Learning by Doing: The Role of Contractors in Building Electrification

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Motivation

The Need For Heat Pumps

The US and EU are facing increasing pressure to reach their net-zero emissions targets for 2050. In the US, the building sector represents 1/3 of national emissions, with on-site heating being a significant barrier to building electrification[1]. Approximately 71% of buildings are heated by either natural gas or oil, nearly all of which would need to be replaced by electric heat pumps to achieve net-zero[2]. Two primary barriers for heat pumps, however, are high upfront cost and demand for trained contractors.

The Need for Properly Installed Heat Pumps

Heat pumps are sensitive to the quality of installation, with the U.S. Department of Commerce identifying heat pump sizing as one of the key faults leading to performance degradation.[3] Furthermore, the sizing of heat pumps requires a more complex assessment than their gas heater predecessors.

The Role of Contractors

Contractors are at the forefront of the push for electrification. They directly affect the cost and quality of installation. Moreover, they are facing a mismatch between skills previously needed for gas or oil heating and the new demands of heat pump installation.

Research Question

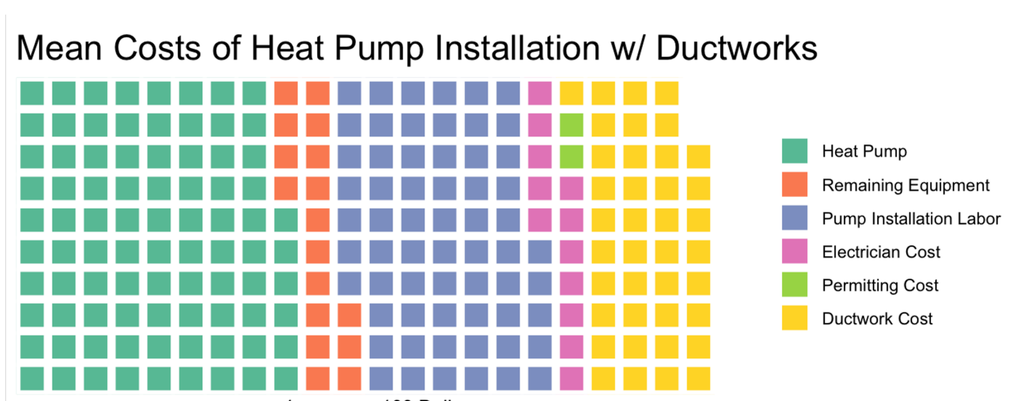
How does contractor installation behavior differ, and how is it shifting with increased installation experience? The implications of these questions can inform policy to accelerate the electrification of buildings performed by experienced and qualified contractors.

Data

Summary Statistics

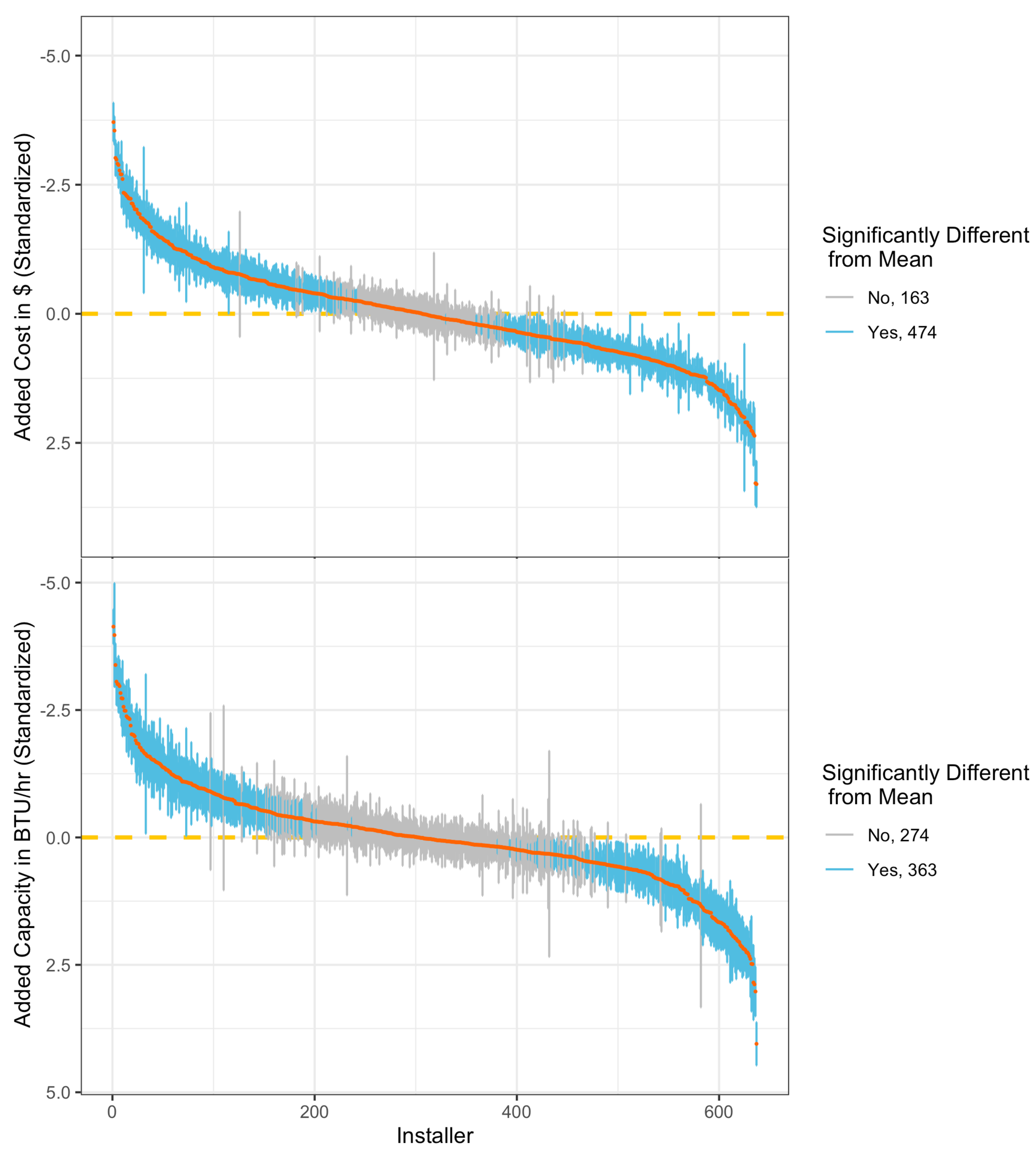
Variables	Count	Mean	Standard Dev.	Min	Max
(A) Heat-Pump Installations					
Year of Installation	14369	2017	1.2	2014	2019
Total Cost of Installation (USD)	14369	9367	5449	1000	53000
Number of Heat Pump Units	14369	1.3	0.6	1	5
Installed Heating Capacity	14369	29157	13809	6968	144000
Fuel Type	14126	-	-	-	-
Natural Gas	5350	0.43	-	-	-
Oil	6052	0.38	-	-	-
Electric Resistance	1842	0.13	-	-	-
Propane	636	0.05	-	-	-
Wood Stove	246	0.02	-	-	-
(B) Home Data					
Living Area (Sqft)	14369	1894	1074	260	59567
Number of Bedrooms	14369	3.2	0.8	1	5
Number of Bathrooms	14369	2	0.8	1	5
Year Home Built	14302	1959	38	1650	2019
Last Selling Price	11420	325765	258638	1	6232500
Assessed Value of Property	14369	612746	367555	130300	9326400
Home Type	14369	-	-	-	-
Single-Family	13392	0.93	-	-	-
Condo	432	0.03	-	-	-
Multi-Family	422	0.03	-	-	-
Apartment	53	0.00	-	-	-
Unknown	14	0.00	-	-	-
Townhouse	31	0.00	-	-	-
Lot	10	0.00	-	-	-
Manufactured	15	0.00	-	-	-
(C) Contractor Data					
Year Established	147	1978	32	1872	2019
Number of Employees	305	11.6	14.8	0	100
Number of Installations	14343	75	85	1	606

Heat Pump Installation Cost Breakdown



Results

Contractor Fixed Effects



- For a contractor's added cost, the majority of contractors significantly deviate from the mean (474 compared to 163).
- Here one standard deviation representing a $0.44 (per square foot) difference in added cost, with the average cost of a heat pump installation in the home being $9,367.
- Similar results are seen for a contractor's effect on installed capacity, with 363 contractors significantly deviating from the mean.
- In this case one standard deviation represents a divergence of 0.36 BT U/(hr · sqf t) from the mean.
- For reference, heating a 12x12 ft room with average insulation performance requires 13,824 BTU to heat in a Massachusetts winter. The same room with poor insulation takes 29,030 BTU to heat, and a room with above average insulation requires 8,294 BTU.

Learning Effects

	(1)	(2)	(3)	(4)	(5)	(6)
(A) Installed Capacity Models						
Ln(Number Past Installations)	0.0072 (0.0073)	-0.032 (0.014)	-0.026** (0.012)	-0.029** (0.012)	-0.031** (0.012)	-0.033*** (0.012)
DF Residuals	13,537	13,521	13,503	13,017	12,992	12,990
R-Squared	0.10	0.10	0.27	0.33	0.36	0.36
(B) Total Cost of Installation Models						
Ln(Number Past Installations)	0.053*** (0.0066)	-0.017 (0.014)	-0.011 (0.013)	-0.018 (0.014)	-0.020 (0.014)	-0.021 (0.014)
DF Residuals	13,537	13,521	13,503	13,017	12,992	12,990
R-Squared	0.20	0.21	0.34	0.38	0.4	0.4
Controls						
Installer FEs	Yes	Yes	Yes	Yes	Yes	Yes
Year Installed FEs	No	Yes	Yes	Yes	Yes	Yes
Month Installed FEs	No	Yes	Yes	Yes	Yes	Yes
Hedonic Controls	No	No	Yes	Yes	Yes	Yes
Town FEs	No	No	No	Yes	Yes	Yes
Previous Heating Controls	No	No	No	No	Yes	Yes
Heat Pump Brand	No	No	No	No	No	Yes

- Once controlling for time effects, we estimate that *added experience leads to a decrease in installed capacity.*
- As controls for the characteristics of the home and location enter the model, this effect becomes increasingly significant and negative.
- For our final model (6), the interpretation for the estimates is that *for each additional percentage increase in installations completed, the next heating system the contractor installs is downsized by −0.033%.*

Methods

Learning Model

We use a fixed-effects model to estimate the relationship between added experience in heat pump installations and contractor behavior, conditional on the relevant characteristics of the home and heating system:

$$\ln(Y_{ict}) = \lambda_c + \tau_t + \gamma \cdot \ln(Experience_{c,d}) + \beta \cdot X_i + \epsilon_{i,c,t}$$

$Y_{i,c,t}$ describes the two main outcomes describing the performance and costs of each installation in our sample: $\ln(Capacity_{i,c,t}$, and $\ln(Total\ Cost_{i,c,t}$ represent the log of installed capacity (per square footage) of the heating system and the total cost (per square footage) of the project for home i completed by contractor c in time t. λ_c describes the fixed effects associated with contracting company c, and τ_t describes the time fixed effects. Our coefficient of interest is γ, that describes the changes in costs and installed capacity for each additional heat pump installation by contractor c at year t.

Lastly, β includes a vector of coefficients associated with the list of controls for characteristics of the heating system and home that are controlled for. In particular, the vector includes the size, year built, value of the property, type of house, number of bedrooms and bathrooms, and the baseline heating type in the property at the time of the heat-pump installation. The standard errors are clustered at the contracting company level, for the purpose of capturing unobserved variation at the contractor level.

Conclusions

Through our fixed effects analysis, there are large amounts of heterogeneity in installation behavior between contractors, which remains consistent across various controls. The high variance in cost and heating capacity not only leads to greater uncertainty for consumers on what the upfront costs of an installation and its benefits will be, but also indicates the existence of suboptimal behavior in a subset of contractors, potentially undermining the goal of the heat pump rebate program.

Second, we find a consistently significant and negative relation between increased past installations and the installed capacity of heating systems. The effect of increased experience on cost is non-significant but is observed to be positive.

Future Work

We are expanding the data to see how contractor experience leads to changes in the final electricity consumption of households. In addition, we are currently implementing energy models in our sample of houses to examine what the optimal installed capacity should be, and how the selected capacity by the installer deviates from the model recommendations and are forming learning curve estimates for the rate at which optimal amounts of learning has occurred.

References

1. IEA, "Installation of about 600 Million Heat Pumps Covering 20% of Buildings Heating Needs Required by 2030."
2. IEA, "Heating – Analysis"
3. Domanski et al, "Sensitivity Analysis of Installation Faults on Heat Pump Performance"

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