention (to whatever calls it) then they pay even less attention to what is not in frame – thus dissolving the idea that any information not disclosed will be thought of as "very bad" – this is unlikely to be true. Inattention to missing information would then be worsened by the introductory of such information because now it is in frame or in the "tunnel". Evoking tunnel vision as a reference, researchers Sendhil Mullainathan and Eldar Shafir find that this tunneling happens under psychological stress and only certain information makes it into the "tunnel".

Research from psychology has also found a myriad of cognitive biases. People gravitate toward information that fits their biases and motivates them, in turn rejecting information which does not fit – this would render information disclosure ineffective. People who need the information may reject it because it is uncomfortable – think here of checking investments during a trough compared to a boom or in a more tragic case, people refusing to be tested for HIV because of the horrible possibility of testing positive even though they'd be better off knowing sooner.

While information being supplied to the market is one facet of market intervention and an example of information disclosure, it is not the primary focus of the research. This research is targeting a psychological effect of making information public. The psychological response of disclosing information or being a recipient of information, as well as explanations for why psychological findings and economic agent assumptions do not mix, serve as a foundation for this research. Taking what is known about assumptions in information disclosure policy and what of those assumptions has been challenged by psychology, I want to assess whether or not individuals, absent any market motivation, respond to disclosing information. Previous work assesses the "boost" that psychology gives to financial or other incentives but these are hard to separate. To separate the psychological (intrinsic motivation) from the economic "better off" grounding, there needs to be no direct financial incentive on the horizon but still be an environment in which a response can be measured. The public energy benchmark policy appears to provide good grounds for this.

Government Role: Mandating and Demonstrating

Given existing work on the benefits of green labeling (Eicholtz, 2010) and unlabeled buildings built under more stringent energy codes (Papinau, 2016); showing higher rents, higher resale and full capitalization of energy savings; along with other work supporting the idea that government procurement of green building certification can stimulate increased adoption in the private sector (Simcoe, 2012), it follows then that government owned and operated buildings can (and perhaps should) lead the way in demonstrating transparency in and reductions of resources consumed. Whether or not (and by how much) the information disclosure mandate of this affects post-policy energy consumption is the purpose of this and ongoing research.

State and city level ordinances have been adopted which mandate that private and public buildings, exceeding varying gross square feet being of certain building types, must benchmark and disclose energy consumption along with other information. As per several policies leading up to the present (EPAct 2005, EISA 2007) and Executive Orders EO 13423, 13514 and most recently 13693 (March 2015), public buildings over 50,000 square feet are required in certain jurisdictions to disclose annual energy consumption in thousands of British thermal units (kBtu, sometimes labeled MBtu). The ordinances, for example in Minneapolis, MN, stipulate that any publicly owned bundling, over 50,000 gross square feet (gsf), must submit its total energy use for benchmarking and any privately owned building, over 100,000 gsf must also submit its total energy use for benchmarking. All cities included in this study import data and benchmark buildings through Energy Star Portfolio Manager, a free online tool created by the Environmental Protection Agency (EPA) for this exact purpose though it is not limited to cities currently under ordinance. There are currently seven cities participating and adoption across cities is staggered where some opted in prior to the mandate being passed or activated but 2013-2014 appears to be a consistent entry point according to the data. Other cities, such as Atlanta and Seattle, have adopted the ordinances, are in the process of benchmarking public and private buildings but have not yet published to a public database and are therefore not included in this study.

To frame this out a bit more, some additional context and imagination is required. First, we must state assumptions around energy consumption as a signal. Some work has been done around this (Sexton, 2011) specifically with sustainability or "green" motifs in mind. The author's note a willingness to pay above other comparable cars (when controlling for market and hedonic features) for that very ability to signal how "environmentally conscious they are". This is another form of conspicuous consumption, perhaps even a special case or shadow of a Veblen good where people are willing to pay more for features which signal something particular and unique. Similarly, in green labeled buildings and Energy Star appliances, consumers are obtaining some monetary benefit (better rents and resale or less energy consumed, respectively) which makes such a decision desirable but this may also be bundled together with a desire to signal. That is, are there other areas in which a consumer could obtain similar savings but not be able to strut their environmental plumage and therefore trade-off monetary savings for the ability to signal. Further, might this be more pronounced in certain regions than in others – such as an office building in San Francisco compared to an office building in Minneapolis.

The public building energy disclosure mandates are unique in this way: there should be no response to the market pressure or competition for valuation and there are different regional backdrops. Ever-present in energy consumption in residential homes and private building stock, the next unit of energy not consumed is a marginal savings. This incentive only exists presumably to those who benefit from that incentive, the strongest case being residential homes. It is my formal assumption that this incentive is not or at the very least only weakly present in public buildings. In private buildings, this marginal incentive to save is bound up with market pressures for obtaining higher rents and resale values as well as operational savings. Public building operators do not benefit in the same way from saving on energy. What this allows for is the ability to measure a nearly pure behavioral response to the public knowing how much one's building is consuming. While monetary motivation is not present, the desire to signal may remain. Relating this back to conspicuous consumption and signaling, the desirable response once consumption is publicly known would be to reduce consumption in the subsequent year.

To make this a bit more precise, the hypothesis is that if an entity is mandated to disclose information "Set A" (quantitative) to the public in year *t,* and general consensus of the public is that, with respect to "Set A", a higher value is better or desirable than in year *t+1,* holding all else constant, "Set A" would be higher. This is the slightly more technical definition I am giving to the "disclosure effect"; a psychological effect of changing behavior after releasing information about that same behavior to the public. The same can be said of the inverse of the previous scenario: if the general public consensus is that *less* of "Set A" is desirable, then we should observe a decrease in the quantity reported on in "Set A" in year *t+1*. Other sources need to be looked at to get a sense of work already completed would be experiments, natural or otherwise, where individuals disclosed something related to them to the public. The response we would want to see to correlate with this research would be an increase in the measure if more is perceived as desirable (by the public or receiving party) and a decrease of the measure if less is perceived as desirable. Suppose an individual is required to post this year's volunteer hours on her work's website. It is reasonable that the public views volunteer hours as good, so next year, holding all else constant, we should see an increase in her volunteer hours reported. Or suppose a publicly traded company is mandated to publish charitable spending for this year; we would expect that figure (as a proportion) to increase next year as public perceptions of charitable spending are that it is good - possibility of perverse effects based on *which* charity aside. Now imagine a company needs to publish its toxic inventory report in year *t*, as analyzed by (Konar, 1997), where public perception of toxic material is bad. In year *t+1*, holding all else constant, we would expect that toxic inventory list to be reduced by some quantity or proportion. All these examples are attempting to illuminate the disclosure effect but the last one maps easily to the research at hand. Energy is a "good" but it's byproduct, pollution, is an economic "bad" implying that less energy consumed should be what the public perceives as desirable and therefore be what the public building operator is responding to. Publishing energy consumed to a publicly viewable database should illicit a response to reduce energy in the following year, holding all else constant. Testing this assumption, as a hypothesis, allows us to observe if reducing the economic "bad" to appease the public perception is detectable or if it is impeded by other frictions.

The potential impacts of this information disclosure in public and private buildings come in three primary forms posed by Hsu. The first is the awareness, gathering the required information for benchmarking makes users aware. The second is the act of publishing to the database, the motivation here is now the public can see if your building consumes a lot of energy. The third is publishing an Energy Star score, which may be more salient than energy use as the units (kBtu), are not widely used and understood outside of energy management. On the gathering of information creating awareness and guiding some action, this may be true but is fairly weak compared to the others. Yes, the public owner-operator becomes intimately aware of consumption and expenditure but gathering alone gives no reference point except to one's own building. Further, a savvy energy manager, the type who may already have a reference point or mental benchmark is not affected by the policy in the same way someone who is doing this for the first time. On publishing to the database; now the owner-operator has a reference point and has the public eye at least as a possibility. As has been referenced in the existing literature, private owner-operators appear to respond desirably and reduce energy use. The database and gathering may now be giving people the leverage needed for capital dollars to make energy-reducing improvements or they could be using the lever a different way to elicit better control and behaviors in the building within existing technology and constraints. There is also the policy of energy reduction targets in some cities so the responses, as measured in use per square foot, are attempts at achieving those goals. On Energy Star score posting, the naming it a "score" could invite competition between building owner-operators, even if only intrinsic, to beat their previous score or to be better than neighboring buildings to which they have visibility into now. This last effect can also backfire and may give some explanation to the initial results from public buildings. If public building owners thought they were doing much worse compared to other private and public buildings before the database was established and now see peer buildings consuming the same or more energy may give you license to relax a bit with capital requests or tighter controls and the outcome is more energy consumed! Psychology can assist in mitigating this by normalizing levels of consumption. First, prompts can highlight undesirable, high levels of energy consumption as only a small percentage of buildings and second, highlighting desirable, low levels of energy consumption as happening in a majority of buildings.

Section III: Data and Empirical Estimation

As part of the disclosure mandate, standard practice is for buildings to enter their data into an online tool. Energy Star Portfolio Manager is a free online tool, created by the Environmental Protection Agency, for building owners and operators to manager their buildings' performance. This provides a fairly standard data format to be public facing, through platforms like OpenData. OpenData provides the endoskeleton and then cities publish any and all data they desire to or that the public is asking for. Exports were taken from each of these cities' data portals and data were then prepared using Stata. One city, San Francisco, had its *t+1* data only in PDF format, in a report – this was then manually coded to fit the format of the other datasets. Some of these cities have disclosure data for longer than the staggered two periods which I am analyzing but all had at least two periods, which is why this research is specified this way.

As stated previously, cities were selected based on two criterion: the city had adopted a public energy benchmark disclosure ordinance and published the data from this ordinance to a public facing database. Data were imported from open data portals or files in separate repositories, each file per city corresponded to a year. Since this research is testing public building operators' response to everyone being able to see their data, datasets with the earliest annual timestamp are declared observations, per city, in time *t* and observations in the year immediately following, *t + 1*, are declared as "year after". Recall, across the cities, *t* and *t+1* do not align always nor do they need to for this model. Observations per city can be seen in the table below:

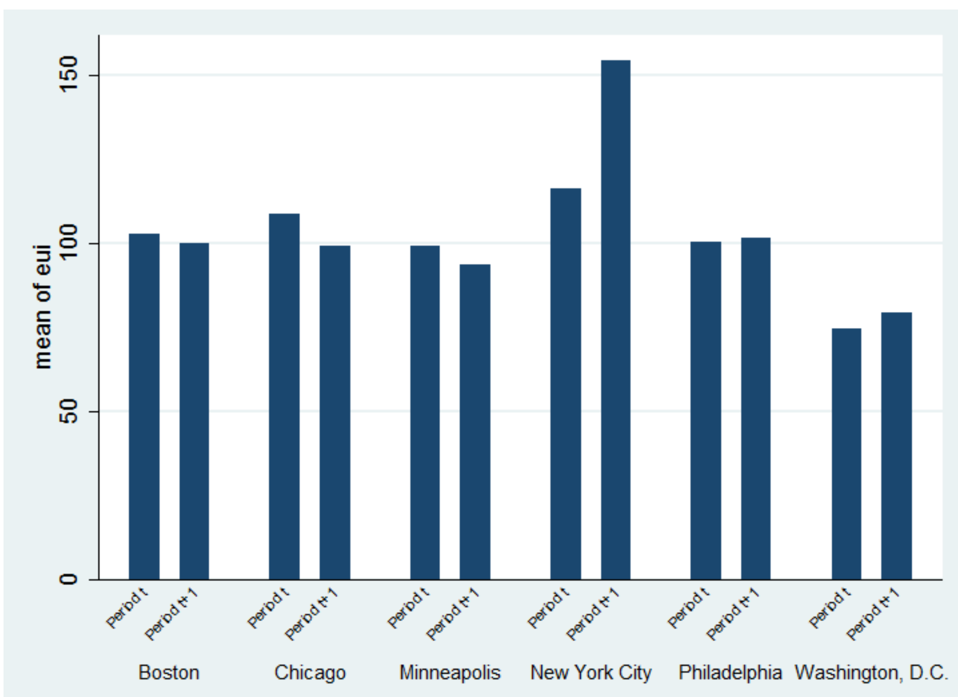
City	N	
NYC	9,773	49%
San Francisco	3,294	16%
Washington, D.C.	2,679	13%
Boston	1,973	10%
Philadelphia	1,480	7%
Chicago	444	2%
Minneapolis	345	2%
Total	19,988	100%

The staggered rollout of the ordinance adoption and therefore publishing to a viewable database, as it comes together in the dataset for this research, goes as follows showing period *t* with period *t+1* following in the year after per city-building stock type combination:

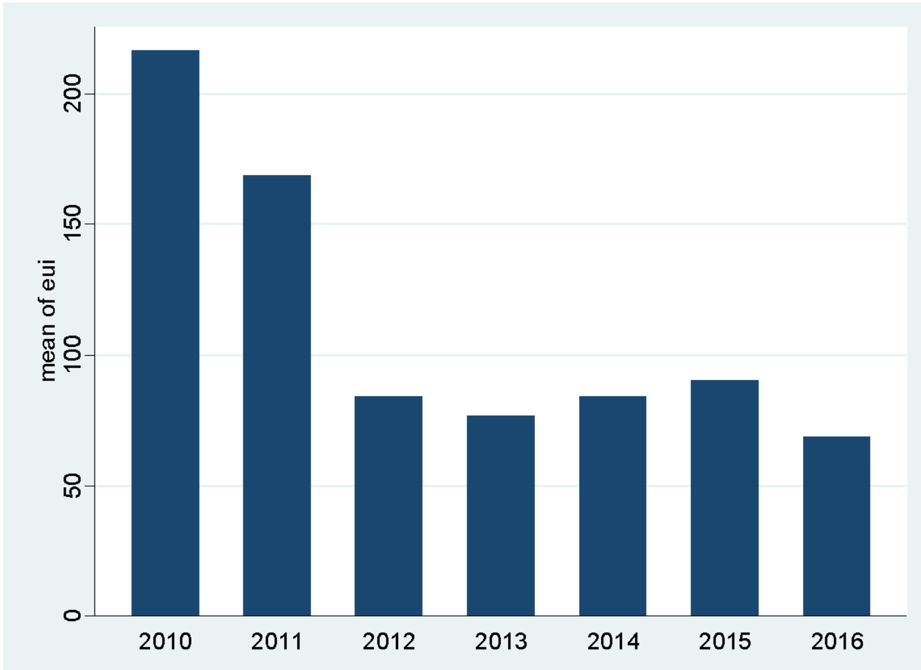
	2010	2011	2012	2013	2014	2015
New York City	Public	Private				
Washington, D.C.				Public	Public & Private	
San Francisco		Private		Public		
Boston					Public & Private	
Philadelphia		Public		Private		
Chicago					Public & Private*	
Minneapolis					Public & Private	

A note on two cities, San Francisco and Chicago; though the data portal describes this dataset as a mix of public and private buildings, it is not defined in the Chicago data. Some city files stated so in the file name, for private building disclosure data it was typically referred to as "Existing Buildings" and for public building disclosure data, the description included "Municipal Buildings". There are some suffixes in the Chicago data, such as "-CPS" indicating Chicago Public Schools, so I could mark some of these as public but it is limited to schools as office and other building types have no such description. On Washington D.C. which rolls out as "Public" then "Public and Private" the year after, this is due to some public buildings being released and then another unique set of public buildings, along with private buildings, being released the period after. Cities which have public and private clearly marked in the data are presented in the table below with average energy use intensity, expressed in thousands of British Thermal Units per square foot, (kBtu) and typically noted as EUI – remember this as automobile fuel efficiency, Gallons per Mile (GPM), but for buildings. Observations at the extreme ends of the data range for EUI range were removed, that is EUI > 1000 and EUI < 1. The upper bound is possible (>1000) but improbable given the context. Comparisons across public and private building stock are shown in the table below:

	Private	Public
Boston (n)	1,421	552
Mean EUI	*101*	*95*
Minneapolis (n)	46	299
Mean EUI	*85*	*90*
New York City (n)	3,287	6,486
Mean EUI	*92*	*216*
Philadelphia (n)	1,436	44
Mean EUI	*99*	*147*
San Francisco (n)	2,383	911
Mean EUI	*66*	*62*
Washington, D.C. (n)	2,339	340
Mean EUI	*74*	*93*



Average EUI per city, that is an average building's energy use per square foot in each city, shows a stark drop if this were looked at as time series data. What is important to note, however, referring back to the staggered rollout, is that in 2010 only one city's buildings are present, New York City public buildings.



Building types or use descriptions are provided by the individuals reporting the buildings and are somewhat constrained by selection menus in the Portfolio Manager tool, a table of the top ten building types is below:

Use Description	N	Percent
Office	4,656	34.85
Multifamily Housing	1,719	12.87
K-12 School	954	7.14
Hotel	644	4.82
Other	581	4.35
College/University	369	2.76
Education	295	2.21
Warehouse (Unrefrigerated)	256	1.92
Non-Refrigerated Warehouse	236	1.77
Retail Store	215	1.61

In the built environment, where buildings consume resources based on a mixture of needs ranging from the occupants, such as a comfortable office space, to a need for core business functions, such as running manufacturing equipment in a production facility, some level of energy consumption is required and that varies across types. There is much to be said about the interplay between incentives, lack or lag in information signals via utility bills, principal-agent problems, transparency, automation and human decision making as they relate to how much energy buildings consume. While building use descriptions are important considerations for measuring energy consumption and the effect of policies on energy consumption, accounting for all types begins to come at the expense of model tractability. Therefore, for the purposes of my model, I only use Office, Multifamily Housing and K-12 School as each of these has public and private representation.

Methodological Design

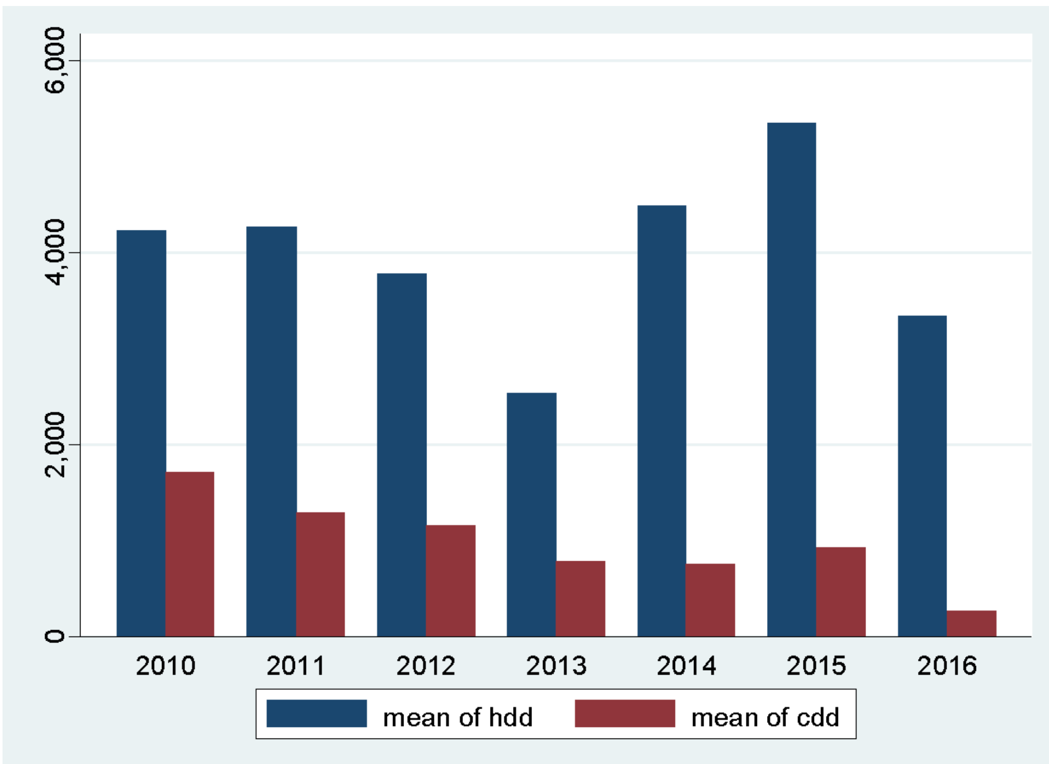
In Mostly Harmless Econometrics, the authors note the best place to start is to sketch the ideal experiment to measure what one is trying to measure, no constraints. The gold standard for experiments is Randomized Control Trials: 2 groups, one treatment and an easy t test. For measuring behavioral response to energy information disclosure we would want the following for an RCT: 2 groups of people randomly selected from commercial buildings (though residential may work as well), one group receives the treatment which is to publish their energy consumption and the other does not. This would be a repeated measure analysis as energy is consumed continuously and so we would want enough observations to establish sufficient power along with the obvious detectable difference in control vs. treatment groups. Ideally, the treatment group consumes less energy following disclosure and continues to do so.

While the policy date of implementation is important and ideal for exploiting a natural experiment, this paper will hold time periods constant, effectively, as the primary interest is that regardless of when the policy has been adopted, I want to measure a response in the following time period after energy data becomes public. The empirical estimation, though limited for reasons explained later, should allow me to assess the disclosure effect of the public knowing what both public and private buildings are consuming. Most research has focused on the disclosure of information as a remediation for market failure, claiming that transparency will lead to better energy efficiency, higher rents and increased resale value - an effect which should appeal primarily to private building owners. In a difference in differences strategy then this "private building after policy" becomes the treatment variable where the control group are similarly situated public buildings. What seems to be occurring is a focus on how this disclosure lifts, makes salient or brings into focus a private building owner or operator's marginal incentive to save and rightfully so. What I am interested in is estimating a different disclosure effect using the inverse where public is the treatment group; the assumption being that in public buildings the lack of market pressure reduces the marginal incentive to save (if so, weakly present) and therefore any reduction after treatment is attributable to intrinsic motivation. This same intrinsic motivation could be present in private building treatment but it is bundled with the ability to save or capitalize and would require a more experimental design.

Recall, this paper aims to do is exploit a few features of the building data set from all selected cities (n=19,988) looking for a "disclosure effect". Though the mandates are passive, does the disclosure of what a building is consuming invoke owners and operators of the buildings to then consume less? The first is to estimate a simple model pooling both private and public building stock together. This model assesses energy consumption for building_{it+1} where $t+1$ is the period following disclosure and comparing that to building_{it} where t is the benchmark year, looking for the difference to be (-) when controlling for weather and building characteristics. Second, I adapt Hsu's model to estimate the effect absent market pressure by isolating public buildings in a difference in differences strategy and third, I regress first order differences over the same independent variables as in the previous models with on key difference: initial level of consumption is now included. There will be geographical differences, which I hold constant, given the novelty of the policy and data limitations.

The model is slightly different as well in the building controls; previous work coupled the benchmark data with real estate information - I am only using the public information. The control variable set is gross floor area, age (when available) and weather as measured by degree days using a base temperature of 65*F and both linear and nonlinear terms. Though the dependent variable is already compressed or 'normalized' by square feet, to make comparisons across different building sizes, some variation can still be accounted for by including gross floor area as a control variable as there may be economies of scale in certain building layouts and this is important to account for in estimating energy use. However, the gross floor area and age reduce useable observations from ~20,000 down to ~7,000 so for initial results these are assumed constant unless stated so in the estimation tables.

In energy analysis, weather clearly influences the use of energy in general but also affects different fuel inputs differently as these inputs serve different loads. For instance, natural gas is used almost exclusively for heating, perhaps a bit for cooking but rarely if ever for cooling within a building. Electricity, by contrast, can be used for cooling, heating, computers, lights, etc. It is difficult to empirically tease these two primary fuels apart to assess effect on energy use without observable separation at the utility meter level within a building. To control for weather, researchers employ the use of degree days, which are a measure of daily average temperature and compare that to a balance point temperature. The concept of a balance point is an outside temperature which, theoretically, imposes no thermal load on the building – no heating or cooling needed. This is highly variable but full thermal load studies of building envelope, orientation and other contributing factors are costly, time consuming and still fail to represent reality. Degree day analysis makes for a tractable control variable in regression models. A balance point temperature is selected, typically (and for this research) 65°F and degree days are calculated off of that temperature. Given this, any deviation from the balance point temperature imposes a thermal load which must be accounted for through heating or cooling the building. If the average daily temperature for a given day is 75°F, then that is 10 (75-65) cooling degree days (CDD) as the daily temperature is higher than the balance point, necessitating mechanical cooling. Similarly, if the average daily temperature is 55°F, then that is 10 (65-55) heating degree days (HDD) requiring some type of heating. To assess weather assuming a linear effect of CDD and HDD fails to appreciate aspects of both regression theory and thermal dynamics. A linear assumption of weather assumes that changes in temperature from 0-10°F imposes the same thermal load as 45-55°F, this cannot be true as interior conditions of occupied buildings demand certain temperature ranges to hold. Further, a linear assumption could potentially overstate the baseload or non-weather dependent energy consumption as the intercept component of the regression. Given these two factors, I add a squared term for each variable which addresses both concerns of changes in temperature not being constant and minimizes risk of overstating the non-weather dependent load (Dubin, 2008). Daily temperature data were downloaded from NOAA, degree days were calculated using average daily temperatures within the time range of the panel. These values were then collapsed down to annual summations per city and merged in to the energy consumption data set.



The OLS regression models are estimated using the following equations:

$$\ln y = \alpha + \beta X + \beta T + \varepsilon \qquad (1)$$

$$\ln y = \alpha + \beta X + \beta A + \beta T + \beta T * A + \varepsilon \quad (2)$$

$$\Delta y = \alpha + \beta X + \beta T + \beta I + \varepsilon \qquad (3)$$

Where in equation (1) $\ln y$ is the natural log of Site EUI (previous research from New York City uses Source EUI), α is some constant, X is a vector of weather controls, βT is a dummy variable for all buildings in period $t+1$ and ε is a randomly distributed error term. In equation (2), $\ln y$ again is identical to (1) however I now control for differences between consumption in public and private buildings in time periods t and $t+1$. Model 2a adds fixed effects and clustered error around building types. In model (3), y is now a calculated first order difference, with βT being public buildings and βI added to control for initial EUI in period t. What this should help to estimate is the intuition that more intense energy users "feel" more inclined to reduce as a response to a) new reference point of other buildings and b) the public being able to see what they consume. We might interpret this variable's interaction with βI as a "shame effect". This assumes that less intense users "feel" less shame and perhaps also have less ability to reduce consumption. This model does not apply that gradient, rather just controls for the initial level when estimating the treatment effect.

Section IV: Results

The results of the two consumption models (1) and (2) specified in Section III are presented below reflecting a 3% decrease when assuming building stock type constant and an 1% increase (not significant) when estimating treated buildings (public), respectively:

Model	(1) ln y	(2) ln y	(2a) ln y
Public t+1 Dummy		0.0141	-0.0641***
		(0.31)	(-4.65)
Period t+1 Dummy	-0.0318*	-0.0396**	-0.0341***
	(-2.44)	(-2.79)	(-5.53)
HDD	-0.0000872***	-0.0000634**	0.0000823***
	(-4.14)	(-2.77)	(5.21)
CDD	0.0000466	0.0000594	0.00113***
	(0.51)	(0.62)	(7.47)
HDD^2	1.78e-08***	1.37e-08***	-4.98e-09**
	(6.97)	(4.69)	(-2.89)
CDD^2	0.000000169**	0.000000165**	-0.000000448***
	(3.16)	(2.95)	(-7.70)
Public Building Dummy		0.0678	-0.108**
		(1.89)	(-2.67)
Constant	3.956***	3.921***	3.711***
	(70.78)	(65.87)	(34.51)
N	7329	7006	19487
R^2	0.067	0.065	0.023
Fixed Effects	No	No	Yes

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Model 2a employs fixed effects and clustered errors around building types (e.g. Office, K-12 School, Warehouse, etc.) which allows for all observations to be utilized in the model and suggests a 6% decreasing in energy use in the year following disclosure.

The results of the difference model (3) specified in Section III are presented in the table below and reflect a decrease of approximately 7 kBtu per square foot:

Model	(3) Δy
Public Buildings	-6.828***
	(-4.42)
EUI_{it}	-0.140***
	(-14.47)
HDD	-0.00590***
	(-3.77)
CDD	0.0291***
	(5.03)
HDD^2	0.000000643***
	(3.33)
CDD^2	-0.0000188***
	(-5.57)
Constant	14.06***
	(3.49)
N	3667
R^2	0.078

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

These results indicate a few things and the first being that indeed, initial EUI in period *t* matters. With the addition of this initial level dummy variable in the difference model, the results show a 7 unit decrease in energy per square foot, about 5.5% of the mean. This challenges a few previous assumptions and this warrants some explanation, as well as the change in specification of the controls vector X.

First, the addition of the initial level of consumption to the model and its effect on the estimation suggests that indeed, initial level matters. This was not considered in the previous research by Hsu focused on New York City. Public building owners have their own reference for how their building is doing and they imagine their buildings consume a lot of energy and operate poorly. Then, the disclosure happens and these same building operators can now see peer buildings, who perhaps consume the roughly same amount. Given this new reference point, there is an unintended effect as higher consumption becomes relatively normalized in period *t+1*.

Lastly, as will be discussed in Section V, energy is consumed on a continuous basis. Therefore, there is opportunity for trend analysis and autocorrelation will be present. Preliminary testing using this data shows that EUI in period *t*, regardless of level, is the strongest predictor of EUI in period *t+1*. There are two ways in which this can be teased apart. The first is to allow more time for this policy to be active and obtain more annual observations. The second is to obtain data for these same buildings at monthly intervals pre- and post-policy (database disclosure) and use econometric techniques for teasing out how much savings, if any, can be attributed to the disclosing of energy consumption.

Section V: Conclusion and Recommendations

This research has empirically attempted to estimate effects on energy consumption from disclosure. Consumption models showed an overall 3% decrease but a 1% increase when assessing only public building response (statistically insignificant), when looking at buildings which had both public and private representation. Using all building types and a tighter estimation strategy, results suggest public building owner-operators indeed respond and reduce energy by about 6%. Controlling for the initial level in the previous period, in the differences model, suggests that initial level matters however what gradient or bins has not been evaluated. The differences model showed public buildings use 7 kBtu per square foot less than their private counterparts and themselves in the period prior. The focus on public buildings was to exploit a scenario where operators of a building and presumably those who pay or report to who pays the bills do not have a marginal incentive to save, at least arguably not as strong as those in the private building pool given market pressure for increased valuation and rents. The primary reason for the reasonableness for this assumption (though it certainly warrants technical backing and more frequent observations) is that those paying energy bills in the public buildings do not benefit from an additional dollar saved, it does not go to them whereas this is the case, in some form, in private buildings. Private building owners at least have the theoretical possibility of marginal incentive where public building operators and stewards do not. And according to the weakness of the evidence, without market pressure, it seems based on the available data and estimation strategy that the intrinsic motivation to reduce energy use is not strong enough to be detected at this point. It could also point to barriers which public buildings face in obtaining capital for improvements to the building; more research needs to be done assessing this important topic and policy.

This study can really be expanded by addressing some of the current shortcomings, namely that this is annual data. Energy is consumed continuously and for this research and evidence to be taken seriously, we must obtain monthly interval consumption data on the buildings. Second, we must obtain energy consumption data for a few years prior to the mandate and public database publishing. Third, which combines the first and second, is to obtain monthly energy data, from both public and private buildings, in a jurisdiction where the policy has not been adopted as an ordinance - this data should also have be sometime prior and post to current ordinance adoption dates. The last possible improvement is to exploit the stipulation of certain square foot thresholds in each of the public and private building data sets. For example, cutoffs are 25,000 square feet for public buildings and 100,000 square feet for private buildings. Depending on evidence from whether or not initial levels of consumption matter in year t as it relates to any reduction in year $t+1$, these threshold values could be exploited to further refine estimates of the treatment by looking at buildings' energy use with square footages just under and just over the defined values. The last effect that could be tested for is substitution effects. If a building owner and operator discloses their energy use, uses less in the following year, is that consistent with other utilities like water consumption or by way of moral licensing, could water use be shown to increase. Ideally this research, along with other research on disclosure policies, help policy makers understand what has happened thus far and be open to experimental design in jurisdictions where this energy benchmarking disclosure policy is likely to be adopted.

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