NBER WORKING PAPER SERIES

INCENTIVE PAY AND SOCIAL RETURNS TO WORKER EFFORT IN PUBLIC PROGRAMS: EVIDENCE FROM THE WEATHERIZATION ASSISTANCE PROGRAM

Peter Christensen
Paul Francisco
Erica Myers

Working Paper 31322
http://www.nber.org/papers/w31322

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
June 2023

We are indebted Mick Prince, Chad Wolfe, the PRISM Climate Group for assistance with data and experimental implementation. We thank Bryan Parthum, Tengjio Chen, Hansen Shao, and Mateus Souza for excellent research assistance. We received excellent feedback and comments from Hunt Alcott, Meredith Fowlie, Nathan Hendren, Matt Kahn, Kelsey Jack, Rob Metcalfe, Dave Rapson, Rich Sweeney and seminar participants at the CU Environmental and Resource Economics Workshop, the Dallas Fed, UC Berkeley's Electricity Camp, Georgia State University, the Kelley School of Business, Michigan State University, the Online Agricultural and Resource Economics Seminar (OARES), UC Santa Barbara, the Heartland Workshop, the University of Pennsylvania, the Urban Economics Association meeting, and UC San Diego. We acknowledge generous support from the Alfred P. Sloan foundation and the Illinois Department of Commerce and Economic Opportunity's Illinois Home Weatherization Assistance Program. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Incentive Pay and Social Returns to Worker Effort in Public Programs: Evidence from the Weatherization Assistance Program
Peter Christensen, Paul Francisco, and Erica Myers
NBER Working Paper No. 31322
June 2023
JEL No. H41,J0,Q4,Q50

ABSTRACT

Aligning compensation with recipient outcomes has the potential to improve the efficiency of government programs. We perform a field experiment to evaluate the impact of performance bonuses on the returns to spending in a large low-income energy efficiency assistance program. We find that performance-based bonuses dramatically increased program natural gas savings by 24%. The bonuses generate $5.39-$14.53 in social benefits for every dollar invested and increase the social net benefits from home-level weatherization more than two-fold. Contractors performing at high quality at baseline respond disproportionately to the incentives, suggesting that gains in the program's cost-effectiveness result from more efficient allocation of worker effort across workers who differ in their marginal effort cost. We do not find evidence of learning within the two-year study period or of increased deficiencies among non-incentivized tasks.

Peter Christensen
Agriculture and Consumer Economics
University of Illinois at Urbana-Champaign
1301 W. Gregory
Urbana, IL 61801
and NBER
pchrist@illinois.edu

Paul Francisco
University of Illinois at Urbana-Champaign
2111 South Oak Street
Suite 106, MC 699
Champaign, IL
pwf@illinois.edu

Erica Myers
Department of Economics
University of Calgary
414 Social Sciences Building
2500 University Drive NW
Calgary, AB T2N 1N4
Canada
and E2e
and also NBER
erica.myers@ucalgary.ca

A randomized controlled trials registry entry is available at
https://www.socialscienceregistry.org/trials/2985

1 Introduction

When effort is unobservable, contracts that more closely align workers' pay with employers' targeted outcomes have the potential to improve effort and productivity relative to fixed pay structures (e.g., Lazear, 2000; Shearer, 2004). Incentive pay contracts are widely used in many private sector applications (Gittleman and Pierce, 2013), though they are less common and potentially under-utilized in the public sector (Bloom and Van Reenen, 2011). A growing body of empirical evidence has begun to document the impacts of performance pay contracts on the effort and effectiveness of public sector workers such as teachers (Biasi, 2021; Lavy, 2020; Lavy, 2009; Aucejo, Romano, and Taylor, 2019), tax collectors (Khan, Khwaja, and Olken, 2019; Khan, Khwaja, and Olken, 2016), and civil servants (Bandiera et al., 2021; Bertrand et al., 2020; Kim, Kim, and Kim, 2020; Burgess et al., 2017). However, this literature has not yet been able to evaluate impacts on the efficiency of public spending by explicitly quantifying the net benefits from performance pay interventions.

The present study addresses this gap in the literature with findings from a 2-year field experiment examining the impact of pay-for-performance incentives in the Weatherization Assistance Program (WAP), America's largest energy efficiency program and, in recent policy actions, a core instrument of national climate policy.[1] The WAP provides a unique setting for quantifying the effects of incentives on worker effort in a large government program, including rich microdata on all tasks completed by contractors as well

*University of Illinois at Urbana-Champaign; †University of Calgary; Emails: Christensen (pchrist@illinois.edu), Francisco (pwf@illinois.edu), Myers (erica.myers@ucalgary.ca). We are indebted Mick Prince, Chad Wolfe, the PRISM Climate Group for assistance with data and experimental implementation. We thank Bryan Parthum, Tengjio Chen, Hansen Shao, and Mateus Souza for excellent research assistance. We received excellent feedback and comments from Hunt Alcott, Meredith Fowlie, Nathan Hendren, Matt Kahn, Kelsey Jack, Rob Metcalfe, Dave Rapson, Rich Sweeney and seminar participants at the CU Environmental and Resource Economics Workshop, the Dallas Fed, UC Berkeley's Electricity Camp, Georgia State University, the Kelley School of Business, Michigan State University, the Online Agricultural and Resource Economics Seminar (OARES), UC Santa Barbara, the Heartland Workshop, the University of Pennsylvania, the Urban Economics Association meeting, and UC San Diego. We acknowledge generous support from the Alfred P. Sloan foundation and the Illinois Department of Commerce and Economic Opportunity's Illinois Home Weatherization Assistance Program.

[1] In the United States, The Biden Administration's American Jobs Plan proposes investments of \$213 billion to "produce, preserve, and retrofit more than two million affordable and sustainable places to live" (The White House, 2021). Investment in the WAP has expanded dramatically as part of federal climate and stimulus initiatives over the past two decades. Under ARRA, funding was temporarily increased from \$450 million annually to almost \$5 billion for program years 2011-2012 and, more recently, the Bipartisan Infrastructure Investment and Jobs Act set aside a historic \$3.5 billion to expand the program.

as the program's primary welfare-relevant outcome – energy consumption.[2] We recover a measure of the effect of the intervention on workers' effort costs and examine effort allocation efficiency as a specific channel through which performance pay can increase the marginal value of public funds. Identifying and addressing misallocation in energy efficiency programs, in particular, is of urgent concern given that they represent a central component of global climate policy with hundreds of billions of dollars invested annually (European Parliament, 2012; EEA, 2018; ARB, 2017; IEA, 2020).

We partnered with the Illinois Home Weatherization Assistance Program (IHWAP) to study the effects of a piece-rate incentive for air sealing retrofits. These retrofits are one of the "big four" energy-saving retrofits in the program and they represent just over 12% of total expenditures in the average home.[3] Air sealing retrofits provide a promising starting point for introducing incentive-based pay into energy efficiency programs because they are straightforward to evaluate using a blower door test that measures the "leakiness" of a home. The blower door test is routinely conducted as part of a pre-weatherization home energy audit and again upon completion of the work contract. As illustrated in Figure 1, the CFM50 levels measured by a blower door test are highly correlated with energy consumption.[4] Air sealing opportunities can vary widely from house to house, creating potential for the attention and skill of the contractor to have an impact on identifying and properly sealing the leaks. Heterogeneity in the housing stock and contractor skills interact to produce substantial variation in the the marginal cost of additional air sealing improvements.

In this study, we randomly assigned contracts (jobs) into two treatment groups that correspond to "high" ($1.00) or "low" ($0.40) payments for each unit of air seal-

[2] Quantifying welfare relevant outcomes is challenging in other contexts, such as measuring human capital improvements from performance-based teacher incentives. Even with long run studies demonstrating higher adulthood earnings (e.g., Lavy, 2020), it is difficult to disentangle the effect of the incentives creating more human capital in early years from them merely creating higher test scores, improving access to better quality post-secondary education.

[3] Wall insulation, attic insulation and furnace replacements represent the remaining 3 major retrofits types. The term "air sealing" describes the methodical identification and sealing of air leakage sites, including those in the attic, walls, basement, and/or crawlspace.

[4] The blower door test assesses the volumetric flow rate of air from the home when the home is depressurized by a set amount (50 Pascals [Pa]). The leakier the home, the more air needs to be moved to cause that amount of depressurization. The unit of measurement from the blower door test is cubic feet per minute at 50 Pa (CFM50).

ing achieved beyond target. Contracts assigned to the control group were not eligible for bonus incentives.[5] We use the high and low treatment levels to examine how effort responds to different incentive levels and then identify two points on the supply curve of air sealing (as a function of the piece rate) to construct a measure of producer surplus. Aside from the presence or absence of bonus payments for air sealing, all other components of the program continued as before, including the enforcement of minimum quality standards on all retrofits. A certified quality control inspector in each agency conducts an inspection after the work has been completed and can require contractors to rectify any deficiencies. Whereas low-quality workmanship can be partially addressed through the enforcement of minimum quality standards, piece-rate bonuses have the potential to allocate contractor effort more efficiently.

We report three key findings on the overall effectiveness of air sealing performance incentives in the IHWAP. Performance bonuses lead to: (1) increases in the homes' air-tightness, (2) reductions in the likelihood that contractors are called back by inspectors to fix deficiencies in air sealing retrofits, and (3) additional reductions in household energy use. Our findings suggest there is significant misallocation of resources when using typical public program contracts, when pay is not linked to the welfare outcomes of program participants. Using central estimates, we find that the addition of the performance bonuses increases the social net present benefits (NPB) from IHWAP more than two-fold, from net negative ($-488) to net positive ($652). The intervention generates $5.39-14.53 in social benefits for every dollar invested in bonus payments, after accounting for the workers' effort costs. This contrasts with $0.95-1.14 in social benefits for retrofits in baseline WAP contracts.

The present study contributes to a growing body of empirical evidence identifying opportunities for incentive pay to improve effort and effectiveness in the public sector (Biasi, 2021; Lavy, 2020; Lavy, 2009; Khan, Khwaja, and Olken, 2019; Khan, Khwaja, and Olken, 2016; Bandiera et al., 2021; Bertrand et al., 2020; Kim, Kim, and Kim, 2020). Our findings provide the first evidence of the impacts of performance pay on the marginal

[5] Treatment assignment at the job-level offered substantial gains in statistical power relative to contractor-level randomization.

value of spending in a major government program, also linking the public sector literature on worker incentives and burgeoning research on "green jobs." Research on the mechanisms underlying the widely documented gap between projected and realized savings in energy efficiency programs[6] has identified contractor performance as a primary contributor, revealing that incentive problems affect the quality of building retrofits (Christensen et al., 2021; Giraudet, Houde, and Maher, 2018; Blonz, forthcoming). Sealing this gap will be critical for increasing the marginal value of public spending on energy efficiency for low income households and reducing the marginal cost of greenhouse gas abatement (Gillingham and Stock, 2018). While additional evidence is needed to assess the impacts of comprehensive incentive-based pay systems including energy efficiency improvements that lie outside the scope of the current study, the results reported here suggest that interventions that better align contractor incentives with social benefits provides a promising path forward.

We also contribute to a literature that, beginning with the seminal work of Holmstrom and Milgrom (1991), demonstrates that performance incentives can induce workers to re-allocate effort from non-compensated to compensated tasks in multi-dimensional contracts. The impact of a piece-rate bonus on effort re-allocation is ambiguous, as it depends on whether tasks are complements, substitutes, or independent in the contractor's private cost function. One contribution of our work is we are able to directly test for evidence of this type of effort reallocation.

Empirical work on the impacts of incentive pay on effort reallocation has been limited by challenges in observing effort on non-compensated tasks (Muralidharan and Sundararaman, 2011; Lavy, 2009; Barlevy and Neal, 2012; Lavy, 2020; Aucejo, Romano, and Taylor, 2019; Gaduh et al., 2021; Hong et al., 2018). We designed the study to evaluate the reallocation of effort along two dimensions. First, our job-level randomization allows us to estimate the effects of effort reallocation *between* jobs. Our intervention created

[6] Realized savings have been shown to be lower than projection across settings including home retrofit programs (Fowlie, Greenstone, and Wolfram, 2018; Allcott and Greenstone, 2017; Zivin and Novan, 2016; Berry and Gettings, 1998; Dalhoff, 1997; Sharp, 1994), appliance rebate programs (Houde and Aldy, 2017; Davis, Fuchs, and Gertler, 2014), and efficient new construction (Levinson, 2016; Bruegge, Deryugina, and Myers, 2019; Davis, Martinez, and Taboada, 2020).

random variation in the number of simultaneous treatment or control jobs that firms work on at any given time, allowing us to quantify the effects of any effort reallocation on the reported deficiencies, building envelope tightness, and energy usage in contemporaneous jobs.[7] Second, we collected inspection data to determine whether the incentives induce contractors to divert attention away from non-compensated tasks *within* treatment jobs, as evidenced by an increase in deficiencies in those tasks. We do not find any evidence that incentive treatments increase deficiencies in non-compensated retrofits that are part of a treated contract (e.g. furnace repairs, which do not affect CFM50 reductions). Further we do not find evidence that incentive contracts on some jobs negatively affect performance on contemporaneous jobs. This finding provides evidence that performance pay for one type of task does not necessarily have deleterious impacts on non-incentivized tasks. The size and direction of net effects in multi-task contracts can depend on several factors that enter a contractor's cost function, such as whether tasks are complements or substitutes, the presence and enforcement of quality standards on non-incentivized tasks, and labor supply or other general market conditions.

Finally, this paper contributes to a literature that seeks to disentangle the channels through which performance pay or other workplace interventions affect the productivity of workers who may vary in skill or other attributes. We introduce piece-rate bonuses, which have the potential to allocate contractor effort more efficiently than minimum quality standards. The assignment of jobs to contractors is independent of treatment in the IHWAP setting, allowing us to isolate within-worker productivity effects (Friebel et al., 2017; Lazear and Shaw, 2007; Lazear, 2000) in the absence of sorting/selection processes (Dohmen and Falk, 2011; Lemieux, MacLeod, and Parent, 2009). Consistent with results from canonical models of performance pay (Lazear, 2018) and emerging evidence in other empirical settings (Frederiksen, Hansen, and Manchester, 2022; Franceschelli, Galiani, and Gulmez, 2010), we find that contractors who performed better at baseline (using the year preceding the intervention) respond to incentives with disproportionately larger improvements in their air sealing work. We also find a higher variance of CFM50

[7] IHWAP jobs are assigned to firms in batches of several jobs at a time through a queue.

and gas use outcomes with the piece rate, which is consistent with the prediction that contractors will invest additional effort on lower marginal cost homes under that regime. These findings demonstrate that cost-effectiveness increases under the bonus result from more efficient allocation of effort within the program, thus indicating that minimum air sealing standards are a significant source of effort misallocation. There may be similar opportunities to increase returns to public spending for a wide range of critical public goods, given that governments rely heavily on social service providers (U.S. Government Accountability Office, 2021) who may vary in experience or skill and rarely compensate them on the basis of welfare-relevant outcomes (Hawkins, Bieretz, and Brown, 2019).

2 Setting and Experimental Design

2.1 Institutional Background

The Weatherization Assistance Program (WAP) is the largest U.S. residential weatherization program, having provided assistance to over 8 million households since it began in 1976. It aims to reduce energy bills for low income households while maintaining health and safety. The Bipartisan Infrastructure Investment and Jobs Act, passed in November 2021, set aside $3.5 billion to significantly expand the program over the following years. Therefore, it is timely to consider ways to improve the efficiency of delivering services in the program.

Our study was carried out in cooperation with Illinois' implementation of the federal program, the IHWAP. Implementing agencies throughout the state are responsible for administering the program. There are approximately 33 agencies serving Illinois' 106 counties, with some agencies serving a single county when that county has a larger urban center and some agencies serving up to nine counties in less-populated portions of the state. Which retrofits are performed in each house are determined during a pre-weatherization energy audit. An agency energy auditor collects detailed measurements on the structure of the house, characteristics of mechanical systems, and health and safety information. Department of Energy (DOE) funding for a home is allocated using these measurements as inputs to an optimization strategy, which is intended to direct program funding to the most cost-effective among the feasible retrofits. Cost-effectiveness is determined by the savings-to-investment ratio (SIR) and retrofits are selected from highest to lowest SIR until either (1) the available funding is exhausted or (2) there are no more remaining retrofits with SIRs of 1.0 or greater.

Prior to 2016, all IHWAP funding – including non-DOE funding – followed DOE rules to select retrofits. However, starting in some pilot locations in 2016 and then program-wide in 2017, additional funding from non-DOE sources, including LIHEAP (HHS) funds, state funds, and utility funds has been used to do additional retrofits that may not always meet DOE rules. This "braided funding" is often used to do measures that are ineligible for DOE funding, such as replacing old water heaters or old air conditioners or rectifying health and safety concerns that fall outside WAP guidelines. The goal is to use additional funds to do measures that treat the whole house and help the family independent of DOE eligibility and SIR. Therefore, measures with SIR<1 are often selected. The extent to which braided funds can be used depends on the household – not all funding sources have the same eligibility requirements and so some families are not eligible for some funds. Once the complete list of retrofits have been selected across all funding sources, the administrative software directly converts this list into a work order, which is provided to the contractor who will implement the work.

Air sealing, the focus of our experiment, is performed in all homes. It is always deemed cost-effective given the low-cost and long-lived energy savings achieved when finding and sealing leakage sites in attic, walls, basements or crawl spaces. This type of work directly affects the tightness of the building envelope. Other retrofit categories can impact building envelope tightness as well, including some types of attic insulation, wall insulation, crawl space insulation, basement insulation, rim insulation and windows and door upgrades. The tightness of the building envelope is measured by a blower door test. To implement the test, an experienced energy specialist will temporarily install a large fan in the frame of a home's outside doorway. After calibrating the device, the fan draws air out of the house and reduces the air pressure inside. The test then assesses the volumetric flow rate of air from the home when the home is depressurized by a set amount

(50 Pascals [Pa]). In a leakier home, more air needs to be moved to cause the same amount of depressurization. The unit of measurement from the blower door test is cubic feet per minute at 50 Pa (CFM50). Lower CFM50 values indicate that the home is better air-sealed, and thus well suited to retain heated or cooled air. The IHWAP program uses a pre-defined formula to estimate the amount of air sealing expected based on a pre-retrofit blower door test performed during the initial energy audit. The leakier the home, the greater the expected air leakage reductions. This formula is used to determine a quantity target (CFM50 reductions) for each individual home.

The set of contractors that serve the program and how much they are paid for each retrofit is determined through a competitive bidding process at the start of each program year. Contractors submit itemized bids for their labor and materials costs for each of the suite of retrofits performed by the program. For example, they will submit their costs per cubic foot of wall or attic insulation or furnace installation. These bids determine the compensation that the selected contractors receive for work performed in that program year. As a result, payments are pre-determined in each contract but vary job-to-job for each firm according to which measures appear on the work order and may vary across firms for the same work order due to differences in their bids.[8]

A house enters a job queue once it has been approved and the auditor has selected the retrofits to be implemented. Once in the queue, most jobs are assigned in sequential order independent of any characteristics about the home, measures assigned, or the contractors themselves.[9] Contractors frequently receive a bundle of work orders at once.

The WAP enforces quality standards through inspections performed when all work is completed.[10] The agency inspector documents findings and deficiencies for any measures that did not meet the quality standard associated with a given type of retrofit. Certain findings will warrant a callback for the contractor to return to the site to correct a

[8] In some instances, if a retrofit was incorrectly selected for a particular home or some other type of error in the work order, the contractor can file for a "change order," which might affect the total payment for the job. In Appendix A we demonstrate that the treatment had no economically or statistically significant impact on spending for the non-bonus aspects of the program.

[9] There are some instances, especially in smaller agencies, where jobs may be assigned to a particular contractor on the basis of something like equipment availability.

[10] The quality control inspectors receive accredited training and must be certified by the Building Performance Institute (DOE, 2013).

deficiency, such as poor wall insulation or a furnace installation issue. Others do not, if for instance, air sealing does not quite hit target or duct work was not ideally performed.[11] Callbacks are costly for firms since they do not receive any additional compensation for having to perform the extra work.

2.2 Experimental Design

In this study, we evaluate the impact of piece-rate bonus incentives to contractors for air sealing improvements based on blower door readings. The study was implemented over the course of two program years: 2018 and 2019.[12] The sampling frame included all Illinois jobs completed outside of Cook County (which includes Chicago), which represents approximately half of the state program. The agency serving Chicago is the one agency in the U.S. that we are aware of that already compensates their contractors for air sealing based on measured air-tightness outcomes (performance pay contracts). The rest of the state compensates contractors using pre-set sums that are based on the degree of expected air leakage reductions. As a result, Cook County-based jobs were excluded from the intervention. The sampling frame was further restricted to single-family homes served by one of the major 3 utilities that serve the study region, with whom we had a data sharing agreement.

The intervention consisted of two different piece-rate bonus regimes: a "high" payment ($1.00) and a "low" payment ($.40) per CFM50 reduction. Bonus payments were made on top of pre-set compensation assigned to a specific project, such that contractors who achieved CFM50 readings below the minimum target required by the state received a bonus paid on the number of additional CFM50 reduction achieved.[13] A third set of control jobs were not eligible for bonus payments, instead receiving nothing beyond the

[11] In practice, the state allows contractors to achieve slightly less than the target on any given job. The guidance is to allow a contractor to achieve a CFM50 reduction that is no more than 10% above the "target" on at least 90% of jobs. The 10% allowance by the state acts as a safeguard against imposing excessive penalties against contractors by accounting for the fact that some homes have characteristics that make achieving target especially difficult.

[12] A program year begins in July and ends in June of the following year, such that program year 2018 included jobs from September, 2017-May 2018.

[13] At the start of the experiment, bonuses were paid based on reductions achieved beyond 10% above target, DOE's guidance for the minimum allowable reduction without having to perform a callback. However, the adjustment was made due to budgetary considerations.

normal pre-set compensation.

At the annual IHWAP meeting before the start of our intervention in the program year 2018, we alerted the implementing agencies that contractors need to sign up as vendors with the University of Illinois in order to receive bonus payments. We also made them aware that information about the bonus payments would appear at the top of the work orders for treatment jobs. As of the beginning of the program year, eligible jobs were randomized into the three treatment groups. After new work orders were initiated in IHWAP's administrative software, they were automatically assigned to the "high" payment treatment, "low" payment treatment, or control regimes. Randomization was implemented through custom application that was embedded in the software that generated work orders for the IHWAP program. The magnitude of incentive payments under example scenarios were clearly printed on the work order that each contractor received at the outset of a job (See Appendix B for examples of the full language that was printed on the work order).

Architectural work on this job is eligible for a bonus of $1 per CFM50 below target. The target for this job is 1200 CFM50 reduction. A reduction of 1400 CFM50 will receive a $200 bonus payment. A reduction of 1600 CFM50 will receive a $400 bonus payment. A reduction of 1800 CFM50 will receive a $600 bonus payment.

Several program features described above are worth highlighting for interpreting the results our experimental intervention. First, treatment assignment happens at the point at which the work order is printed (i.e., after the pre-weatherization audit is completed). Therefore, the audit cannot affect blower door targets or retrofits performed because the energy auditor has no way of knowing what treatment status will be when inputting initial measurements. Second, contract pay for each retrofit task is specified and fixed for each firm at the start of the program year. As a result, the compensation for non-air sealing components of the job cannot be affected by the treatment. Third, jobs are assigned through a queue system, which limits the potential for productivity sorting of firms and allows us to isolate the impact of piece-rate incentives on worker output with a constant pool of human capital (Dohmen and Falk, 2011). Fourth, because contractors must perform callbacks at their own expense, the existing quality control regime would be expected reduce effort reallocation away from uncompensated tasks within and across jobs.

Finally, the use of braided funding during the program years studied here allowed many measures to be performed simply as a means to offer aid to low income households and were not intended to be cost-effective in terms of energy savings. Under this regime, spending per home almost doubled and the overall expected SIR of the suite of retrofits was much lower compared to previous years (see Appendix Table C1). This has implications for interpreting cost-effectiveness of the WAP, since it is not possible to disentangle the impacts of DOE versus other funding sources in this period.

3 Data

We make use of three types of data to estimate the effects of pay-for-performance intervention on program outcomes and cost-effectiveness. We obtain comprehensive administrative data on the homes and households served by the IHWAP program. This includes all home characteristics and building measurements recorded during the pre-weatherization energy audit, pre/post blower door test, homeowner demographics and household information, contractor information, the expected labor and material costs for all retrofits completed as part of a project, and project audit and completion dates.

We additionally obtained information on all inspection reports completed by quality control inspectors serving each of the agencies administering the program. This information includes measurements of deficiencies in contractor work (blower door test, insulation thickness, installations), which are classified as one of two categories: (1) callbacks identify a deficiency that is sufficiently problematic to warrant the return of a contractor prior and re-inspection prior to finalizing a project and issuing payment; (2) findings identify a deficiency irrespective of whether it is sufficiently problematic to warrant a callback. Finally, we obtained pre-treatment and post-treatment monthly billing data from the three major utilities (gas and electric) that serve households participating in the IHWAP. We convert energy use measurements to monthly MMBtus for a consistent metric for measuring effects on gas and electricity consumption.

Table 1 provides descriptive statistics for the variables examined in the study and reports the results of tests for balance across each of the treatment groups. The average home in the sample has 2.8 bedrooms, 1.3 stories, and a total living space of 1,450 square feet. The average household has 2.4 occupants. The average CFM50 level recorded in a pre-weatherization blower door test is 3,600-3,900. The baseline CFM50 levels can range up to 10,000 in some homes. For the study, we exclude homes with baseline CFM50 levels that exceed 10,000 due to concern about measurement error in the tests for this sample of homes. Homes can legitimately have CFM50 levels over 10,000, but those homes also have extremely large discrete leaks and so are unlike the rest of the sample.

As a stratified randomization process was not possible in our context, there are a few characteristics of the jobs that are not completely balanced across treatments. In particular, the low treatment group has somewhat leakier homes (higher CFM50) than the control and high treatment groups at baseline. Since the pre-weatherization blower door reading determines the target CFM50 reductions for a home, this imbalance could affect the comparison of raw means across treatments. Therefore, all of our estimates of treatment effects include controls for the pre-weatherization blower door reading. We also provide estimates of treatment effects controlling for home characteristics and expenditures to control for any other imbalance in the samples of homes.

4 Results

4.1 The Contractor Response to Performance Incentives

We begin by investigating the effects of the bonus treatment on the contracted outcome, building envelope tightness. Our setting closely resembles that of Lazear (2000), where a piece rate is introduced on top of a minimum quality standard coupled with a minimum guaranteed payment. His model predicts that if the existing minimum standard does not change, the introduction of a piece rate will not reduce effort. To the extent that some workers respond to the incentive, average effort and output will increase. In our setting, workers should respond with increases in CFM50 reductions (beyond the minimum standard) whenever the marginal costs of effort and materials required are lower than the piece-rate bonus.[14]

We test whether the bonus treatment increases output (CFM50 reductions) and effort, as proxied by fewer deficiencies on incentived measures identified as part of a post-weatherization quality control control inspection. Air sealing is performed with the sole goal of improving building envelope tightness, and thus is directly incentivized by the bonus, though other retrofit categories, including windows, doors, and insulation of all types (e.g. attic, wall, foundation) can also improve blower door readings. We estimate treatment effects using the following model:

$$Y_i = \beta_0 + \beta_1 T_{Hi} + \beta_2 T_{Li} + \mathbf{X_i'}\beta + \varepsilon_i, \tag{1}$$

where Y_i is an experimental outcome (CFM50 reduction or callback indicator), T_{Hi} is an indicator for the high treatment group with signed contractor, T_{Li} is an indicator for the low treatment group with signed contractor. The $\mathbf{X}_i$ contains a vectors of controls. We include month-year fixed effects for the month the job was completed, and increase power and precision by flexibly controlling for any imbalance in pre-treatment covariates using indicators for binned values of a home's pre-treatment blower door measurement and indicators for binned values of retrofit spending and home characteristics variables in Table 1.

A small number of contractors did not sign up for the bonus program and contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois. Given the possibility that take-up was correlated with unobservable skills that affect success in CFM50 outcomes, we report all main results obtained from a 2-stage least squares estimator that uses the randomized treatment assignment as an instrument for treatment jobs with eligible contractors. This is also the policy relevant result because if this bonus were rolled out program-wide, all contractors would receive payments from the implementing agencies directly rather than through a

[14]In Appendix D, we derive this result using principal-agent model of effort allocation in a multi-task setting that integrates insights from both Holmstrom and Milgrom (1991) and Lazear (2000)

third party vendor. See Appendix E for tables of corresponding reduced form estimates.[15]

Effects on Air-Sealing (CFM50 Reductions)

Table 2 reports estimates of average treatment effects on CFM50 reductions. Panel A reports estimates for the pooled treatments groups. All estimates include controls for the pre-weatherization blower door reading to control for imbalance in that characteristic among the low treatment group and the high treatment and control groups. Columns 2-4 progressively add more inclusive sets of controls for expenditures across the retrofit categories, month of completion and home characteristics. The magnitudes of the estimates are consistent across all specifications. The most precisely estimated coefficient in column 4 indicates that the bonus payment regime results in an average reduction of 89 CFM50 beyond the 1563 control mean reduction achieved using the pre-set compensation at the level of the target (standard). The magnitude of this effect is equivalent to 5.7% of the CFM50 reduction achieved in the control group (dependent variable mean) and approximately 2.5% of the pre-weatherization CFM50 level. Panel B reports estimates for each treatment separately. Point estimates suggest that the magnitude of CFM50 reductions was higher among homes randomized into the high bonus treatment than the low bonus treatment, though the difference is not not statistically distinguishable in our sample.

Effects on Air-Sealing Callbacks

Table 3 reports estimates of average treatment effects on deficiencies in air sealing work documented in each project's post-weatherization quality control inspection. Callback data were collected from agencies administering the program and were available for nearly all (1670/1698) of the jobs in our sample.[16] Panel A reports estimates for the pooled treatment groups. The estimate in Column 4 indicates that performance incentives reduced the probability of a deficiency by 2.95 percentage points, a reduction of just over a third of the 8.4% control mean callback rate. Point estimates in Panel B suggest that effects on callback rates may result primarily from responses to the higher bonus

[15] These intent-to-treat estimates are qualitatively quite similar–usually within 90% in magnitude–to those reported in the main text, because almost all contractors signed up as vendors.

[16] In Appendix Table F1 we show that the blower reduction results with this subsample are consistent with the full sample presented in Table 2

payment, though the differences between the groups are not statistically significant in our sample. These results are consistent with increased effort on air sealing in response to the bonus payments.

We performed a similar analysis for the effect of treatment on callbacks for deficiencies among all incentivized tasks combined (Appendix Table G1) and the point estimates are similar to those for air sealing alone, though the estimates are not as precise.[17]

4.2 Effects on Energy Consumption

Energy savings is the welfare-relevant outcome of interest in the program. The random assignment of performance bonuses allows us to disentangle the effect of these incentives from the base effect of weatherization under minimum quality standards using the following model:

$$Y_{it} = \beta_0 + \beta_1 W * T_{Hit} + \beta_2 W * T_{Lit} + \beta_3 W_{it} + W_{it} \cdot \mathbf{X_i'}\beta + \delta_t + \gamma_i + \varepsilon_{it} \tag{2}$$

where Y_{it} is the energy use (MMBtu) for household i in month t, $W * T_{Hit}$ is an indicator for the post-weatherization condition in the high treatment group, $W * T_{Lit}$ is an indicator for the post-weatherization condition in the low treatment group. We include month-of-sample (δ_t) fixed effects to control for monthly consumption patterns common to all households and home fixed effects (γ_i) to control for any time-invariant unobservable factors about a home that affect consumption. To control for any imbalance in covariates among the groups, we allow the baseline weatherization effect to vary by observable characteristics of the home and household. The matrix $W_{it} \cdot \mathbf{X_i}$ is an interaction between an indicator for post-weatherization and a vector of controls, including home's pre-treatment blower door measurement, spending for each retrofit category, indicators for the month

[17] Incentivized tasks include any retrofit categories that are done with the express purpose of reducing air leakage and include: thermal boundary, air sealing, windows, and doors. We designate retrofit categories that do not affect the blower door reading as non-incentivized, including non-insulation, mechanical system standards such as "Combustion Efficiency Venting," "Heating System Replacement," "Water Heater Retrofits," or "Gas Ovens".

of sample the project was completed, and home characteristics variables.[18] As before, we estimate the model using 2 stage least squares estimator where the randomized treatment assignment instruments for treatment jobs with eligible contractors.[19]

Table 4 reports estimates of average treatment effects on monthly gas consumption. Panel A provides pooled estimates of treatment effects. All models reported include house and month-of-sample fixed effects as well as a control for the interaction between weatherization and pre-treatment CFM50 levels. Columns 2-4 progressively add controls for weatherization interacted with: retrofit-specific expenditures (Column 2), fixed effects for the month-year of project completion (Column 3), and household and property characteristics (Column 4). Estimates are consistent across the specifications and indicate a pooled treatment effect of 0.29-0.38 MMBtu from pay-for-performance incentives. Estimates with the most comprehensive controls indicate that the bonus reduces monthly gas consumption by 5.5% relative to the control mean of 6.88 MMBtu. Compared to the baseline weatherization effect observed in the control group (-1.597 MMBtu), the effects of the bonus are substantial–increasing the overall impact by 20-25%.[20] There are several plausible explanations for why the effect of the bonus treatment is proportionally larger compared to the baseline weatherization effect for energy than for CFM50. For example, some retrofits, such as insulation, reduce air leakage, but reduce energy consumption proportionally more. Or, as we discuss below, there may be complementarities in a contractor's cost function, particularly among tasks that reduce CFM50. For example, if contractors responded to the incentive with increased supervision of employees' air sealing work, it may have made it easier to increase supervision on other architectural aspects of the job, such as insulation.

[18]Given that there is continuous random assignment to treatment throughout the sample period, our estimates will not suffer from the near term bias that can be present with staggered rollout (e.g., Goodman-Bacon, 2021). There are also unlikely to be significant differences in treatment effects across cohorts in the sampling period biasing our effects. We demonstrate in Appendix H that the treatment effects are quite similar when we reduce our sample size to ensure each WAP project gets equal weight in our estimates.

[19]Because utility consumption data is only available for a subset of the homes in our experiment (1216/1670), we also report results on our primary blower door outcome for this subsample in Appendix Table F2, which are consistent in magnitude with those presented in Table 2.

[20]The effect size for both the blower door reading and gas consumption appear to have remained consistent over the trial period and do not change as a function of experience with the bonus (see Appendix Tables K1 and K2).

We report estimates of average treatment effects on monthly electricity consumption in Appendix Table I1. While air sealing and other retrofits can increase the efficiency of electricity usage, reductions in electricity consumption are considered a comparatively minor component of the IHWAP given the smaller fraction of household cooling in the low income sample served by the IHWAP and the smaller fraction of cooling months than other regions served by the WAP program. This can be seen from the comparative mean effect of weatherization on electricity usage of -0.47 MMbtu in control homes, which is approximately 30% the magnitude of the effect of weatherization on gas consumption. The estimated treatment effects of our intervention are statistically non-significant. However, as shown in Appendix Table I1, we cannot rule out an effect size similar in magnitude to what we observe for gas (23% increase in the effect of the WAP). In estimates of social benefits, we assume that the intervention did not affect electricity usage and limit our benefits estimates to those from gas reductions.

4.3 Do Workers Re-allocate Effort?

Unlike the setting in Lazear (2000), our setting does not consist of a workers producing a single output. Rather, contractors complete multiple retrofit tasks for an IHWAP contract, such that increasing effort on one type of retrofit task may impact effort allocated to other retrofits. Holmstrom and Milgrom (1991) demonstrate that changes in effort and output in non-incentivized tasks in response to the introduction of an incentive depends on whether inputs to those tasks are complements or substitutes in the worker's private cost function. In Appendix D, we discuss a basic model drawing on insights from Holmstrom and Milgrom (1991) and derive these predictions for our setting. If non-incentivized retrofits are complementary to air sealing, the introduction of the bonus could increase effort and output in the non-incentivized dimension. If they are substitutes, then the bonus could reduce effort and output in the non-incentivized dimension.

It is not obvious ex ante whether tasks in a weatherization contract are characterized by complementarity or substitution. On the one hand, improvements in wall and attic insulation can increase returns to effort on air sealing. Improved supervision of a crew's air sealing work may also reduce the cost of supervising other aspects of the job. To the extent these kinds of complementarities exist, a piece-rate bonus on the blower door reading could increase effort not only on air sealing, but on other tasks. However, to the extent that contractors face constraints in their capacity to adjust the size of their crew, or time spent on each job, an incentive on air sealing may result in re-allocation from substitute tasks. Or it could be that certain retrofit tasks may not act as complements or substitutes in a contractor's cost function, such that an incentive payment on one type of retrofit would not affect effort or output on other retrofits. The evidence of proportionally larger net reductions in gas consumption than blower door readings reported in the prior section are consistent with complementarities and suggest a limited role for substitution from non-incentivized to incentivized tasks in the WAP. However, our experimental design and data collection allows for a more formal analysis of contractor responses and for more comprehensive evidence on substitution than is often possible in empirical work on incentive pay in a multi-task setting. We are able to directly test for the impacts of reallocation from: 1) control jobs and 2) treatment job tasks that do not affect the blower door reading.

Between-Job Reallocation Effects

We begin by considering reallocation of effort from control jobs that are completed simultaneously with a treated contract. We take advantage of the fact that batches of several jobs are typically assigned to a contractor at a time through a queue. Random assignment guarantees that for a CFM50 reduction for a given project i in month t the ratio of work orders in treatment versus in control assigned simultaneously will be exogenous. We define jobs as occurring simultaneously if there is any overlap between their completion windows. We define the completion window for a job as the period between the date of the pre-weatherization audit and the job's completion date.

To test for reallocation between jobs, we include controls for the numbers of simultaneously treated and control projects completed by the same contractor in our main regression specifications:

$$Y_{it} = \beta_0 + \beta_1 T_{it} + \beta_2 T_{it} \times Simultaneous\,Treat\,Jobs + \beta_3 T_{it} \times Simultaneous\,Control\,Jobs + \beta_4 Simultaneous\,Treat\,Jobs + \beta_5 Simultaneous\,Control\,Jobs + \mathbf{X_i'}\beta + \epsilon_{it}, \quad (3)$$

where Y_{it} is the CFM50 reduction for project i in month t, $Simultaneous\,Treat\,Jobs$ is the number of treated jobs (demeaned) simultaneously assigned with project i, and $Simulataneous\,Control\,Jobs$ is the number control jobs (demeaned) simultaneously assigned with project i. As in our main treatment effects estimation, the vector $\mathbf{X}_i$ contains month-year fixed effects for completion month, indicators for binned values of a home's pre-treatment blower door measurement, binned values for the retrofit spending, and home characteristics variables described in Table 1. We use the pooled version of treatment in the main text for ease of interpretation, given the large number of interaction terms, and report results including interactions of high and low treatment separately in Appendix Table J1.

Since we define simultaneous jobs using the demeaned number of treatment and control jobs, β_1 represents the effect of the incentive treatment for a job where the contractor has the mean number of simultaneous treatment and control jobs in the sample. The coefficients β_2 and β_3 estimate the differential effect of simultaneous treatment or control jobs on CFM50 reductions for treated jobs. The coefficients β_4 and β_5 estimate the effect of an additional simultaneous treatment or control job on CFM50 reductions for all jobs. If the coefficient on treatment (β_1) does not change across specifications that include or omit these controls, it indicates that spillovers to simultaneous jobs are not a significant biasing factor in the primary estimates reported in Table 2.

Table 5 reports estimates of the impacts of simultaneous jobs on CFM50 reductions. While we cannot rule out small spillovers in either direction given the point estimates and standard errors, we find no evidence that a contractor working on a treatment or a control job achieves a statistically different CFM50 reduction when the job is completed simultaneously with another control or treatment home. The point estimate of the treatment coefficient (β_1) with these controls is also consistent with estimates in Table 2, indicating that reallocation does not affect the magnitude of our treatment effects.

Table 6 reports analogous estimates of the impacts of simultaneous jobs on gas consumption. We estimate equation 2 with additional terms for post-weatherization-by-number of simultaneous treatment or control jobs and post-weatherization-by-treatment-by number of simultaneous treatment or control jobs. We again use demeaned counts of simultaneous jobs. Rather than additional treatment jobs inducing a substitution of effort from simultaneous jobs, we find some evidence of *larger* pre/post weatherization differences in control jobs when completed alongside additional simultaneous control jobs and *smaller* pre/post weatherization differences in control jobs when completed alongside additional simultaneous treatment jobs. However, these differences are small in magnitude (less than 10% of the pooled treatment effect) and given the random assignment of contract incentives, the expected impact of these equal and opposite effects on simultanously completed jobs equates to a statistical zero. We do not find any evidence of simultaneous jobs deferentially affecting treatment jobs. As with the blower door outcome, the estimated effects of treatment on gas consumption (β_1) are consistent with those in Table 4, indicating that spillover effects are not a significant biasing factor in our primary analysis.[21] Taken together, these results suggest that the presence of treatment jobs does not appear to create complementarities with or substitution from control jobs.

Further, the effects for treatment and control jobs appear to be stable across the 2-year study period, indicating that these patterns do not change as a function of experience with the bonus. In Appendix Tables K1 and K2, we examine heterogeneity in both treatment and control outcomes by the number of bonus jobs the contractor performs. The effects by experience are neither statistically nor economically significant, suggesting a limited role for learning-by-doing within the 2-year experiment.

Within-Job Reallocation Effects

Rather than shift effort between jobs, contractors may respond to incentives by allocating their effort differently *within* a given project when it is assigned to the performance pay treatment. We consider callbacks for deficiencies associated with "non-incentivized" tasks–any retrofit categories that are mechanical and do not impact the blower door

[21] In Appendix Tables J3 and J4 we report results on the impact of simultaneous treatment and control jobs on air sealing callbacks and do not find any evidence of spillovers from treatment to control jobs on these callback rates.

reading, such as blown insulation in the attic. Table 7 reports the results. The estimates in Panels A and B do not suggest any evidence of an effect of performance incentives on the quality of the work done on non-incentivized tasks. This indicates that substitution of effort from non-incentivized to incentivized tasks within jobs does not appear to be a significant concern in our setting. Rather, tasks such as attic insulation are likely independent from air sealing in a contractor's private cost function.

4.4 Misallocation Under Minimum Quality Standards

Many public programs adopt minimum quality standards or quotas using metrics such as "tasks performed" or "clients served" to incentivize worker effort (Hawkins, Bieretz, and Brown, 2019). To the extent there is variation in marginal costs across cases due to heterogeneity across recipients' circumstances or heterogeneity in worker ability, piece-rate bonuses have the potential to allocate effort more efficiently. To examine how this mechanism operates in our setting, we consider two testable hypotheses from the model in Appendix D: 1) higher-quality contractors will be more responsive to the intervention, given their lower marginal effort costs and 2) the variance in outcomes will be higher for treatment jobs than control jobs. Heterogeneity in the housing stock creates variation in the marginal cost of additional air sealing improvements such that under the piece-rate bonus, contractors–particularly those who are high quality–will go further on lower marginal cost jobs relative to higher marginal cost jobs. This is something that minimum quality standards do not encourage, demonstrating the efficiency advantage of piece-rate contracts.[22]

Our data agreement with the IHWAP creates a unique opportunity to identify higher-quality contractors at baseline by measuring their performance during the program year *prior to* the performance-pay intervention (program year 2017). Unlike many settings where estimating individual value added is complicated by negative assortative matching (e.g. between managers and stores or workers in hospitals), WAP jobs are ar-

[22]This prediction is in line with Lazear's (2000) canonical model, which predicts that workers will choose type-specific levels of output under piece rates, thereby increasing the variance in productivity. Piece-rate performance incentives could induce a more efficient allocation of effort than the baseline regime of minimum quality standards in the WAP, as all contractors (and especially high quality contractors) invest additional effort in lower marginal cost homes.

bitrarily assigned to contractors through a queue (Metcalfe, Sollaci, and Syverson, 2023). As demonstrated in Christensen et al. (2021), this allows us to separately identify worker skill from selection into jobs. We do this by estimating each contractor's mean effect on gas reductions on jobs in 2017, conditional on observable characteristics about the home and household and expenditures on retrofits performed. Mechanically, these are the estimated contractor fixed effects from a model that regresses house-specific gas savings on contractor fixed effects along with flexible controls for home and household characteristics, service utility, and expenditures on retrofits performed. We calculate house-specific savings in two steps. First, we estimate counterfactual consumption based on county, month, and year fixed effects along with flexible controls indicating bins of home and household characteristics. We then subtract observed consumption from this counterfactual to get house-month treatment effects (See Appendix L). Finally, we group the contractors into quintiles based on their mean reductions and define the top two quintiles as "high quality" contractors.

Table 8 reports estimates of treatment effects from a model that adds: 1) an indicator for the job being performed by a high-quality contractor and 2) an interaction between that indicator and treatment to equation 1. The results reveal significantly and substantially stronger responses to the bonus from the high quality group. In our sample, CFM50 reductions in homes with the performance bonus were more than twice as large when assigned to contractors in the high quality group as they were when assigned to their counterparts in the lower-quality group. These results are consistent with a model where higher ability contractors can achieve output at lower costs. Table 9 reports estimates of the differential treatment effects on gas consumption for high-quality contractors relative to lower-quality contractors. While these differences are not statistically significant in our sample, point estimates suggest stronger responses from performance incentives in the high-quality group, which is consistent with the findings on CFM50 reductions.

In Appendix J, we test whether the variance in both CFM50 and gas reductions are higher under piece-rate performance incentives (treatment) relative to minimum quality standards (control). In Table J5, we report the results from a ratio test for homogeneity of variances. The results indicate that the standard deviation is statistically significantly higher for homes assigned to treatment relative to control. This is consistent with the hypothesis that piece-rate performance incentives induce a more efficient allocation of effort than minimum quality standards because contractors invest additional effort on lower marginal cost homes in the former regime, but not in the latter. Both sets of hypotheses tested in this section indicate that piece-rate performance incentives can help address the misallocation of effort resulting from compensation for tasks performed and clients served subject to minimum quality standards, which are a feature of contract design in many public programs.

5 Returns from Energy Efficiency with Incentive Pay

We use the experimental results above to provide estimates of two distinct measures of the welfare impacts of the bonus payments. Equation 4 defines the more traditional net present value of social benefits calculation and Equation 5 defines the marginal value of public funds (MVPF) of the performance pay bonuses in the IHWAP using the framework proposed in Hendren and Sprung-Keyser (2020) and Finkelstein and Hendren (2020). As shown in recent work, these two measures can lead to different conclusions about optimal public spending on a given program (Garcia and Heckman, 2022; Hendren and Sprung-Keyser, 2022).[23] We find that their comparison yields an informative set of insights regarding spending on incentive-pay in an energy efficiency programs, particularly when considering the optimal level of bonus incentives.

Equation 4 defines the net present value of social benefits from the bonus payment, defined as the difference between the marginal benefit of public expenditure to the net marginal cost to the government:

[23] A key limitation of the NSB approach includes the typical assumption that a government has a fixed quantity of funds, making it difficult to compare the return to on an additional dollar of spending across different programs or alternative instruments such as subsidy levels (within a program) that may vary in size (Hendren and Sprung-Keyser, 2022). A key limitation of the MVPF approach includes the inability to draw conclusions about the optimal size of the government budget or the welfare effects of expanding the budget to fund a new program (Garcia and Heckman, 2022). The approaches also differ in how they address the distortionary cost of generating revenue by raising the linear income tax. We follow current practice and ignore that issue in the present analysis, allowing for direct comparability between the measures.

$$\text{NSB} = \sum_{t=1}^{T_i} \left[\frac{\hat{\beta}^e \times \text{social benefit}_{\text{elec},t}}{(1+r)^t} + \frac{\hat{\beta}^g \times \text{social benefit}_{\text{gas},t}}{(1+r)^t} \right] + PS - \text{Bonus Cost} \quad (4)$$

The marginal value of public funds (MVPF) is defined as the ratio of the marginal benefit of public expenditure to the net marginal cost to the government:

$$\text{MVPF} = \frac{\sum_{t=1}^{T} \left[\frac{\hat{\beta}^e \times \text{social benefit}_{\text{elec}}}{(1+r)^t} + \frac{\hat{\beta}^g \times \text{social benefit}_{\text{gas}}}{(1+r)^t} \right] + PS}{\text{Bonus Cost}} \quad (5)$$

where $\hat{\beta}^e$ and $\hat{\beta}^g$ are the estimated annual electricity and natural gas savings. Given that Table I1 indicates that the average effect of the bonus payments on electricity consumption is not different from 0, we assume $\hat{\beta}^e = 0$. We compute annual gas savings $\hat{\beta}^g$ by multiplying the monthly treatment effect estimates in column 4 in Table 4 by 12.

We convert the energy savings ($\hat{\beta}^g$) into monetary benefits using the social benefits of avoided energy consumption, including avoided generation, transmission and distribution costs, as well as benefits from reduced GHG and local air pollution, indicated by $\text{cost}_{\text{elec}}$ and cost_{gas} (Davis and Muehlegger, 2010; Borenstein and Bushnell, 2022).[24] We use a range of estimates of the social cost of carbon (SCC) to account for the benefits from avoided GhG emissions, including estimates of \$151 and \$185 per ton from recent studies (Carleton and Greenstone, 2022; Rennert et al., 2022). Since the EPA has not yet adopted their recently proposed value of \$190 per ton and most prior work on the cost-effectiveness of WAP and other energy efficiency programs has relied upon older estimates of \$40-60 per ton[25], we include the previously EPA-approved estimate of \$51 per ton to illustrate the effects of updated SCC estimates on the cost-effectiveness of investments in energy

[24] For electricity, we estimate the difference between retail prices and social marginal costs for the areas of the state which we analyze using data provided by Borenstein and Bushnell (2022). We then apply that difference to the month-of-year averages of residential electricity prices for our study period. The resulting social marginal benefits of reductions from all retrofits are: \$8.51 per MMBtu for natural gas and \$37.95 per MMBtu for electricity. We calculate marginal private costs of natural gas using average citygate prices in Illinois during the 2017-2018 study period. We account for expected price escalation of natural gas and electricity using the energy price indices and projections from the DOE that are used by OMB for Census Region 2 (Illinois).

[25] (Christensen et al., 2021; Fowlie, Greenstone, and Wolfram, 2018; Allcott and Greenstone, 2017; Zivin and Novan, 2016)

efficiency.

T represents the expected lifetime of the retrofits. Baseline estimates are computed using the cost-weighted average lifetime of the 34.5 years for the retrofits performed in the IHWAP program (Christensen et al., 2021).[26] Benefits are discounted using the 2018 DOE-recommended discount rate (r) of 2%. We examine the sensitivity of estimates to alternate lifespan assumptions in Appendix N.

PS is the producer surplus associated with the incentives, which we calculate as the difference between the bonus payment and contractors' supply curve for CFM50 reductions. As shown in Appendix M, we compute a linear approximation of these values using the treatment effect estimates from column 4 of Table 2, assuming that supply curves are piece-wise linear from the CFM50 target to the mean reduction at \$0.40 and between the mean reductions at \$0.40 and \$1.00.

We assume that there are no non-energy benefits to the household from weatherization, such as health impacts, which could increase true benefits relative to our estimates. Program Cost reflects the cost of baseline retrofits, including the bonus incentive for the average contract in treatment. We provide estimates using the high and low incentive treatments. We assume that this reflects the full effects of the performance pay intervention on the government budget, as it would not meaningfully affect any other fiscal outlays.[27] We also assume that the effect of the transfer to program recipients will not result in meaningful increases in tax revenue through consumption on other goods. Either of these effects would make our estimates a lower bound on the true MVPF from the intervention.

[26] Lifespans for individual retrofits range from from 5 years for fluorescent lamps to 25 years for insulation according to expected lifespans for individual upgrades from internal WAP documentation. However, recent engineering literature suggests that inert materials in air sealing and insulation retrofits should have substantially longer lifespans, such as 50 years for cellulose fiber (ISOCELL GmbH, 2014), 35-50 years for expanded polystyrene (EPS) (EUMEPS, 2017; IVH, 2015), or the full building lifetime for extruded polystyrene (XPS) (50-150 years) (EXIBA, 2019). Accounting for the longer lifespans associated with inert materials results in a 34.5 average lifespan for the IHWAP program (Christensen et al., 2021). Given that air sealing retrofits are the target of the performance incentives in this program, we use this lifespan as the baseline scenario in our cost-effectiveness calculations.

[27] Unlike the EITC and other programs that affect tax revenue as discussed in (Finkelstein and Hendren, 2020), any fiscal externalities from performance pay in the WAP would likely be small in magnitude.

Returns from Performance Incentives

Panel A of Table 10 reports estimates of returns from the performance incentive using the NSB from equation. 4 and the MVPF from equation. 5. Column 1 reports the average payment for the high and low payment treatment jobs. Column 2 reports estimates of producer surplus (for IHWAP contractors) for high ($1.00/CFM50) and low ($0.40/CFM50) performance incentives as described above. The resulting estimates are $13/home in producer surplus for contractors in the low treatment and $99/home in the high treatment.

Columns 3-8 report estimates of (a) the social net benefits and (b) the marginal value of public funds from expenditures on performance incentives and the reductions in energy use that result. The incentive treatment was remarkably cost effective under the full range of SCC estimates, ranging from $773 to $1,644 in social net benefits for the low treatment and from $880 to $1,872 for the high treatment. The equivalent MVPF estimates range from $6.89 to $14.53 for the low bonus level and from $3.46 to $6.96 for the high bonus level. This comparison of the two welfare measures offers important policy insights. The social net benefits from the high bonus incentive is slightly higher on a per home basis, indicating that program expansion by using larger bonus payments ($1.00 per CFM50) would yield additional surplus relative to a program with the equivalent number of contracts at the lower bonus level. However, the MVPF is much higher at the lower bonus level ($0.40 per CFM50), suggesting that a smaller incentive level may be advantageous when considering trade-offs between allocating larger incentive payments to a smaller pool of contracts versus smaller incentive payments to a larger pool of contracts.[28]

Effects of Incentives on Returns to Weatherization Tasks

For the sample program years in IHWAP, the estimates of social returns from investments in IHWAP retrofits are highly sensitive to assumptions about the social cost of

[28]These measures do not account for the distortionary cost associated with raising revenue from a linear income tax, which under standard assumptions would reduce the optimal level of total expenditure in the program. Feldstein (1999) estimates a greater than $2 deadweight loss associated with increases existing tax rates, though estimates sometimes used in empirical welfare analysis vary widely.

carbon. With the lowest SCC estimate of $51, which has generally been used to estimate the cost-effectiveness of investments in energy efficiency programs, the baseline program yields $-2,699 in net benefits per home and a MVPF of $0.72. This increases to $-488 per home and a MVPF of $0.95 using the SCC estimate of $125 and to $1,306 and a MVPF of $1.14 using the SCC estimate of $185.[29] In rows 2 and 3 of Panel B, we assume these same returns to spending to estimate the benefits of spending on air sealing retrofits and the broader category of incentivized retrofits targeted by the intervention.[30]

What is the effect of performance pay on the returns from air sealing measures completed in a home? To answer this question, we compare the estimates of benefits from air sealing retrofits in control (Panel B) to the benefits from air sealing retrofits with performance bonuses. To recover the latter estimates, we combine the benefits and costs from baseline air sealing (Panel B) with the benefits and costs from performance bonuses on air sealing (Panel A). We report the results of this exercise in Panel C. We find that the bonus treatment has a large effect on both the low and high incentive levels, increasing the net benefits to positive irrespective of the assumed SCC and increasing the MVPF from baseline air sealing retrofits by 76-208%. In the high treatment group, MVPF increases from 0.95 to over 1.84 using the more conservative of the two recent SCC estimates=$125 or from 1.14 to 2.30 using the higher estimate of SCC=$185.

The set of calculations in Panel D compares the estimates of the MVPF from the broader set of tasks that may have been affected through complementarity with air sealing retrofits in achieving CFM50 reductions, including: foundation, duct repair, and doors and windows. We compare the social net benefits from this set of "All Incentivized" tasks in control (Panel B) to their benefits in a setting with performance bonuses. We find that the bonus treatment also has an important effect on this larger category of expenditures, increasing the MVPF from 0.95 to 1.49 using the more conservative of the two recent estimates of SCC=$125 or from 1.14 to 1.85 using the higher estimate of SCC=$185.

[29] In interpreting this result, note that returns per dollar spent in the baseline IHWAP are also sensitive to the introduction of braided funding wherein some measures were performed to help households irrespective of SIR. For example, in the three years before it was introduced, NPBs in IHWAP ranged between $616 and $736 2021 USD (Appendix Table C2).

[30] Since we estimate the net benefits of weatherization for each home, we cannot disentangle the net benefits of air sealing from other retrofits done in each home.

Effects of Incentives on Overall Returns to WAP Investments

While the incentive-based pay intervention studied in the current paper shifted incentives for a fairly narrow set of tasks in the average IHWAP contract, an additional policy-relevant question concerns the effect of the bonus payments for air sealing on the social net benefits from investments in the IHWAP program as a whole (See Panel E). Similar to the approach used to recover estimates in Panel C and D, we combine the benefits and costs from baseline retrofit tasks (Panel B) with the benefits and costs from performance bonuses on air sealing (Panel A).

The impact of air sealing bonus on overall program cost-effectiveness is substantial. Using the more conservative of the two recent SCC estimates (SCC=$125) the incentive payments increase the social net benefits from home weatherization more than two-fold from net negative ($-488) to net positive ($652). Using the higher of the two recent SCC estimates of $185, the incentive payments in both low and high bonus regimes also result in a more than doubling of social net benefits. Across both payment levels and irrespective of assumptions about SCC, we find that the incentive pay intervention increases the overall MVPF of the IHWAP program by 10-13%. Using a SCC of $125, the incentive payments increase the MVPF from 0.95 to 1.07. Any differences in the returns from low versus high incentive payments becomes less economically meaningful when considering the social benefits from spending on the program as a whole.

As illustrated in Panel B, treated tasks represent a modest fraction of total average home expenditures – 12% for air sealing tasks and 21% for air sealing tasks plus those that could be affected through compelementarity. Even when applied to this relatively small fraction of contracted expenditures, performance incentives have a meaningful impact on the overall returns to spending in the IHWAP program. This suggests that the application of performance incentives to more tasks that could be similarly incentivized in the program could be substantial.

6 Conclusion

As governments increase their reliance on social service providers and contract work to provide key public goods, some have called for the use of performance incentives to better align contracts with measurable outcomes that directly relate to welfare-relevant program/policy objectives. This paper presents findings form a 2-year field experiment on the impacts of piece-rate performance incentives in the Weatherization Assistance Program. We find that these performance incentives generate significant increases in energy savings, reduce the probability of a reported deficiency in a contractor's air sealing work, and increase the social net benefits from IHWAP more than two-fold. Expenditures on performance incentives are highly cost-effective, even when they take the form of bonuses paid on top of standard payments for air sealing tasks in the program.

We test several hypotheses regarding the behavioral mechanisms underlying these effects. We find evidence of disproportionate increases in air sealing outcomes among contractors who were performing at a high level at baseline, suggesting that producers respond according to (lower) expected marginal costs. We do not find any evidence that performance incentives on air sealing (CFM50) outcomes lead to increases in reported deficiencies on non-incentivized tasks or compromise the energy efficiency outcomes on non-incentivized projects that are completed the same time as incentivized projects.

These results shed new light on the mechanisms underlying performance pay and their potential impacts in a nation-wide social welfare program. They also have implications for the Weatherization Assistance Program and other energy efficiency programs, where increases in cost-effectiveness could have a critical impact on public investments in climate policy over the next 2 decades. We note that there is a strong precedent for the use of performance incentives in the WAP – the Cook County (CEDA) program in the IHWAP adopted performance pay contracts for air sealing in 2016. While there has been no formal evaluation of the success of that intervention in the CEDA program, our experimental results provide evidence to suggest that it may have important impacts on the cost-effectiveness of CEDA projects and may worth considering at scale.

Figures

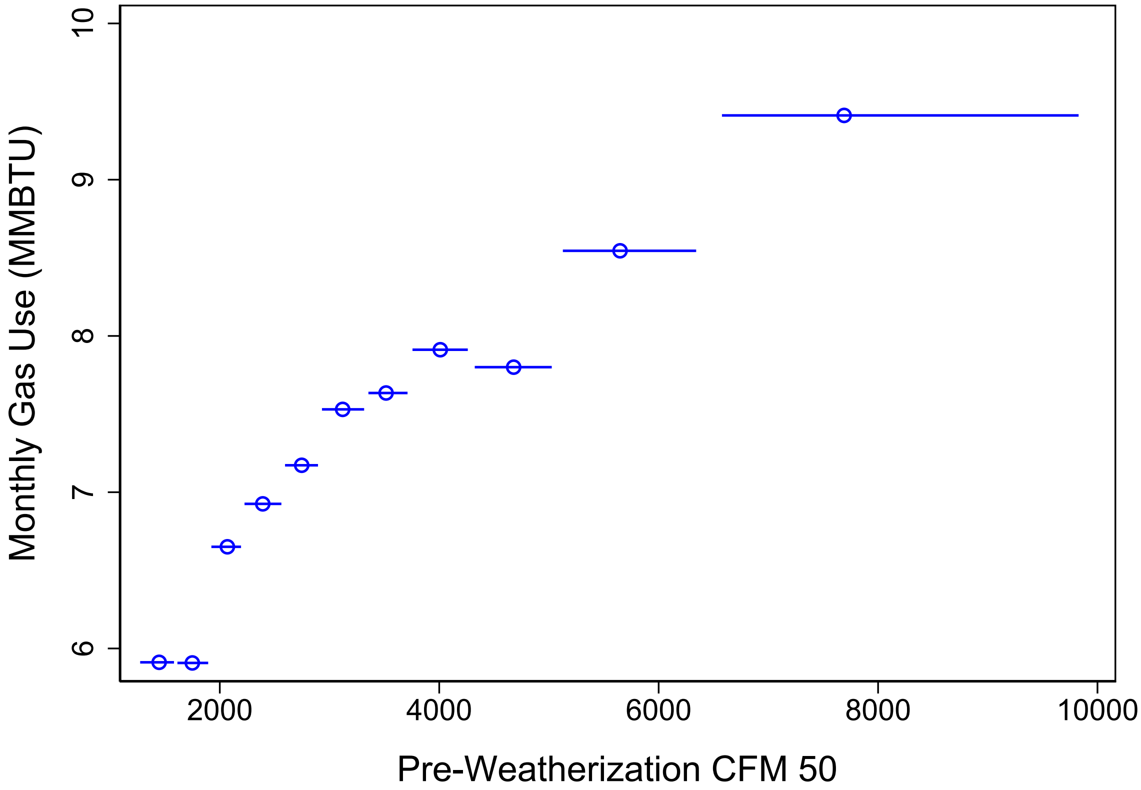


Figure 1: Correlation Between Energy Consumption and CFM Pre-Weatherization

Notes: This figure is a binned scatter plot of the relationship between residual variation in gas consumption and the pre-weatherization blower door reading after controlling for year-month fixed effects (Cattaneo et al., 2019a; Cattaneo et al., 2019b). For the purposes of scaling, the mean of each variable is added back to the residuals.

Tables

Table 1: Balance Tests

	Control ITT	Low ITT	High ITT	T-test Difference		
	(1)	(2)	(3)	(1)-(2)	(1)-(3)	(2)-(3)
Pre Blower Door (CFM)	3597.431	3853.595	3597.140	-256.164**	0.291	256.455**
	(60.812)	(92.208)	(88.859)			
Stories	1.331	1.383	1.319	-0.052*	0.011	0.064*
	(0.016)	(0.025)	(0.023)			
Square Feet	1462.424	1462.318	1424.125	0.106	38.299	38.193
	(22.588)	(28.636)	(32.664)			
Occupants	2.338	2.336	2.400	0.002	-0.062	-0.064
	(0.058)	(0.081)	(0.087)			
Bedrooms	2.830	2.830	2.844	0.000	-0.014	-0.014
	(0.033)	(0.044)	(0.044)			
Year Built	1952	1948	1951	3.31**	0.18	-3.14*
	(0.952)	(1.325)	(1.341)			
General Expenditure	164.613	175.163	140.404	-10.550	24.209	34.759
	(17.211)	(24.242)	(22.167)			
Furnace Expenditure	2250.197	2199.479	2164.936	50.718	85.261	34.543
	(54.683)	(86.941)	(78.163)			
Foundation Expenditure	706.431	798.493	722.235	-92.062	-15.804	76.258
	(30.221)	(52.141)	(46.841)			
Door Expenditure	99.135	102.389	111.526	-3.254	-12.392	-9.138
	(9.807)	(14.961)	(15.227)			
Baseload Expenditure	504.131	540.622	489.527	-36.491	14.604	51.095
	(17.069)	(23.871)	(23.540)			
Attic Expenditure	1268.694	1244.520	1236.052	24.174	32.642	8.468
	(33.316)	(47.627)	(48.170)			
Air Sealing Expenditure	1081.983	1131.378	1080.131	-49.395	1.852	51.247
	(21.424)	(33.098)	(31.072)			
Air Conditioning Expenditure	1875.025	1649.447	1734.628	225.578***	140.397*	-85.181
	(46.440)	(66.609)	(67.788)			
Water Heater Expenditure	886.323	892.574	899.538	-6.251	-13.215	-6.964
	(33.504)	(48.931)	(50.194)			
Wall Insulation Expenditure	393.884	406.441	299.889	-12.557	93.995**	106.552*
	(28.174)	(44.599)	(34.804)			
Window Expenditure	68.892	53.927	58.926	14.965	9.967	-4.999
	(10.721)	(15.821)	(18.192)			
Total Observations	867	432	399			
Observations matched with site details	794	393	365			

Notes: The value displayed for t-tests are the differences in the means across the groups. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level. "Site Details" include stories, square feet, occupants, bedrooms, and decade built.

Table 2: Effects of Bonus Treatments on Building Envelope Tightness (CFM50)

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-64.09*	-73.97**	-75.96**	-88.67***
	(32.88)	(31.96)	(32.36)	(31.48)
Panel B: Effect by Treatment Group				
Low Treat	-57.25	-58.58	-54.25	-66.17*
	(40.23)	(39.41)	(39.67)	(39.08)
High Treat	-71.49*	-90.26**	-99.91**	-113.8***
	(40.49)	(39.43)	(39.98)	(39.06)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1698	1697	1697	1601
Adjusted R^2	-0.002	-0.034	-0.051	-0.082
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 3: Effects of Bonus Treatments on Callback Rate: Air Leakage

Air Leakage Callback	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-0.0325*	-0.0358**	-0.0265	-0.0295*
	(0.0169)	(0.0167)	(0.0173)	(0.0176)
Panel B: Effect by Treatment Group				
Low Treat	-0.0201	-0.0222	-0.0161	-0.0195
	(0.0214)	(0.0212)	(0.0214)	(0.0216)
High Treat	-0.0455**	-0.0496***	-0.0374*	-0.0402**
	(0.0192)	(0.0189)	(0.0196)	(0.0203)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	-0.006	-0.050	-0.072	-0.117
Control Group Dep. Variable Mean	0.078	0.078	0.078	0.078

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to air sealing. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 4: Effects of Bonus Treatments on Gas Usage (MMBtu)

Gas MMBtu	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Weatherization × Treatment	-0.285**	-0.347***	-0.359***	-0.376***
	(0.117)	(0.114)	(0.114)	(0.115)
Panel B: Effect by Treatment Group				
Weatherization × Low Treat	-0.327**	-0.353***	-0.345**	-0.353***
	(0.141)	(0.137)	(0.136)	(0.136)
Weatherization × High Treat	-0.239	-0.340**	-0.375**	-0.402***
	(0.149)	(0.146)	(0.147)	(0.151)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1216	1216	1216	1164
Observations	66423	66423	66423	63676
Adjusted R^2	0.001	0.007	0.006	0.006
Baseline Weatherization Reduction	-1.582***	-1.582***	-1.582***	-1.623***
	(0.101)	(0.101)	(0.101)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.283	7.283	7.283	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 5: Effects on Building Envelope Tightness (CFM 50): Simultaneous Jobs Within Contractor

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
Treat	-64.41*	-80.14**	-79.34**	-88.72***
	(33.38)	(32.39)	(33.01)	(32.14)
Treat × Simultaneous Treat Jobs	4.242	6.925	6.278	3.515
	(4.713)	(4.618)	(4.620)	(4.520)
Treat × Simultaneous Control Jobs	-6.822	-7.450	-7.230	-4.196
	(5.111)	(4.872)	(4.850)	(4.819)
Simultaneous Treat Jobs	-4.356	-5.187	-3.440	0.0841
	(3.765)	(3.864)	(4.210)	(3.951)
Simultaneous Control Jobs	3.973	3.704	1.812	-1.229
	(4.326)	(4.165)	(4.576)	(4.389)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1697	1696	1696	1600
Adjusted R^2	-0.002	-0.036	-0.051	-0.082
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 6: Effects on Gas Usage (MMBtu): Simultaneous Jobs Within Contractor

Gas MMBtu	(1)	(2)	(3)	(4)
Weatherization × Treatment	-0.283**	-0.357***	-0.388***	-0.415***
	(0.119)	(0.116)	(0.119)	(0.120)
Weatherization × Treat × Simultaneous Treat Jobs	0.0171	0.0194	0.0189	0.0216
	(0.0172)	(0.0162)	(0.0164)	(0.0164)
Weatherization × Treat × Simultaneous Control Jobs	-0.0208	-0.0202	-0.0204	-0.0238
	(0.0188)	(0.0174)	(0.0178)	(0.0178)
Weatherization × Simultaneous Treat Jobs	-0.0252**	-0.0243**	-0.0342**	-0.0337**
	(0.0114)	(0.0110)	(0.0133)	(0.0133)
Weatherization × Simultaneous Control Jobs	0.0271**	0.0259**	0.0366**	0.0388**
	(0.0133)	(0.0125)	(0.0150)	(0.0151)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1215	1215	1215	1163
Observations	66372	66372	66372	63625
Adjusted R^2	0.001	0.007	0.005	0.006
Baseline Weatherization Reduction	-1.607***	-1.607***	-1.607***	-1.623***
	(0.0974)	(0.0974)	(0.0974)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.264	7.264	7.264	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Weatherization and Weatherization×Treat are each interacted with the demeaned number of simultaneous treatment or control jobs the contractor worked on. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 7: Effects on Callback Rate: Non-Incentivized Retrofits

Non-Building Envelope Callback	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	0.0219	0.0221	0.0151	0.0174
	(0.0141)	(0.0144)	(0.0149)	(0.0152)
Panel B: Effect by Treatment Group				
Low Treat	0.0227	0.0199	0.0131	0.0150
	(0.0178)	(0.0178)	(0.0186)	(0.0195)
High Treat	0.0212	0.0245	0.0172	0.0199
	(0.0179)	(0.0185)	(0.0186)	(0.0186)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	-0.002	-0.049	-0.072	-0.118
Control Group Dep. Variable Mean	0.051	0.051	0.051	0.053

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to retrofits that are not incentivized by the bonus payments. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 8: Effects of Bonus Treatments on Building Envelope Tightness (CFM 50) by Contractor Quality

CFM60 (Post - Pre)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
High Quality	-66.93	-31.57	-29.63	-50.90
	(44.02)	(45.35)	(45.54)	(44.15)
ITT	-38.46	-44.19	-44.57	-58.33*
	(33.90)	(33.01)	(33.65)	(32.86)
ITT × High Quality	-120.9*	-120.7*	-125.9*	-118.0*
	(69.74)	(69.67)	(69.39)	(70.56)
Panel B: Effect by Treatment Group				
High Quality	-66.99	-32.10	-30.14	-50.97
	(44.05)	(45.43)	(45.61)	(44.25)
Low ITT	-41.53	-41.19	-33.66	-43.00
	(42.01)	(41.30)	(41.61)	(40.70)
High ITT	-35.21	-47.60	-57.12	-75.86*
	(40.08)	(38.99)	(39.93)	(39.42)
Low ITT × High Quality	-64.24	-58.68	-79.19	-90.82
	(81.62)	(81.46)	(81.92)	(86.25)
High ITT × High Quality	-184.6*	-189.0**	-177.3*	-147.7
	(95.25)	(93.53)	(92.83)	(92.95)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1670	1669	1669	1579
Adjusted R^2	0.743	0.766	0.766	0.792
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1557.014	-1557.014	-1557.014	-1552.336

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. High Quality indicates that the contractor that performed the work was in the upper 2 quintiles of performance in the program year that preceded the intervention (2017). Performance was measured as mean gas reductions associated with each contractor, conditional on the measures performed and home and household characteristics. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 9: Effects of Bonus Treatments on Gas Usage (MMBtu) by Contractor Quality

Gas MMBtu	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Weatherization × Treatment	-0.266**	-0.310**	-0.322**	-0.351***
	(0.129)	(0.125)	(0.126)	(0.127)
Weatherization × Treat × High Quality	-0.117	-0.221	-0.232	-0.178
	(0.294)	(0.284)	(0.283)	(0.292)
Weatherization × High Quality	-0.0329	0.126	0.125	0.0489
	(0.198)	(0.193)	(0.191)	(0.192)
Panel B: Effect by Treatment Group				
Weatherization × Low Treat	-0.317**	-0.324**	-0.317**	-0.333**
	(0.159)	(0.153)	(0.152)	(0.152)
Weatherization × High Treat	-0.212	-0.294*	-0.328**	-0.372**
	(0.161)	(0.159)	(0.159)	(0.164)
Weatherization × High Treat × High Quality	-0.169	-0.277	-0.300	-0.220
	(0.412)	(0.395)	(0.399)	(0.417)
Weatherization × Low Treat × High Quality	-0.0694	-0.172	-0.172	-0.143
	(0.320)	(0.315)	(0.313)	(0.319)
Weatherization × High Quality	-0.0326	0.126	0.126	0.0501
	(0.198)	(0.193)	(0.191)	(0.192)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1204	1204	1204	1154
Observations	65905	65905	65905	63254
Adjusted R^2	0.001	0.007	0.005	0.006
Baseline Weatherization Reduction	-1.582***	-1.582***	-1.582***	-1.623***
	(0.101)	(0.101)	(0.101)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.283	7.283	7.283	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. High Quality indicates that the contractor that performed the work was in the upper 2 quintiles of performance in the program year that preceded the intervention (2017). Performance was measured as mean gas reductions associated with each contractor, conditional on the measures performed and home and household characteristics. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table 10: Effects of Performance Incentives on Social Welfare

			SCC = $51		SCC = $125		SCC = $185	
	Cost	Producer Surplus	Net Benefits	MVPF	Net Benefits	MVPF	Net Benefits	MVPF
Panel A. Performance Incentive								
Low Treat	$114	$13	$773	$6.89	$1,254	$11.11	$1,644	$14.53
High Treat	$283	$99	$880	$3.46	$1,428	$5.39	$1,872	$6.96
Panel B: Baseline WAP								
Baseline: All Retrofits	$9,655	.	$-2,699	$0.72	$-488	$0.95	$1,306	$1.14
Baseline: Air Sealing	$1,128	.	$-317	$0.72	$-57	$0.95	$153	$1.14
Baseline: All Incentivized	$2,037	.	$-572	$0.72	$-103	$0.95	$277	$1.14
Panel C: Baseline Air Sealing + Incentive								
Baseline Air Sealing + Low Treat	$1,242	$13	$355	$1.29	$1,096	$1.88	$1,695	$2.37
Baseline Air Sealing + High Treat	$1,411	$99	$379	$1.27	$1,186	$1.84	$1,841	$2.30
Panel D: Baseline All Incentivized + Incentive								
Baseline All Incentivized + Low Treat	$2,151	$13	$100	$1.04	$1,049	$1.49	$1,819	$1.85
Baseline All Incentivized + High Treat	$2,320	$99	$124	$1.05	$1,140	$1.49	$1,964	$1.85
Panel E: Baseline All Retrofits + Incentive								
Baseline All Retrofits + Low Treat	$9,769	$13	$-2,040	$0.79	$652	$1.07	$2,836	$1.29
Baseline All Retrofits + High Treat	$9,938	$99	$-2,102	$0.79	$657	$1.07	$2,895	$1.29

Notes: Panel A reports estimates of the social net benefits and MVPF for expenditures on performance incentives on air sealing retrofits using estimates of treatment effects from Table 4. Panel B reports estimates of social net benefits and MVPF for all baseline retrofits and baseline air sealing retrofits. Estimates of benefits from baseline air sealing retrofits are assumed to be proportional to expenditures on air sealing given control mean weatherization effect. Panels C-D report estimates of social net benefits and MVPF of combining the baseline air sealing investments (Panel C) or all incentivized investments (Panel D) with performance incentives. Panel E reports estimates of social net benefits and MVPF for all baseline retrofits combined with performance incentives. Net present energy benefits use gas and electricity prices per MMBTU for 2017. Emissions factors were obtained from EPA (1998). Data provided by Borenstein and Bushnell (2018) is used to estimate the difference between retail residential electricity prices and social marginal costs for the study region. The resulting social marginal benefits of reductions from all retrofits are: $8.51 per MMBtu for natural gas and $37.95 per MMBtu for electricity. Retrofit lifespans are based on the weighted average for of retrofit-specific lifespans in the average home in the sample: 19.25 years when assuming a 20-year lifespan for long-lived insulation materials vs. 34.5 years when assuming a 150-year lifespan for long-lived air-sealing materials.

References

Allcott, Hunt and Michael Greenstone (2017). "Measuring the Welfare Effects of Residential Energy Efficiency Programs." *NBER Working Paper* 23386.

Athey, Susan and Guido W Imbens (2022). "Design-based analysis in difference-in-differences settings with staggered adoption". *Journal of Econometrics* 226(1), pp. 62–79.

Aucejo, Esteban, Teresa Romano, and Eric S Taylor (2019). "Does Evaluation Distort Teacher Effort and Decisions? Quasi-Experimental Evidence from a Policy of Retesting Students." *Centre for Economic Performance* No. 1612.

Bandiera, Oriana, Michael Carlos Best, Adnan Qadir Khan, and Andrea Prat (2021). "The Allocation of Authority in Organizations: A Field Experiment with Bureaucrats." *The Quarterly Journal of Economics* 136(4), pp. 2195–2242.

Barlevy, Gadi and Derek Neal (2012). "Pay for Percentile." *American Economic Review* 102(5), pp. 1805–31.

Berry, Linda G. and Michael B. Gettings (1998). "Realization Rates of the National Energy Audit." *Thermal Performance of the Exterior Envelopes of Buildings VI Conference*. URL: https://weatherization.ornl.gov/wp-content/uploads/pdf/1996_2000/RealizationRatesoftheNationalEnergyAudit.pdf.

Bertrand, Marianne, Robin Burgess, Arunish Chawla, and Guo Xu (2020). "The Glittering Prizes: Career Incentives and Bureaucrat Performance." *The Review of Economic Studies* 87(2), pp. 626–655.

Biasi, Barbara (2021). "The Labor Market for Teachers Under Different Pay Schemes." *American Economic Journal: Economic Policy* 13(3), pp. 63–102.

Blonz, Joshua (forthcoming). "The Welfare Costs of Misaligned Incentives: Energy Inefficiency and the Principal-Agent Problem." *American Economic Journal: Economic Policy*.

Bloom, Nicholas and John Van Reenen (2011). "Human Resource Management and Productivity". *Handbook of Labor Economics*. Vol. 4. Elsevier, pp. 1697–1767.

Borenstein, Severin and James B Bushnell (2022). “Do Two Electricity Pricing Wrongs Make a Right? Cost Recovery, Externalities, and Efficiency.” *American Economic Journal: Economic Policy* 14(4), pp. 80–110.

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess (2021). “Revisiting Event Study Designs: Robust and Efficient Estimation”. *Working Paper.*

Bruegge, Chris, Tatyana Deryugina, and Erica Myers (2019). “The Distributional Effects of Building Energy Codes.” *Journal of the Association of Environmental and Resource Economists* 6(S1), S95–S127.

Burgess, Simon, Carol Propper, Marisa Ratto, Emma Tominey, et al. (2017). “Incentives in the Public Sector: Evidence from a Government Agency”. *Economic Journal* 127(605), pp. 117–141.

California Air Resources Board (2017). *California's 2017 Climate Change Scoping Plan.* [Online; accessed in 2020]. URL: https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

Callaway, Brantly and Pedro HC Sant'Anna (2021). “Difference-in-differences with multiple time periods”. *Journal of Econometrics* 225(2), pp. 200–230.

Carleton, Tamma and Michael Greenstone (2022). “A Guide to Updating the US Government's Social Cost of Carbon”. *Review of Environmental Economics and Policy* 16(2), pp. 196–218.

Cattaneo, Matias D, Richard K Crump, Max H Farrell, and Yingjie Feng (2019a). “Binscatter regressions”. *arXiv preprint arXiv:1902.09615.*

Cattaneo, Matias D, Richard K Crump, Max H Farrell, and Yingjie Feng (2019b). “On binscatter”. *arXiv preprint arXiv:1902.09608.*

Christensen, Peter, Paul Francisco, Erica Myers, and Mateus Souza (2021). “Decomposing the Wedge Between Projected and Realized Returns in Energy Efficiency Programs.” *The Review of Economics and Statistics*, pp. 1–46.

Dalhoff, Gregory K. (1997). “An Evaluation of the Performance of the NEAT Audit for the Iowa Low-Income Weatherization Program”. *1997 Energy Evaluation Conference.*

URL: https://weatherization.ornl.gov/wp-content/uploads/pdf/1996_2000/IEPECDalhoffIowaNEATEvaluation.pdf.

Davis, Lucas W, Sebastian Martinez, and Bibiana Taboada (2020). "How Effective is Energy-Efficient Housing? Evidence from a Field Trial in Mexico." *Journal of Development Economics* 143, p. 102390.

Davis, Lucas W., Alan Fuchs, and Paul Gertler (2014). "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico." *American Economic Journal: Economic Policy* 6(4), pp. 207–38.

Davis, Lucas W. and Erich Muehlegger (2010). "Do Americans Consume Too Little Natural Gas? An Empirical Test of Marginal Cost Pricing." *The RAND Journal of Economics* 41(4), pp. 791–810. URL: http://www.jstor.org/stable/25746054.

de Chaisemartin, Clément and Xavier D'Haultfœuille (2020). "Two-Way Fixed Effects Estimators with Heterogeneous Treatment Effects". *American Economic Review* 110(9), pp. 2964–96. URL: https://www.aeaweb.org/articles?id=10.1257/aer.20181169.

Dohmen, Thomas and Armin Falk (2011). "Performance Pay and Multidimensional Sorting: Productivity, Preferences, and Gender." *American Economic Review* 101(2), pp. 556–90.

European Extruded Polystyrene Insulation Board Association (2019). "Extruded Polystyrene (XPS) Foam Insulation with halogen free blowing agent". *Institut Bauen und Umwelt e.V. (IBU)*. URL: https://ibu-epd.com/en/published-epds/.

European Manufacturers of Expanded Polystyrene (2017). "Expanded Polystyrene (EPS) Foam Insulation (shape moulded, density 25 kg/m^3)". *Institut Bauen und Umwelt e.V. (IBU)*. URL: https://eumeps.construction/content/8-downloads/2-epds-for-eps/expanded-polystyrene-eps-foam-insulation-shape-moulded-density-25-kgm.pdf.

European Parliament (2012). "Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency". URL: http://data.europa.eu/eli/dir/2012/27/oj.

Executive Office of Energy and Environmental Affairs (2018). *Massachusetts Global Warming Solutions Act: 10-Year Progress Report*. [Online; accessed in 2020]. URL: https://www.mass.gov/doc/gwsa-10-year-progress-report/download.

Feldstein, Martin (1999). "Tax Avoidance and the Deadweight Loss of the Income Tax". *Review of Economics and Statistics* 81(4), pp. 674–680.

Finkelstein, Amy and Nathaniel Hendren (2020). "Welfare Analysis Meets Causal Inference." *Journal of Economic Perspectives* 34(4), pp. 146–67.

Fowlie, Meredith, Michael Greenstone, and Catherine Wolfram (2018). "Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program". *The Quarterly Journal of Economics* 133(3), pp. 1597–1644.

Franceschelli, Ignacio, Sebastian Galiani, and Eduardo Gulmez (2010). "Performance Pay and Productivity of Low-and High-Ability Workers." *Labour Economics* 17(2), pp. 317–322.

Frederiksen, Anders, Daniel Baltzer Schjødt Hansen, and Colleen Flaherty Manchester (2022). "Does Group-Based Incentive Pay Lead To Higher Productivity? Evidence from a Complex and Interdependent Industrial Production Process."

Friebel, Guido, Matthias Heinz, Miriam Krueger, and Nikolay Zubanov (2017). "Team Incentives and Performance: Evidence from a Retail Chain". *American Economic Review* 107(8), pp. 2168–2203.

Gaduh, Arya, Menno Pradhan, Jan Priebe, and Dewi Susanti (2021). "Scores, Camera, Action." Policy Research Working Paper 9748.

Garcia, Jorge Luis and James J Heckman (2022). *On Criteria for Evaluating Social Programs*. NBER Working Paper 30005.

Gillingham, Kenneth and James H Stock (2018). "The Cost of Reducing Greenhouse Gas Emissions." *Journal of Economic Perspectives* 32(4), pp. 53–72.

Giraudet, Louis-Gaëtan, Sébastien Houde, and Joseph Maher (2018). "Moral Hazard and the Energy Efficiency Gap: Theory and Evidence." *Journal of the Association of Environmental and Resource Economists* 5(4), pp. 755–790.

Gittleman, Maury and Brooks Pierce (2013). "How Prevalent is Performance-Related Pay in the United States? Current Incidence and Recent Trends." *National Institute Economic Review* 226, R4–R16.

Goodman-Bacon, Andrew (2021). "Difference-in-differences with variation in treatment timing". *Journal of Econometrics* 225(2), pp. 254–277.

Hawkins, Rayanne, Brian Bieretz, and Madeline Brown (2019). "Incentivizing Results: Contracting for Outcomes in Social Service Delivery".

Hendren, Nathaniel and Ben Sprung-Keyser (2020). "A Unified Welfare Analysis of Government Policies". *The Quarterly Journal of Economics* 135(3), pp. 1209–1318.

Hendren, Nathaniel and Ben Sprung-Keyser (2022). *The Case for Using the MVPF in Empirical Welfare Analysis.* NBER Working Paper 30029.

Holmstrom, Bengt and Paul Milgrom (1991). "Multitask Principal–Agent Analyses: Incentive Contracts, Asset Ownership, and Job Design." *The Journal of Law, Economics, and Organization* 7, pp. 24–52.

Hong, Fuhai, Tanjim Hossain, John A List, and Migiwa Tanaka (2018). "Testing the Theory of Multitasking: Evidence from a Natural Field Experiment in Chinese Factories." *International Economic Review* 59(2), pp. 511–536.

Houde, Sebastien and Joseph E Aldy (2017). "Belt and Suspenders and More: The Incremental Impact of Energy Efficiency Subsidies in the Presence of Existing Policy Instruments." *American Economic Journal: Economic Policy* 9(4), pp. 227–255.

IEA (2020). "World Energy Investment 2020." IEA Paris.

Industrieverband Hartschaum e.V. (2015). "EPS rigid foam (Styropor®) for ceilings/floors and as perimetric insulation (in German)". *Institut Bauen und Umwelt e.V. (IBU).* URL: https://ibu-epd.com/en/published-epds/.

ISOCELL GmbH (2014). "Blown insulation made of cellulose fibre". *Bau EPD GmbH.* URL: http://www.bau-epd.at/wp-content/uploads/2014/11/EPD-_ISOCELL_Ecoinvent_20140825-English.pdf.

Khan, Adnan Q, Asim I Khwaja, and Benjamin A Olken (2016). "Tax Farming Redux: Experimental Evidence on Performance Pay for Tax Collectors." *The Quarterly Journal of Economics* 131(1), pp. 219–271.

Khan, Adnan Q, Asim Ijaz Khwaja, and Benjamin A Olken (2019). "Making Moves Matter: Experimental Evidence on Incentivizing Bureaucrats through Performance-Based Postings". *American Economic Review* 109(1), pp. 237–70.

Kim, Hyuncheol Bryant, Seonghoon Kim, and Thomas T Kim (2020). "The Role of Career and Wage Incentives in Labor Productivity: Evidence from a Two-Stage Field Experiment in Malawi." *Review of Economics and Statistics* 102(5), pp. 839–851.

Lavy, Victor (2009). "Performance Pay and Teachers' Effort, Productivity, and Grading Ethics." *American Economic Review* 99(5), pp. 1979–2011.

Lavy, Victor (2020). "Teachers' Pay for Performance in the Long-Run: The Dynamic Pattern of Treatment Effects on Students' Educational and Labour Market Outcomes in Adulthood." *The Review of Economic Studies* 87(5), pp. 2322–2355.

Lazear, Edward P (2000). "Performance Pay and Productivity." *American Economic Review* 90(5), pp. 1346–1361.

Lazear, Edward P (2018). "Compensation and Incentives in the Workplace." *Journal of Economic Perspectives* 32(3), pp. 195–214.

Lazear, Edward P and Kathryn L Shaw (2007). "Personnel Economics: The Economist's View of Human Resources." *Journal of Economic Perspectives* 21(4), pp. 91–114.

Lemieux, Thomas, Bentley MacLeod, and Daniel Parent (2009). "Performance Pay and Wage Inequality." *The Quarterly Journal of Economics* 124(1), pp. 1–49.

Levinson, Arik (2016). "How Much Energy Do Building Energy Codes Save? Evidence from California Houses". *American Economic Review* 106(10), pp. 2867–94.

Metcalfe, Robert D, Alexandre B Sollaci, and Chad Syverson (2023). *Managers and Productivity in Retail.* Tech. rep. National Bureau of Economic Research.

Muralidharan, Karthik and Venkatesh Sundararaman (2011). "Teacher Performance Pay: Experimental evidence from India." *Journal of Political Economy* 119(1), pp. 39–77.

Rennert, Kevin, Frank Errickson, Brian C Prest, Lisa Rennels, Richard G Newell, William Pizer, Cora Kingdon, Jordan Wingenroth, Roger Cooke, Bryan Parthum, et al. (2022). "Comprehensive Evidence Implies a Higher Social Cost of CO2." *Nature*, pp. 1–3.

Sharp, T.R. (1994). "The North Carolina Field Test: Field Performance of the Preliminary Version of an Advanced Weatherization Audit for the Department of Energy's Weatherization Assistance Program". *ORNL/CON-362, Oak Ridge National Laboratory, Oak Ridge, Tennessee*. URL: https://weatherization.ornl.gov/wp-content/uploads/pdf/1991_1995/ORNL_CON-362.pdf.

Shearer, Bruce (2004). "Piece Rates, Fixed Wages and Incentives: Evidence from a Field Experiment." *The Review of Economic Studies* 71(2), pp. 513–534.

Strezhnev, Anton (2018). "Semiparametric weighting estimators for multi-period difference-in-differences designs". *Working Paper*. URL: https://www.antonstrezhnev.com/research/.

Sun, Liyang and Sarah Abraham (2021). "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects". *Journal of Econometrics* 225(2), pp. 175–199.

The White House (2021). "FACT SHEET: The American Jobs Plan". URL: https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.

U.S. Government Accountability Office (June 2021). *A Snapshot of Government-Wide Contracting For FY 2020 (infographic)*. URL: https://www.gao.gov/blog/snapshot-government-wide-contracting-fy-2020-infographic.

US Department of Energy (2013). "Weatherization Program Notice 14-4". *Published by the National Association for State Community Services Programs*. URL: https://nascsp.org/wp-content/uploads/2018/02/WPN-14-4.pdf.

Zivin, Joshua G. and Kevin Novan (2016). "Upgrading Efficiency and Behavior: Electricity Savings from Residential Weatherization Programs". *The Energy Journal* 37(4).

Appendices

A Effects of Bonus Treatment on Spending

Tables A1-A3 display the results of estimation of the impact of the bonus treatments on total job-level expenditure, job-level non-health and safety expenditure, and job-level air sealing expenditure during the sample period. We estimate equation 1 as described in the main text with nominal expenditure in 2018 and 2019 USD as the outcome variable. Across expenditure categories and specifications, the results indicate that there is no change in expenditures in the program as a result of the introduction of the bonus. The point estimates are neither economically nor statistically significant. This means that contractors were not able to adjust the non-bonus aspects of their compensation in response to treatment.

Table A1: Effects of Bonus Treatments on Total Job Expenditure ($)

Total Spending	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-202.2	-29.43	-83.63	54.94
	(201.1)	(120.0)	(125.4)	(101.7)
Panel B: Effect by Treatment Group				
Low Treat	-203.5	-74.96	-113.8	82.12
	(244.8)	(143.1)	(146.4)	(125.0)
High Treat	-200.8	19.05	-50.13	24.54
	(248.9)	(148.9)	(155.8)	(124.5)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1695	1694	1694	1601
Adjusted R^2	-0.005	-0.038	-0.056	-0.087
Control Group Dep. Variable Mean	10676.923	10676.923	10676.923	10700.263

Notes: The dependent variable is job-level nominal expenditure in 2018 and 2019 USD. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table A2: Effects of Bonus Treatments on Non-Health and Safety Expenditure

Non-H&S Spending	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-228.2	-11.59	17.93	7.313
	(193.5)	(79.24)	(83.09)	(84.28)
Panel B: Effect by Treatment Group				
Low Treat	-154.5	21.58	46.47	47.68
	(239.0)	(99.60)	(101.9)	(103.6)
High Treat	-307.5	-46.63	-13.49	-37.74
	(236.9)	(95.12)	(99.63)	(99.84)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1549	1548	1547	1544
Adjusted R^2	-0.004	-0.041	-0.060	-0.090
Control Group Dep. Variable Mean	9550.307	9550.307	9550.307	9550.307

Notes: The dependent variable is job-level nominal expenditure on non-health and safety measures in 2018 and 2019 USD. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table A3: Effects of Bonus Treatments on Air Sealing Expenditure

Air Sealing Spending	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	29.84	11.16	15.15	18.59
	(34.40)	(31.76)	(32.57)	(33.05)
Panel B: Effect by Treatment Group				
Low Treat	60.06	24.36	23.10	30.31
	(43.10)	(40.37)	(40.89)	(41.40)
High Treat	-2.714	-2.777	6.403	5.507
	(41.88)	(37.42)	(38.42)	(38.98)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1552	1551	1550	1547
Adjusted R^2	-0.004	-0.041	-0.060	-0.090
Control Group Dep. Variable Mean	1094.055	1094.055	1094.055	1094.055

Notes: The dependent variable is job-level nominal expenditure on air sealing in 2018 and 2019 USD. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

B Experimental Design

Performance Incentive: Contract Language

High Bonus Contract:

Architectural work on this job is eligible for a bonus of $1.00 for each CFM50 reduced below the target number. For example, if the target is 2,500 CFM50, every CFM50 below 2,500 is paid a bonus of $1.00. If the final blower door reading is:

- 2,400 then you will be paid a bonus of $100.00

- 2,300 then you will be paid a bonus of $200.00

- 2,200 then you will be paid a bonus of $300.00

Readings will be based on the QCI's final blower door reading. All discrepancies will be determined by the agency. Any purposely inflated numbers to receive unearned bonuses will be cause for disqualification from the bonus program. In order to receive bonus payments, contractors performing architectural work must be registered as a vendor with the University of Illinois.

Low Bonus Contract:

Architectural work on this job is eligible for a bonus of 40 cents for each CFM50 reduced below the target number. For example, if the target is 2,500 CFM50, every CFM50 below 2,500 is paid a bonus of 40 cents If the final blower door reading is:

- 2,400 then you will be paid a bonus of $40.00

- 2,300 then you will be paid a bonus of $80.00

- 2,200 then you will be paid a bonus of $120.00

Readings will be based on the QCI's final blower door reading. All discrepancies will be determined by the agency. Any purposely inflated numbers to receive unearned bonuses will be cause for disqualification from the bonus program. In order to receive bonus payments, contractors performing architectural work must be registered as a vendor with the University of Illinois.

C Trends in Total Household-Level Spending and Cost-Effectiveness by Program Year

Table C1: IHWAP Program Trends

Program Year	DOE Predicted SIR	Homes Served	Average Spending (2021 USD)
2013	3.59	5687	$6,078
2014	2.27	3638	$6,370
2015	2.22	4683	$6,195
2016	3.02	2477	$7,129
2017	1.67	1763	$12,104
2018	2.12	1532	$12,535
2019	2.09	1891	$11,089
2020	1.78	1611	$10,739

Notes: Table reports the DOE predicted overall SIR for a home, number of homes served and average spending per home for each program year in the full IHWAP program in 2021 USD.

Table C2: Average Net Present Benefits by Program Years 2009-2016

Panel A: Evaluated at Social Marginal Costs of Energy			
Program Years	Average NPB (US$)	Std. Dev.	Number of Homes
PY 2009	-434.85	1910.31	497
PY 2010	-1021.81	1821.02	1015
PY 2011	-1145.38	1749.61	990
PY 2012	-173.81	1904.09	570
PY 2013	726.95	2111.72	489
PY 2014	736.25	1806.88	438
PY 2015	615.62	1816.55	554
PY 2016	-388.92	1851.94	96
PYs 2009-2012	-809.33	1868.39	3072
PYs 2013-2016	622.50	1928.74	1577

Panel B: Evaluated at Retail Energy Prices			
Program Years	Average NPB (US$)	Std. Dev.	Number of Homes
PY 2009	87.08	2281.54	497
PY 2010	-568.88	2204.09	1015
PY 2011	-748.27	2148.88	990
PY 2012	324.80	2291.56	570
PY 2013	1516.03	2475.11	489
PY 2014	1493.54	2181.53	438
PY 2015	1371.05	2154.17	554
PY 2016	228.95	2212.31	96
PYs 2009-2012	-354.75	2255.49	3072
PYs 2013-2016	1380.50	2286.90	1577

Notes: This table presents average home-specific net present benefits by program year as estimated in (Christensen et al., 2021). Those were obtained by first estimating home-specific net benefits, as in section, and then taking simple averages of those net benefits based on which homes were served in each program year. This table is reproduced from the online appendix in (Christensen et al., 2021).

D Principal-Agent Model of Contractor Effort: Multi-Task Settings with Heterogeneous Ability

In this section, we present a principal-agent model of effort allocation for heterogeneous ability contractors in a multi-task setting that integrates insights from both Holmstrom and Milgrom (1991) and Lazear (2000). The model generates predictions about the effect of a piece-rate bonus on the allocation of effort by contractors, as well as the potential variation for contractors who vary in ability.

D.1 Model Set Up

Suppose the principal has m different tasks for their agent (a contractor), to perform. The contractor chooses levels of effort, $\boldsymbol{t} = (t_1, ..., t_m)$ for a vector of m tasks at a personal, strictly convex cost in each dimension, $C(t_1, ...t_m)$. We begin with the assumption that effort in one dimension i does not affect the marginal cost of effort in any other dimension j, so that the cross-partial is zero, i.e. $C_{ij} = 0$. Let a denote ability, where output, $\mu(t, a)$, is an increasing concave function of both ability and effort for each task (i).

$$\mu_i = f(t_i(a), a) \tag{6}$$

Ability determines the amount of effort required for a given level of output. By differentiating equation 6, we can see that higher ability is associated with lower effort for achieving a given level of output – subscripts on f denote derivatives with respect to ability or effort:

$$\frac{\partial t_i}{\partial a} = -\frac{f_a}{f_{t_i}} < 0$$

The principal observes a vector of signals $\boldsymbol{x(t)} = \boldsymbol{\mu(t)} + \boldsymbol{\varepsilon}$ about the effort expended by a contractor, which are a function of true output ($\boldsymbol{\mu(t)}$) and error terms ($\boldsymbol{\varepsilon}$). Assume the error terms are normally distributed, have a mean vector zero, and are stochastically independent across tasks.

D.2 Minimum Quality Standards

In a baseline condition, the principal uses minimum quality standards to ensure that the agent's incentives are compatible with allocating sufficient effort to maintain quality in the program. The principal pays the contractor a fixed wage, w_i, for each task i, but she withholds payment until minimum quality has been achieved for all tasks. Quality is determined on the basis of the information signals received, $\boldsymbol{x(t)}$. The principal will "call back" contractors to rectify any problems if they do not meet a minimum standard of $\boldsymbol{x^0}$ that she sets.[31]

Without loss of generality, assume the callback has a fixed cost $\boldsymbol{\lambda} = \lambda_1, ...\lambda_m$. The probability of failing the minimum quality standard, $Pr(\boldsymbol{x} < \boldsymbol{x^0}) = \boldsymbol{\phi(t, a)}$, is decreasing and convex in effort and ability, such that the expected cost of a callback, $\boldsymbol{k(t, a)} = E[\boldsymbol{\lambda' \phi(t, a)}]$, is also decreasing and convex in effort and ability ($k_t < 0, k_a; k_{tt} > 0, k_{aa}$).

Assume that the agent is risk neutral, such that the agent chooses the vector $\boldsymbol{t^0}$ that minimizes total costs of effort and callbacks.[32] The first order conditions equate the marginal cost of effort with the expected cost of a callback for each task i as follows, where subscripts i indicate derivatives with respect to t_i.

$$C_i(t, a) = -k_i(t, a) \tag{7}$$

Participation Constraint

For any given set of minimum quality outputs and wages $\{\boldsymbol{x^0}, \boldsymbol{w}\}$, there is a group of contractors who will accept the job. Let $\pi(\boldsymbol{x^0(\underline{a}), w}) = \pi(\boldsymbol{0, 0})$ denote profit of the minimum ability agent that would accept the job in lieu of not working. All contractors with ability levels higher than $\underline{a}$ earn rents from the program. Those willing to work in the program must not have preferred work alternatives. Let the profit that an agent of ability a can get at the best alternative be given by $\pi(\boldsymbol{\hat{x}(a), \hat{w}(a)})$ with associated wage

[31] Given that there is uncertainty in the signal, this could be something like within 10% of the targeted CFM reductions or caulking of gaps.

[32] If the agent were risk averse, payments for effort would be higher, reflecting the risk premium, but the qualitative comparative statics of the model would remain the same.

and output levels $\hat{\boldsymbol{x}}(\boldsymbol{a}), \hat{\boldsymbol{w}}(\boldsymbol{a})$. Given that higher-ability contractors may benefit most from outside options that demand more but pay more, there may exist an upper cutoff in ability $\bar{a}$ such that $\pi(\boldsymbol{x^0}(\bar{\boldsymbol{a}}), \boldsymbol{w}) = \pi(\hat{\boldsymbol{x}}(\bar{\boldsymbol{a}}), \hat{\boldsymbol{w}}(\bar{\boldsymbol{a}}))$, and only those contractors with abilities $[\underline{a}, \bar{a}]$ participate in the program.

D.3 Impacts of Piece-Rate Bonuses

Suppose the principal introduces a piece-rate bonus for task i, which pays b_i for each unit of output above a minimum level $\bar{x}_i$, where $\bar{x}_i \geq x_i^0$, such that compensation across all contractor tasks is as follows.

$$\pi(\boldsymbol{x}, \boldsymbol{w}) = \begin{cases} \sum_{j=1}^{m} \left[w_j - k(t_j^0, a) - C(t_j^0, a)\right] \quad \forall x_i \leq \bar{x}_i, & (8) \\ \sum_{j=1}^{m} \left[w_j - k(t_j^*, a) - C(t_j^*, a)\right] + b_i(x_i^* - \bar{x}_i) \quad \forall x_i > \bar{x}_i & (9) \end{cases}$$

Contractors choose the maximum of 8 and 9, where $\boldsymbol{x^*}$ is the vector of output associated with the optimal amount of effort $\boldsymbol{t^*}$ under a piece rate b_i for task i, which solves the following first order condition where subscripts i indicate derivatives with respect to t_i

$$C_i(t, a) + k_i(t, a) = b_i \cdot x_i^*(t, a) \quad i = 1 \tag{10}$$

and $t_j^* = t_j^0$ for all other tasks $j \neq i$. Under a piece rate, contractors choose t^* such that total private marginal costs are equal to the bonus payment. Whether 8 or 9 maximizes contractor profits will depend on a contractor's ability.

By totally differentiating 10 with respect to ability and rearranging terms, we can see that the optimal level of contractor effort is increasing in ability.

$$\frac{\partial t^*}{\partial a} = \frac{\frac{\partial x_i^*}{\partial a}}{C_{ii} + k_{ii} - x_{ii}^* \cdot b} > 0 \tag{11}$$

Given that higher ability contractors produce more output at any given level of effort, the change in output of higher ability contractors in response to the bonus will increase at a rate that is more than proportional to their increase in effort. This model yields two hypotheses regarding the effect of bonuses on contractor effort:

Hypothesis 1: Effort will not decrease in response to the introduction of a piece-rate bonus.[33]

Hypothesis 2: Higher-ability workers will respond with stronger increases in output than lower-ability workers.[34]

D.4 Effort Reallocation

So far, we have assumed that effort in one dimension does not affect the marginal cost of effort in another, $C_{ij} = 0$. This could be the case if the contractor were not constrained in their capacity to bring in more labor either through hiring or giving existing employees more hours. Introducing a bonus for one task in this case would not affect effort on any other tasks.

Now consider the possibility that effort in one dimension could lower or increase the marginal cost of effort in another, depending on whether the tasks are complements or substitutes in the contractor's private cost function.[35] We can quantify reallocation by totally differentiating the first order condition in (7) for task j with respect to b_i and solving for, $\frac{\partial t_j}{\partial b_i}$, as follows.

$$C_{ji}\frac{\partial t_i}{\partial b_i} + C_{jj}\frac{\partial t_j}{\partial b_i} + k_{ji}\frac{\partial t_i}{\partial b_i} + k_{jj}\frac{\partial t_j}{\partial b_i} = 0$$

$$\frac{\partial t_j}{\partial b_i} = -\frac{(C_{ji} + k_{ji})}{(C_{jj} + k_{jj})}\frac{\partial t_i}{\partial b_i} \tag{12}$$

The effect of the bonus on task i on effort in task j depends on whether i and j are complements or substitutes in the contractor's private cost function. To see this, note that a bonus on one task will increase effort in that task $\frac{\partial t_i}{\partial b_i} > 0$ and $C(t, a)$ and $k(t, a)$ are convex such that their second derivatives are positive, thus $(C_{jj} + k_{jj}) > 0$. If i and

[33] First, as in Lazear (2000), and as long as there is some ability type for which output rises, effort will increase.

[34] A third hypothesis that comes out of this section that we are not able to test empirically is that the piece-rate bonus makes the program more attractive relative to outside options, which may in turn draw in higher ability workers (i.e. increase the level of $\bar{a}$).

[35] Assume for this exercise that the contractor's optimal output under the bonus regime, x^*, is above above a minimum level, $\bar{x}_i$.

j are complementary in a firm's private cost function, such that $(C_{ji} + k_{ji}) < 0$, the expression is positive and a bonus on i leads to an increase in effort on j. Whereas if they are substitutes, $(C_{ji} + k_{ji}) > 0$, the expression is negative and a bonus on i leads to a decrease in effort on j.

Importantly, minimum quality standards will help reduce incentives to pull effort away from those tasks. We can see from equation 12, the more convex the effort cost and callback function, the less responsive effort in one dimension will be to bonuses on another dimension. Therefore, whether the bonus leads to reallocation of effort in other, non-incentivized tasks depends on whether those tasks are complements or substitutes to air sealing in contractors' private costs functions and is an empirical question that we can test given our experimental design and data collection.

E Intent-to-Treat Estimates

This Appendix contains the intent-to-treat (ITT) reduced-form estimates for each of the 2SLS results tables in the text. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. In our 2SLS regression presented in the main body of the paper random assignment instruments for treatment jobs with contractors who are eligible to receive payments. The ITT results can be interpreted as the effect of a job being assigned to treatment and are somewhat lower than the 2SLS estimates because not all contractor-jobs in the program were eligible for payment. The ITT results are qualitatively the same as the 2SLS results with the main ITT treatment effect consistently falling within 88 to 95% of the 2SLS estimate. We view the 2SLS estimate as the policy relevant result because if the Department of Energy were to implement piece rates for blower door reductions, all contractors would be eligible to receive payments.

Table E1: Effects of Bonus on Building Envelope Tightness (CFM50): Intent-to-Treat

CFM50 (Pre - Post)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
ITT	-57.64*	-66.74**	-69.09**	-81.44***
	(29.57)	(28.84)	(29.43)	(28.90)
Panel B: Effect by Treatment Group				
Low ITT	-51.61	-53.03	-49.54	-61.18*
	(36.30)	(35.67)	(36.01)	(35.88)
High ITT	-64.14*	-81.11**	-90.41**	-103.7***
	(36.25)	(35.30)	(36.03)	(35.40)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1698	1697	1697	1601
Adjusted R^2	0.745	0.767	0.768	0.792
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E2: Effects of Bonus on Air Leakage Callback Rate: Intent-to-Treat

Air Leakage Callback	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
ITT	-0.0292*	-0.0322**	-0.0241	-0.0270*
	(0.0152)	(0.0150)	(0.0157)	(0.0161)
Panel B: Effect by Treatment Group				
Low ITT	-0.0182	-0.0202	-0.0149	-0.0183
	(0.0193)	(0.0192)	(0.0195)	(0.0199)
High ITT	-0.0406**	-0.0442***	-0.0336*	-0.0360**
	(0.0170)	(0.0168)	(0.0176)	(0.0182)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	0.027	0.068	0.072	0.084
Control Group Dep. Variable Mean	0.085	0.085	0.085	0.084

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to air sealing. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E3: Effects of Bonus on Gas Usage (MMBtu): Intent-to-Treat

Gas MMBtu	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Weatherization × ITT	-0.266**	-0.324***	-0.336***	-0.353***
	(0.110)	(0.106)	(0.107)	(0.108)
Panel B: Effect by Treatment Group				
Weatherization × Low ITT	-0.308**	-0.331**	-0.325**	-0.335***
	(0.133)	(0.129)	(0.128)	(0.129)
Weatherization × High ITT	-0.222	-0.315**	-0.348**	-0.374***
	(0.139)	(0.135)	(0.137)	(0.141)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1216	1216	1216	1164
Observations	66423	66423	66423	63676
Adjusted R^2	0.751	0.753	0.753	0.753
Baseline Weatherization Reduction	-1.607***	-1.607***	-1.607***	-1.623***
	(0.0974)	(0.0974)	(0.0974)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.264	7.264	7.264	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E4: Effects on Blower Door: Simultaneous Jobs Within Contractor (Intent-to-Treat)

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
ITT	-53.86*	-64.78**	-65.89**	-78.33***
	(29.70)	(29.05)	(29.51)	(29.01)
ITT × Simultaneous ITT Jobs	3.876	6.395	5.849	3.410
	(4.295)	(4.191)	(4.186)	(4.050)
ITT × Simultaneous Control Jobs	-6.634	-7.265*	-7.085	-4.420
	(4.619)	(4.369)	(4.349)	(4.291)
Simultaneous ITT Jobs	-3.800	-4.484	-3.091	0.00836
	(3.237)	(3.264)	(3.646)	(3.377)
Simultaneous Control Jobs	3.188	2.769	1.343	-1.100
	(3.579)	(3.364)	(3.801)	(3.671)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1697	1696	1696	1600
Adjusted R^2	0.745	0.767	0.768	0.791
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Controls for the demeaned number of simultaneous treatment and control jobs that the contractor worked on are included along with the interaction of each of these controls with the treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E5: Effects on Gas Usage: Simultaneous Jobs Within Contractor (Intent-to-Treat)

Gas MMBtu	(1)	(2)	(3)	(4)
Weatherization × ITT	-0.247**	-0.311***	-0.340***	-0.364***
	(0.110)	(0.107)	(0.109)	(0.111)
Weatherization × ITT × Simultaneous ITT Jobs	0.0155	0.0173	0.0167	0.0197
	(0.0158)	(0.0149)	(0.0151)	(0.0152)
Weatherization × ITT × Simultaneous Control Jobs	-0.0200	-0.0192	-0.0194	-0.0231
	(0.0172)	(0.0159)	(0.0162)	(0.0164)
Weatherization × Simultaneous ITT Jobs	-0.0220**	-0.0208**	-0.0304***	-0.0301***
	(0.00994)	(0.00938)	(0.0116)	(0.0116)
Weatherization × Simultaneous Control Jobs	0.0230**	0.0212**	0.0315**	0.0339***
	(0.0113)	(0.0104)	(0.0127)	(0.0129)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1215	1215	1215	1163
Observations	66372	66372	66372	63625
Adjusted R^2	0.751	0.753	0.753	0.753
Baseline Weatherization Reduction	-1.607***	-1.607***	-1.607***	-1.623***
	(0.0974)	(0.0974)	(0.0974)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.264	7.264	7.264	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Weatherization and Weatherization×Treat are each interacted with the demeaned number of simultaneous treatment or control jobs the contractor worked on. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E6: Effects on Callback Rate: Non-Incentivized Retrofits (Intent-to-Treat)

Non-Building Envelope Callback	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
ITT	0.0197	0.0199	0.0137	0.0159
	(0.0127)	(0.0130)	(0.0136)	(0.0139)
Panel B: Effect by Treatment Group				
Low ITT	0.0205	0.0180	0.0120	0.0140
	(0.0162)	(0.0162)	(0.0169)	(0.0180)
High ITT	0.0189	0.0219	0.0155	0.0179
	(0.0160)	(0.0165)	(0.0167)	(0.0167)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	0.002	0.009	0.018	0.016
Control Group Dep. Variable Mean	0.040	0.040	0.040	0.040

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to retrofits that are not incentivized by the bonus payments. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E7: Effects on Building Envelope Tightness by Contractor Quality: Intent-to-Treat

CFM60 (Post - Pre)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
High Quality	-66.93	-31.57	-29.63	-50.90
	(44.02)	(45.35)	(45.54)	(44.15)
ITT	-38.46	-44.19	-44.57	-58.33*
	(33.90)	(33.01)	(33.65)	(32.86)
ITT × High Quality	-120.9*	-120.7*	-125.9*	-118.0*
	(69.74)	(69.67)	(69.39)	(70.56)
Panel B: Effect by Treatment Group				
High Quality	-66.99	-32.10	-30.14	-50.97
	(44.05)	(45.43)	(45.61)	(44.25)
Low ITT	-41.53	-41.19	-33.66	-43.00
	(42.01)	(41.30)	(41.61)	(40.70)
High ITT	-35.21	-47.60	-57.12	-75.86*
	(40.08)	(38.99)	(39.93)	(39.42)
Low ITT × High Quality	-64.24	-58.68	-79.19	-90.82
	(81.62)	(81.46)	(81.92)	(86.25)
High ITT × High Quality	-184.6*	-189.0**	-177.3*	-147.7
	(95.25)	(93.53)	(92.83)	(92.95)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1670	1669	1669	1579
Adjusted R^2	0.743	0.766	0.766	0.792
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1557.014	-1557.014	-1557.014	-1552.336

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. High Quality indicates that the contractor that performed the work was in the upper 2 quintiles of performance in the program year that preceded the intervention (2017). Performance was measured as mean gas reductions associated with each contractor, conditional on the measures performed and home and household characteristics. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table E8: Effects on Gas Usage (MMBtu) by Contractor Quality: Intent-to-Treat

Gas MMBtu	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Weatherization × ITT	-0.249**	-0.289**	-0.303**	-0.331***
	(0.121)	(0.117)	(0.118)	(0.120)
Weatherization × ITT × High Quality	-0.126	-0.229	-0.239	-0.186
	(0.285)	(0.275)	(0.275)	(0.283)
Weatherization × High Quality	-0.0333	0.122	0.121	0.0428
	(0.198)	(0.193)	(0.191)	(0.193)
Panel B: Effect by Treatment Group				
Weatherization × Low ITT	-0.298**	-0.304**	-0.299**	-0.316**
	(0.149)	(0.144)	(0.144)	(0.145)
Weatherization × High ITT	-0.198	-0.274*	-0.307**	-0.348**
	(0.150)	(0.148)	(0.149)	(0.153)
Weatherization × Low ITT × High Quality	-0.0882	-0.191	-0.190	-0.159
	(0.315)	(0.311)	(0.309)	(0.315)
Weatherization × High ITT × High Quality	-0.166	-0.271	-0.292	-0.215
	(0.391)	(0.374)	(0.378)	(0.395)
Weatherization × High Quality	-0.0329	0.122	0.122	0.0438
	(0.198)	(0.193)	(0.191)	(0.193)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1204	1204	1204	1154
Observations	65905	65905	65905	63254
Adjusted R^2	0.751	0.753	0.753	0.753
Baseline Weatherization Reduction	-1.607***	-1.607***	-1.607***	-1.623***
	(0.0974)	(0.0974)	(0.0974)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.264	7.264	7.264	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using OLS. ITT (intent-to-treat) refers to the randomized treatment assignment. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. High Quality indicates that the contractor that performed the work was in the upper 2 quintiles of performance in the program year that preceded the intervention (2017). Performance was measured as mean gas reductions associated with each contractor, conditional on the measures performed and home and household characteristics. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

F Robustness Across Samples

The primary estimates of the effects of performance incentives on building envelope tightness (Table 2) use data from all treated homes in the sample. In this Appendix, we test the robustness of our preferred estimates to subsamples for which we also have data on: (1) contractor callbacks and (2) gas consumption

Table F1 reports estimates from the sub-sample of projects for which we also have contractor callback data provided by quality control inspectors. The pooled estimate in our preferred specification (Column 4) is -118.0. The estimated effect of the low bonus is -86.36 and the effect of the high bonus is -151.7 in this subsample. All estimates are statistically different from zero, but none are different from the main estimates reported in Table 2, which are: -88.67 (pooled estimate); -66.17 (low bonus); -113.8 (high bonus).

Table F2 reports estimates from the sub-sample of homes that contain a minimum of 12 months of utility billing data on gas consumption, ensuring balance across months of the year. This is the exact same sample that is used to estimate the effects of treatment on household gas consumption. The pooled estimate in our preferred specification (Column 4) is -97.27. The estimated effect of the low bonus is -93.67 and the effect of the high bonus is -101.3 in this subsample. All estimates are statistically different from zero, but none are different from the main estimates reported in Table 2, which are: -88.67 (pooled estimate); -66.17 (low bonus); -113.8 (high bonus).

Table F1: Effects of Bonus Treatments on Building Envelope Tightness (CFM50) (Sub-sample with Callback Data)

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-100.8**	-104.3***	-103.0***	-118.0***
	(39.79)	(38.35)	(39.05)	(38.86)
Panel B: Effect by Treatment Group				
Low Treat	-96.07*	-85.05*	-78.78	-86.36*
	(50.39)	(49.25)	(50.31)	(49.53)
High Treat	-105.6**	-123.7***	-128.6***	-151.7***
	(47.60)	(45.86)	(46.25)	(46.17)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	0.001	-0.043	-0.064	-0.108
Control Pre-Weatherization Blower Mean	3704.9	3704.9	3704.9	3687.9
Control Group Dep. Variable Mean	-1611.365	-1611.365	-1611.365	-1611.521

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table F2: Effects of Bonus Treatments on Building Envelope Tightness (CFM50)
(Subsample with 12+ Months of Gas Consumption Data)

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-67.44*	-86.18***	-99.30***	-97.27***
	(35.31)	(33.31)	(33.94)	(33.84)
Panel B: Effect by Treatment Group				
Low Treat	-84.70**	-94.81**	-97.88**	-93.67**
	(42.16)	(40.17)	(40.14)	(40.85)
High Treat	-48.73	-76.97*	-100.9**	-101.3**
	(43.29)	(41.40)	(42.22)	(41.39)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1205	1203	1202	1146
Adjusted R^2	-0.003	-0.046	-0.066	-0.110
Control Pre-Weatherization Blower Mean	3497.9	3497.9	3497.9	3489.9
Control Group Dep. Variable Mean	-1500.761	-1500.761	-1500.761	-1507.106

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

G Effects on Callbacks for All Incentivized Tasks

Table G1 reports results for the effect of treatment on callbacks for all incentivized retrofits combined. These include the following retrofits, all of which have the potential to improve the blower door measure: thermal boundary, air sealing, rim insulation, windows and doors. While the results have somewhat larger standard errors, the treatment effects are consistent in magnitude with those in Table 3 for air sealing callbacks alone. This suggests contractors may be responding by doing all tasks that might impact blower door readings better.

Table G1: Effects on Callbacks: All Incentivized Tasks

Building Envelope	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	-0.0233	-0.0276	-0.0192	-0.0231
	(0.0188)	(0.0191)	(0.0197)	(0.0201)
Panel B: Effect by Treatment Group				
Low Treat	-0.00301	-0.00731	-0.000580	-0.00909
	(0.0241)	(0.0246)	(0.0247)	(0.0248)
High Treat	-0.0444**	-0.0483**	-0.0390*	-0.0381
	(0.0212)	(0.0212)	(0.0221)	(0.0232)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	-0.007	-0.052	-0.074	-0.118
Control Group Dep. Variable Mean	0.099	0.099	0.099	0.099

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to any "incentivized" task: i.e. thermal boundary, air sealing, attic insulation, wall insulation, crawl space insulation, basement insulation, rim insulation, windows and doors. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. High Treat and Low Treat indicate jobs assigned to high and low treatment respectively. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

H Robustness to Potential Cohort Effects

Recent econometric literature as identified potential biases from two-way fixed effects (TWFE) approaches (see, for example: Borusyak, Jaravel, and Spiess, 2021; Athey and Imbens, 2022; Goodman-Bacon, 2021; Strezhnev, 2018; Sun and Abraham, 2021; de Chaisemartin and D'Haultfœuille, 2020; Callaway and Sant'Anna, 2021). Given that treatment is randomly assigned continuously throughout the study period, our two-way fixed effects (TWFE) approach does not suffer from the near-term bias that can occur in staggered rollout settings where the proportion of the sample that is treated is increasing over time. With staggered rollout, TWFE estimators place more weight on portions of the sample with higher variance of the treatment indicator variable (i.e. typically at the middle of the panel).

Given that our estimates of the effects of treatment on household gas use use sample of billing data for projects for which we obtain a minimum of 12 months of pre/post billing data, sample weights for projects occurring earlier in the study period will be greater than those treated later. To the extent there is significant heterogeneity of treatment effects across time or groups of treated units, it could potentially bias our estimates of treatment on the gas use outcome (de Chaisemartin and D'Haultfœuille, 2020). The application process and the queuing system for timing of upgrades in the WAP, make it unlikely that there are substantial and systematic differences in outcomes across the sample period.

Nevertheless, we compare our estimates to an approach that weights the outcomes of each home equally. In Table H1, we estimate the treatment effects of the bonuses on gas consumption using home-specific monthly gas reductions (pre- minus post- weaterization) as the outcome. As with the estimates in the main text, we include homes with at least 12 months of both pre- and post-weatherization gas consumption data. The dependent variable was calculated as follows: (1) we computed the mean consumption for each home-calendar month in both pre- and post-weatherization periods, 2) we computed the annualized monthly mean for the pre- and post-weatherization periods using the mean across the 12 monthly means, 3) we computed energy savings using the difference in annualized monthly means. Because each home in our sample has just one observation with this approach, the estimates weight observations equally. The estimates are quite similar to those estimated with the TWFE approach. The pooled effect of the bonus treatments on gas consumption is 0.354 MMbtu, as compared to 0.376 from the TWFE approach. Given how close the estimates from the two approaches are, it is unlikely that significant heterogeneity in treatment effects across treated units over time are a biasing factor in our main analysis.

Table H1: Effects of Bonus on Gas Reduction (MMBtu): Annualized Monthly Mean

Gas Reduction	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Treat	0.240**	0.325***	0.388***	0.354***
	(0.117)	(0.114)	(0.116)	(0.116)
Panel B: Effect by Treatment Group				
Low Treat	0.231	0.341**	0.384***	0.370***
	(0.142)	(0.140)	(0.139)	(0.140)
High Treat	0.249*	0.307**	0.393***	0.336**
	(0.149)	(0.146)	(0.148)	(0.151)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1216	1203	1202	1146
Adjusted R^2	-0.001	-0.041	-0.059	-0.105
Control Pre-Weatherization Blower Mean	3495.3	3497.9	3497.9	3489.9
Control Group Dep. Variable Mean	0.814	0.819	0.819	0.832

Notes: The dependent variable is mean monthly gas reduction (MMBtu). Homes with at least 12 months of both pre and post weatherization gas consumption data were included. The dependent variable was calculated as follows: Take the mean consumption for each home-calendar month both pre and post weatherization, 2) take the mean across the 12 monthly means for both pre and post, 3) energy savings is the difference in annualized monthly means. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Observations are weighted by the inverse probability of being in their respective treatment or control groups. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

I Impacts on Electricity Usage

In this Appendix, we report estimates of the effects of treatment on electricity usage. While the energy efficiency retrofits mad in the IHWAP program are primarily designed to reduce energy consumption related to winter temperatures, air sealing and other retrofits could also have important effects on the consumption of electricity for cooling in the summer months.

Table I1 reports estimates of the effect of performance incentives on electricity usage. While point estimates in Panel A suggest evidence of a small reduction [-1.2 MMBtu] in monthly electricity consumption, we do not have sufficient power to detect small effect sizes. We note that the effect of summer cooling is small relative to baseload electricity consumption, such that fluctuations in monthly use result in a small change relative to variance in the monthly electricity data. Treatment effects are also not different from zero in the high [-6.6 MMBtu] or low [+3.4 MMBtu] bonus treatments reported in Panel B.

We compare the relative effects of treatment on gas usage to those for electricity usage by examining the ratios of baseline effects of weatherization (control mean weatherization effect) to the additional effect of the incentive treatments as reported in Tables 4 (gas) and I1 (electricity). Estimates in Table 4 (gas) indicate that the pooled effect of performance incentives (-0.376 MMBtu) is equivalent to 23% of the control mean weatherization effect (-1.6723 MMBtu). For electricity consumption, we estimate a control mean weatherization effect of -0.471 MMBtu. If we expect that the relative effect of the incentive treatment to baseline weatherization effects will be constant across the two fuel types, this would yield an expected effect of -10.9 MMBtu in electricity usage. We cannot rule out an effect of this magnitude on the basis of our -1.2 MMBtu [-11.3, 8.9] estimate.

Table I1: Effects of Bonus Treatment on Electricity Usage (MMBtu)

Elec MMBtu	(1)	(2)	(3)	(4)
Panel A: Pooled Treatments				
Weatherization × Treatment	0.00292	-0.00805	-0.0107	-0.0120
	(0.0518)	(0.0519)	(0.0519)	(0.0517)
Panel B: Effect by Treatment Group				
Weatherization × Low Treat	0.0380	0.0271	0.0257	0.0338
	(0.0587)	(0.0585)	(0.0585)	(0.0581)
Weatherization × High Treat	-0.0365	-0.0474	-0.0529	-0.0656
	(0.0703)	(0.0711)	(0.0702)	(0.0713)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1452	1452	1452	1386
Observations	69334	69334	69334	66245
Adjusted R^2	-0.001	0.002	0.001	0.002
Baseline Weatherization Reduction	-0.470***	-0.470***	-0.470***	-0.471***
	(0.0325)	(0.0325)	(0.0325)	(0.0313)
Control Mean Pre-Weatherization Consumption	2.772	2.772	2.772	2.766

Notes: The dependent variable is monthly electricity consumption (MMBtu). Weatherization indicates consumption observations post-retrofits. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Panel A reports results from regressions pooling High and Low payment treatments into one single treatment indicator. Panel B reports results from regressions with separate indicators for High and Low Treatment. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

J Do Workers Reallocate Effort: Further Evidence

In the main analysis, we provide estimates of the effects of treatment on the callback rate for deficiencies in air leakage retrofits (Table 3) and the effects of completing additional treated/control projects contemporaneously with a given project on the reductions in CFM50 (Table 5) and gas use (Table 6) in that given project. In Tables J1 and J2, we report estimates of blower door and gas use effects broken out by high and low bonus treatments. Like the pooled sample test provided in Tables 5 and 6, we find no evidence of effects of additional simultaneous treatment or control jobs. In Tables J3 and J4, we provide an additional test for effects of completing additional treated/control projects contemporaneously with a given project on the *callback rate* associated with deficiencies in air leakage retrofits in that given project. Table J3 reports results from a pooled sample test, while Table J4 reports results for high/low bonus groups. We do not find any statistical effect of additional incentivized contracts on the air leakage callback rate for a given home.

Table J5 reports the results of a ratio test for homogeneity of variances between households assigned to treatment (ITT) and households assigned to control for our two outcomes of interest: CFM50 reductions and gas reductions. To estimate gas reductions at the household-level, we first estimate the mean consumption for each calendar month both pre and post weatherization. We then take the mean across calendar months to get an annualized monthly average consumption for both pre and post weatherization. Finally, we subtract the post-weatherization annualized monthly average from the pre-weatherization annualized monthly average to get an average treatment effect. The first to columns in the table display the standard deviation (SD) of the house-level reductions for ITT and control. We report the F-Statistic and lower one-sided p-value for the alternative hypothesis that the ratio of the standard deviation of control to treatment is less than one. The results indicate that the standard deviation is statistically significantly higher for homes assigned to treatment relative to control. This is consistent with piece rates leading to more efficient allocation of effort than minimum quality standards as contractors will go further on lower marginal cost homes under the former regime, but not the latter.

Table J1: Effects on Building Envelope Tightness: Simultaneous Jobs Within Contractor

CFM50 (Post - Pre)	(1)	(2)	(3)	(4)
Low Treat	-60.34	-69.31*	-64.72	-74.76*
	(39.55)	(38.84)	(39.47)	(39.17)
High Treat	-68.44	-91.48**	-96.88**	-106.6***
	(42.69)	(41.55)	(41.81)	(40.90)
Low Treat × Simultaneous Treat Jobs	7.153	10.22*	10.12*	7.319
	(5.490)	(5.349)	(5.342)	(5.332)
Low Treat × Simultaneous Control Jobs	-10.81*	-11.35**	-11.59**	-8.394
	(5.895)	(5.605)	(5.607)	(5.637)
High Treat × Simultaneous Treat Jobs	0.722	2.962	1.498	-1.328
	(5.609)	(5.517)	(5.551)	(5.309)
High Treat × Simultaneous Control Jobs	-2.265	-3.021	-2.071	0.836
	(6.127)	(5.940)	(5.922)	(5.790)
Simultaneous Treat Jobs	-4.356	-5.211	-3.648	-0.0575
	(3.769)	(3.868)	(4.224)	(3.972)
Simultaneous Control Jobs	3.979	3.786	2.102	-1.023
	(4.330)	(4.170)	(4.593)	(4.422)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1697	1696	1696	1600
Adjusted R^2	-0.004	-0.038	-0.052	-0.083
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. High Treat and Low Treat indicate jobs assigned to high and low treatment respectively. Controls for the demeaned number of simultaneous treatment and control jobs that the contractor worked on are included along with the interaction of each of these controls with the treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table J2: Effects on Gas Use: Simultaneous Jobs Within Contractor

Gas MMBtu	(1)	(2)	(3)	(4)
Weatherization × Low Treat	-0.335**	-0.373***	-0.374***	-0.394***
	(0.148)	(0.144)	(0.143)	(0.143)
Weatherization × High Treat	-0.229	-0.340**	-0.407***	-0.443***
	(0.147)	(0.144)	(0.151)	(0.156)
Weatherization × Low Treat × Simul. Treat Jobs	0.0248	0.0254	0.0261	0.0300
	(0.0195)	(0.0185)	(0.0186)	(0.0186)
Weatherization × Low Treat × Simul. Control Jobs	-0.0277	-0.0247	-0.0270	-0.0308
	(0.0209)	(0.0196)	(0.0199)	(0.0200)
Weatherization × High Treat × Simul. Treat Jobs	0.00785	0.0118	0.00996	0.0108
	(0.0243)	(0.0231)	(0.0233)	(0.0237)
Weatherization × High Treat × Simul. Control Jobs	-0.0127	-0.0148	-0.0125	-0.0155
	(0.0264)	(0.0247)	(0.0251)	(0.0254)
Weatherization × Simultaneous Treat Jobs	-0.0252**	-0.0243**	-0.0345**	-0.0341**
	(0.0114)	(0.0110)	(0.0134)	(0.0134)
Weatherization × Simultaneous Control Jobs	0.0271**	0.0259**	0.0369**	0.0393**
	(0.0133)	(0.0125)	(0.0151)	(0.0153)
House FE	Yes	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes	Yes
Weatherization × Month of Completion FE	No	No	Yes	Yes
Weatherization × Characteristics	No	No	No	Yes
No. of Homes	1215	1215	1215	1163
Observations	66372	66372	66372	63625
Adjusted R^2	0.001	0.007	0.005	0.006
Baseline Weatherization Reduction	-1.607***	-1.607***	-1.607***	-1.623***
	(0.0974)	(0.0974)	(0.0974)	(0.0982)
Control Mean Pre-Weatherization Consumption	7.264	7.264	7.264	7.257

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Weatherization and Weatherization×Treat are each interacted with the demeaned number of simultaneous treatment or control jobs the contractor worked on. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table J3: Air Leakage Callback Rate: Simultaneous Jobs Within Contractor

Reducing Air Leakage	(1)	(2)	(3)	(4)
Treat	-0.0371**	-0.0378**	-0.0221	-0.0261
	(0.0167)	(0.0163)	(0.0174)	(0.0175)
Treat × Simultaneous Treat Jobs	0.00136	0.000629	0.000913	0.000404
	(0.00283)	(0.00274)	(0.00273)	(0.00290)
Treat × Simultaneous Control Jobs	-0.00238	-0.00156	-0.00218	-0.00112
	(0.00312)	(0.00296)	(0.00299)	(0.00313)
Simultaneous Treat Jobs	0.000125	0.000941	0.00504*	0.00460
	(0.00232)	(0.00232)	(0.00269)	(0.00282)
Simultaneous Control Jobs	0.00281	0.00164	-0.00297	-0.00306
	(0.00267)	(0.00262)	(0.00302)	(0.00309)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	0.007	-0.040	-0.056	-0.106
Control Group Dep. Variable Mean	0.085	0.085	0.085	0.084

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to air sealing. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. High and Low payment treatments are pooled into one single treatment indicator. Controls for the demeaned number of simultaneous treatment and control jobs that the contractor worked on are included along with the interaction of each of these controls with the treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table J4: Air Leakage Callback Rate: Simultaneous Jobs Within Contractor

Reducing Air Leakage	(1)	(2)	(3)	(4)
Low Treat	-0.0240	-0.0227	-0.0137	-0.0205
	(0.0210)	(0.0207)	(0.0210)	(0.0210)
High Treat	-0.0509***	-0.0537***	-0.0325*	-0.0343*
	(0.0186)	(0.0184)	(0.0194)	(0.0204)
Low Treat × Simultaneous Treat Jobs	0.00226	0.00168	0.00205	0.00170
	(0.00346)	(0.00335)	(0.00335)	(0.00359)
Low Treat × Simultaneous Control Jobs	-0.00468	-0.00397	-0.00464	-0.00360
	(0.00382)	(0.00365)	(0.00366)	(0.00389)
High Treat × Simultaneous Treat Jobs	0.000686	-0.0000143	0.0000782	-0.000655
	(0.00309)	(0.00311)	(0.00310)	(0.00311)
High Treat × Simultaneous Control Jobs	-0.000248	0.000484	0.0000765	0.00116
	(0.00341)	(0.00341)	(0.00343)	(0.00343)
Simultaneous Treat Jobs	0.000119	0.000889	0.00488*	0.00446
	(0.00232)	(0.00232)	(0.00269)	(0.00283)
Simultaneous Control Jobs	0.00283	0.00175	-0.00276	-0.00287
	(0.00267)	(0.00262)	(0.00302)	(0.00310)
Pre Blower (CFM)	Yes	Yes	Yes	Yes
Expenditures	No	Yes	Yes	Yes
Month of Completion FE	No	No	Yes	Yes
Characteristics	No	No	No	Yes
Observations	1226	1225	1225	1164
Adjusted R^2	0.008	-0.038	-0.054	-0.105
Control Group Dep. Variable Mean	0.085	0.085	0.085	0.084

Notes: The dependent variable is an indicator variable for whether the contractor performing the job was "called back" by the quality control inspector (QCI) to perform additional work to rectify an issue related to air sealing. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. High Treat and Low Treat indicate jobs assigned to high and low treatment respectively. Controls for the demeaned number of simultaneous treatment and control jobs that the contractor worked on are included along with the interaction of each of these controls with the treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table J5: Test for Homogeneity of Variance

	SD Control	SD ITT	F-Statistic	P-value	Observations
Blower Door Reduction	1150.58	1235.36	.868	.0234	1567
Gas Reduction	1.83	1.99	.841	.0166	1216

Notes: This table reports the results of a ratio test for homogeneity of variances between households assigned to treatment (ITT) and households assigned to control. We report the F-Statistic and lower one-sided p-value for the alternative hypothesis that the ratio of the standard deviation of control to treatment is less than one.

K Evidence of Learning

In this Appendix, we test for evidence that the bonus treatment results in improvements in the performance of air sealing tasks completed across the study period. This could occur, for example, if the bonus incentives cause high or especially low-performing contractors to improve the way that they perform, supervise or internally inspect air sealing tasks. We construct a measure of the number of treated jobs completed prior to each job in the sample. We test for evidence of learning by examining the interaction between the "number of previously treated jobs" measure with the treatment indicator to examine whether contractors who have received a greater number of bonus contracts perform differently in their ability to induce reductions in CFM50 (Table K1) or gas use (Table K2). These tests do not reveal strong evidence that contractor performance is increasing as they complete larger numbers of treated or control jobs during the intervention.

Table K1: Effects of Bonus on Building Envelope Tightness by Number of Previously Treated Jobs

CFM50 (Post - Pre)	(1)	(2)	(3)
Panel A: Pooled Treatments			
Treat	-48.07	-65.94	-108.4**
	(52.84)	(53.04)	(51.31)
Treat × Number of Treated Jobs	-0.615	-0.354	0.807
	(1.440)	(1.438)	(1.456)
Number of Treated Jobs	-0.638	-1.075	-1.433
	(0.989)	(0.986)	(0.999)
Panel B: Effect by Treatment Group			
Low Treat	-20.03	-23.64	-69.08
	(67.06)	(67.59)	(67.37)
High Treat	-75.82	-107.2*	-147.2**
	(63.30)	(62.43)	(61.39)
Low Treat × Number of Treated Jobs	-1.354	-1.308	-0.133
	(1.783)	(1.809)	(1.876)
High Treat × Number of Treated Kobs	0.128	0.559	1.696
	(1.693)	(1.670)	(1.708)
Number of Treated Jobs	-0.638	-1.066	-1.430
	(0.989)	(0.987)	(0.999)
Pre Blower (CFM)	Yes	Yes	Yes
Expenditures	No	Yes	Yes
Characteristics	No	No	Yes
Observations	1698	1697	1601
Adjusted R^2	-0.002	-0.033	-0.063
Control Pre-Weatherization Blower Mean	3609.7	3609.7	3585.2
Control Group Dep. Variable Mean	-1569.306	-1569.306	-1562.708

Notes: The dependent variable is the change in building envelope tightness as a result of Weatherization Assistance Program upgrades (Post-Pre). Building envelope tightness is measured in units of 50 cubic feet per minute (CFM50), where higher values indicate a leakier home. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. High Treat and Low Treat indicate jobs assigned to high and low treatment respectively. Controls for the demeaned number of previous jobs that the contractor worked on are included along with the interaction of each of these controls with the treatment indicator. Heteroskedasticity-robust standard errors are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

Table K2: Effects of Bonus on Gas Usage (MMBtu) by Number of Previously Treated Jobs

Gas MMBtu	(1)	(2)	(3)
Panel A: Pooled Treatments			
Weatherization × Treatment	-0.275**	-0.342***	-0.349***
	(0.117)	(0.115)	(0.116)
Weatherization × Treat × Number of Treated Jobs	-0.00466	-0.00241	-0.00453
	(0.00546)	(0.00498)	(0.00516)
Weatherization × Number of Treated Jobs	0.00307	0.000880	0.00315
	(0.00394)	(0.00366)	(0.00376)
Panel B: Effect by Treatment Group			
Weatherization × Low Treat	-0.312**	-0.345**	-0.351**
	(0.142)	(0.139)	(0.139)
Weatherization × High Treat	-0.232	-0.337**	-0.347**
	(0.149)	(0.146)	(0.150)
Weatherization × Low Treat × Number of Treated Jobs	-0.00655	-0.00317	-0.00490
	(0.00620)	(0.00556)	(0.00582)
Weatherization × High Treat × Number of Treated Jobs	-0.00258	-0.00161	-0.00416
	(0.00692)	(0.00649)	(0.00672)
Weatherization × Number of Treated Jobs	0.00307	0.000886	0.00315
	(0.00394)	(0.00366)	(0.00376)
House FE	Yes	Yes	Yes
Month of Sample FE	Yes	Yes	Yes
Weatherization × Demeaned Pre Blower (CFM)	Yes	Yes	Yes
Weatherization × Expenditures	No	Yes	Yes
Weatherization × Characteristics	No	No	Yes
No. of Homes	1216	1216	1164
Observations	66423	66423	63676
Adjusted R^2	0.001	0.007	0.008
Baseline Weatherization Reduction	-1.582***	-1.582***	-1.597***
	(0.101)	(0.101)	(0.102)
Control Mean Pre-Weatherization Consumption	6.910	6.910	6.879

Notes: The dependent variable is monthly gas consumption (MMBtu). Homes with 12 months or more of both pre and post weatherization gas consumption data were included. Weatherization indicates consumption observations post-retrofits. Weatherization and Weatherization×Treat are each interacted with the demeaned number of previous treatment jobs contractor worked on. Contractors were only eligible to receive payments for treatment jobs if they were signed up as vendors with the University of Illinois at the time the work order was printed. The models are estimated using 2SLS where randomized treatment assignment is an instrument for treatment jobs with eligible contractors. Results are from regressions pooling High and Low payment treatments into one single treatment indicator. Standard errors are clustered at the house level and are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10 percent levels.

L Measuring Contractor Quality

We construct a measure of contractor performance at baseline using a research design that leverages the queue-based assignment of contractors to jobs in the IHWAP program to estimate contractor-specific performance in energy savings achieved (Christensen et al., 2021). Whereas in Christensen et al. (2021), the measure is used to examine the extent that heterogeneity in contractor performance can explain the wedge between projected and realized energy savings in a quasi-experimental design, in the present study we use this performance measure and the experimental variation in bonus payments to examine heterogeneous responses to the piece-rate incentive.

To isolate the contribution of each contractor $\hat{\eta}_j$, we create a quality measure that measures the mean savings attributable to contractor j from all homes worked on during a baseline year. We deploy the approach using IHWAP data on jobs and energy outcomes for program year 2017, the year prior to the intervention. The estimates come from a procedure that first predicts the post-weatherization average monthly gas consumption for each home using characteristics of the home and household as well as pre-weatherization monthly gas consumption:

$$\hat{Y_{iym}} = \beta_1 X_i + \gamma_y + \mu_m + \epsilon_i \tag{13}$$

where Y_i is the energy use (MMBtu) for household i during the year prior to weatherization, X_i is a vector of home and household characteristics including county of residence, square footage, number of stories, number of bedrooms, year built and number of occupants. Calendar month and year fixed effects are denoted by μ_m and γ_y respectively. For each home, we then generate an estimate of mean differences in monthly energy use pre/post weatherization by computing the difference between predicted gas consumption in the post-period ($\hat{Y_i}$) from Eq. 13 and and observed gas consumption in the post-period ($\bar{Y_i}$).

$$\hat{\delta_i} = \bar{Y_i} - \hat{Y_i} \tag{14}$$

In a final step, we estimate the contractor-specific contribution to each home's predicted energy savings ($\hat{\delta}_i$) using the following estimating equation:

$$\hat{\delta}_i = \beta_1 X_i + \beta_2 Z_i + \theta_j + \gamma_y + \mu_m \epsilon_i \tag{15}$$

where θ_j is a vector of contractor fixed effects, γ_y and μ_m again denote year and calendar month fixed effects respectively, and X_i is the vector of home and household characteristics from Eq. 13. Z_i is a vector of indicators for binned ranges of spending for each retrofit category. The coefficient estimates on the contractor fixed effects, $\hat{\theta}_j$, capture the mean performance of each contractor j at baseline. The differences among the $\hat{\eta_j}$'s reflect mean contractor-specific differences in the energy savings.

In the absence of unobserved or uncontrolled for determinants of energy savings, these coefficients can be interpreted as a measure of contractor j's performance in achieving energy savings. Given the strong reliance on quasi-experimental variation in Christensen et al. (2021), we conduct several tests for evidence that differences in the coefficient estimates recovered from prior years could be due to unobservable variation (ϵ_j) across the homes to which contractors were assigned. On the basis of that evidence, we argue that the component of a contractor's outcome that is not attributable to quality is likely idiosyncratic in any given year. In the present experimental setting, randomization of treatment ensures that any unobservable variation in our contractor quality measure (ϵ_j) is not correlated with the bonus incentives.

M Estimating Producer Surplus

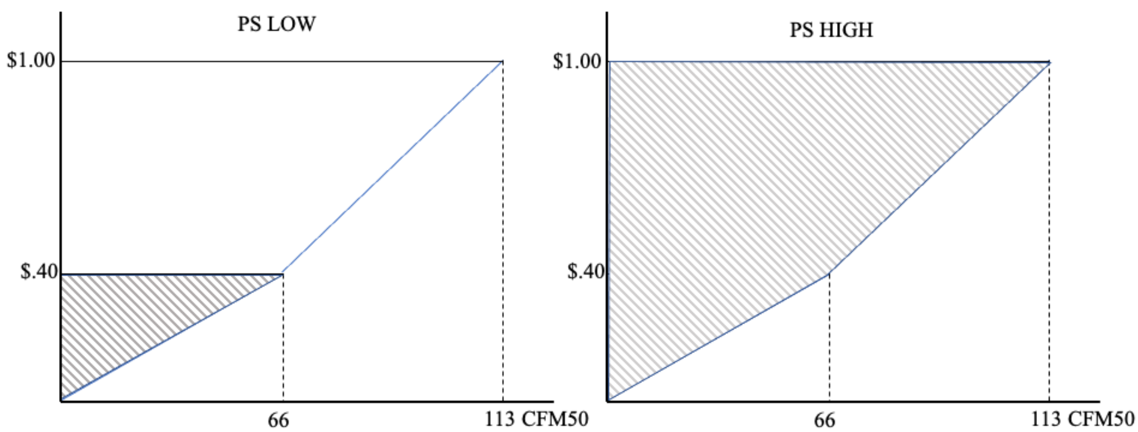
Equations 4 and 5 require estimates of changes in producer surplus that are attributable to the performance incentives. We recover estimates of producer surplus by tracing out the supply curve of air sealing improvements (CFM50 reductions) at the high and low bonus levels extending the model in Appendix D. The supply of CFM50 that is attributable to the piece rate at any given bonus level is:

$$Q_{CFM50} = f(b_{CFM50}(x^*_{CFM50} - \bar{x}_{CFM50})) \tag{16}$$

where Q_{CFM50} is the quantity of additional building envelope sealing (CFM50) observed in the program at any given level of bonus payment (b), which is a function of the optimal output of additional sealing by a given contractor beyond baseline target: x^*_i - $\bar{x}_i$. At any given level of bonus payment, b_{CFM50}, we observe Q_{CFM50} and can compute the level of producer surplus using:

$$PS = b_{CFM50}(Q^*_{CFM50}) - \int_{Q_{control}}^{Q^*_{CFM50}} \hat{\beta}_{CFM50}\, dx \tag{17}$$

We obtain estimates of $Q_{CFM50} = 66$ for the \$0.4 bonus and $Q_{CFM50} = 113$ for the \$1.00 bonus from Table 2. Assuming a piece-wise linear functional form as depicted below, the magnitude of the producer surplus is \$13 for the average contract at the low bonus level and \$99 for the average contract at the high bonus level.



N Social Welfare: Sensitivity Analysis

Table M1: Marginal Value of Public Funds

	Cost	Producer Surplus	SCC = $51		SCC = $125		SCC = $185	
			19.25 Years	34.5 Years	19.25 Years	34.5 Years	19.25 Years	34.5 Years
Panel A. Performance Incentive								
			Social Net Benefits					
Low Treat	$114	$13	$376	$672	$673	$1,153	$914	$1,543
High Treat	$283	$99	$359	$696	$697	$1,244	$971	$1,688
			Marginal Value of Public Funds					
Low Treat	.	.	$4.3	$6.89	$6.9	$11.11	$9.01	$14.53
High Treat	.	.	$2.27	$3.46	$3.46	$5.39	$4.43	$6.96
Panel B: Baseline WAP								
			Social Net Benefits					
All Baseline Retrofits	$9,615	.	$-5,258	$-2,699	$-3,893	$-488	$-2,786	$1,306
Baseline Air Sealing	$1,128	.	$-617	$-317	$-457	$-57	$-327	$153
Baseline All Incentivized	$2,037	.	$-1114	$-572	$-825	$-103	$-590	$277
			Marginal Value of Public Funds					
All Baseline Retrofits	.	.	$0.45	$0.72	$0.6	$0.95	$0.71	$1.14
Baseline Air Sealing	.	.	$0.45	$0.72	$0.6	$0.95	$0.71	$1.14
Baseline All Incentivized	.	.	$0.45	$0.72	$0.6	$0.95	$0.71	$1.14
Panel C: Baseline Air Sealing + Incentive								
			Social Net Benefits					
Baseline Air Sealing + Low Treat	$1,242	.	$-241	$355	$216	$1,095	$587	$1,695
Baseline Air Sealing + High Treat	$1,411	.	$-258	$379	$241	$1,186	$645	$1,841
			Marginal Value of Public Funds					
Baseline Air Sealing + Low Treat	.	.	$0.81	$1.29	$1.17	$1.88	$1.47	$2.37
Baseline Air Sealing + High Treat	.	.	$0.82	$1.27	$1.17	$1.84	$1.46	$2.3
Panel D: Baseline All Incentivized + Incentive								
			Social Net Benefits					
Baseline All Incentivized + Low Treat	$2,151	.	$-738	$100	$-152	$1,049	$323	$1,819
Baseline All Incentivized + High Treat	$2,320	.	$-755	$124	$-127	$1,140	$381	$1,964
			Marginal Value of Public Funds					
Baseline All Incentivized + Low Treat	.	.	$0.66	$1.05	$0.93	$1.49	$1.15	$1.85
Baseline All Incentivized + High Treat	.	.	$0.67	$1.05	$0.95	$1.49	$1.16	$1.85
Panel D: Baseline All Retrofits + Incentive								
			Social Net Benefits					
Baseline All Retrofits + Low Treat	$9,769	.	$-4,895	$-2,040	$-3,233	$652	$-1,885	$2,836
Baseline All Retrofits + High Treat	$9,938	.	$-4,998	$-2,102	$-3,295	$657	$-1,914	$2,895
			Marginal Value of Public Funds					
Baseline All Retrofits + Low Treat	.	.	$0.50	$0.79	$0.67	$1.07	$0.81	$1.29
Baseline All Retrofits + High Treat	.	.	$0.50	$0.79	$0.67	$1.07	$0.81	$1.29

Notes: Table reports sensitivity in estimates reported in Table 10 to assumed lifespans of 19.25 years versus 34.5 years. Retrofit lifespans are based on the weighted average for of retrofit-specific lifespans in the average home in the sample: 19.25 years when assuming a 20-year lifespan for long-lived insulation materials vs. 34.5 years when assuming a 150-year lifespan for long-lived air-sealing materials.