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Smart Thermostat User Behavior Study

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Fannie Mae
Smart Thermostat User Behavior Pilot

2020

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STUDY SUMMARY

From 2018 to 2020, Fannie Mae conducted a randomized, controlled study across five different US markets testing the financial impact of installing a free smart thermostat (Nest Thermostat E) in 578 very low-, low-, and moderate-income homes that received a HomeReady® mortgage. The study looks at both Intent-to-Treat (ITT) and Treatment-on-Treated (TOT) effects.

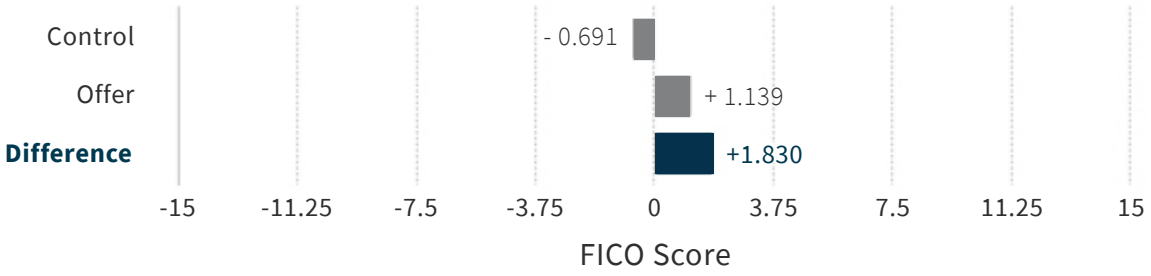
Study Period: Sept. 1, 2018 – Sept. 30, 2019

Offered = 11,369 HomeReady borrowers who were offered a free Nest Theromstat E smart thermostat. Approximately 5% accepted and had a Nest installed (referred to as Accepters), and the rest did not (referred to as Decliners.)

Control = 757 HomeReady borrowers who were randomly assigned to **not** be offered a Nest Therostat E smart thermostat

OVERALL CHANGE IN FICO SCORE

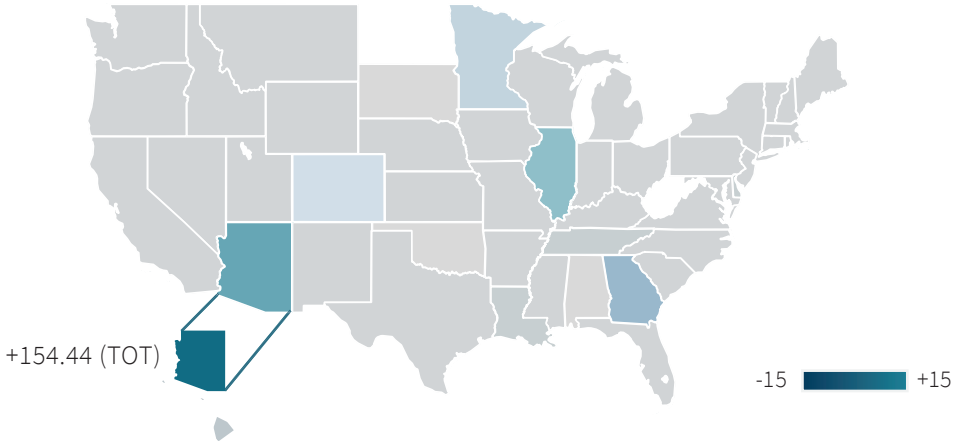
The Offer group increased their FICO score by +1.83 points relative to the Control group but the effect was not found to be significant.



Significant=No, p=0.38, alpha=0.1 | n= 757 (Control), 11,369 (Offer)

CHANGE BY MSA

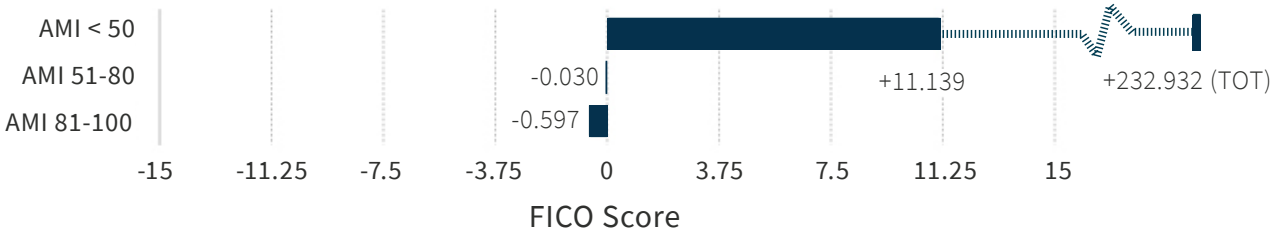
One MSA, Phoenix, had a significant increase in FICO of +7.55 points Intent-to-Treat (ITT). The Treatment-on-Treated (TOT) effect was 154.44 points (SE=79.57).



Significant=Mixed, p=0.05-0.77, alpha=0.1 | n= 134-159 (Control), 1,614-2,783 (Offer)

CHANGE BY AMI

One group, AMI < 50, had a significant increase in FICO of +11.139 points (ITT). The TOT effect was +232.932 points (SE=98.890).



(p=0.02-0.93, alpha=0.1) n= 104-439 (Control); 1,652-4,980 (Offer)

CONTEXT

BACKGROUND

In the United States, approximately 48 million people are at or below the poverty line and may be suffering from energy poverty,[1] which is defined as "spending about 10% or more of income on energy-related expenses."[2] This disparity is particularly prevalent among people who are below 50% of the Federal poverty level. This group will:

- Spend, on average across the nation, 7% of their income on utility bills.[3]
- Spend, for some, more than 20% of their income on home energy bills.[4]
- Spend as much as 50% or more of their income on energy in states such as Maine and North Dakota.[5]

Separate research has shown that using smart thermostat technology in one's home can decrease energy use associated with heating, ventilation and air conditioning (HVAC) by 10-12% on average, and in some cases up to 20%. For lower-income households, an Apex Analytics study (2013-2014) found that:

> *"The lowest income category [<$50,000 annual income], which tended to have more manufactured homes and less education, had the largest percent savings of any subgroup that the team analyzed. This income category also had very large and significant differences in savings from the other two income categories."* [6]

Thus, smart thermostat technology can have a substantial impact on energy savings, especially for lower-income households.

Building on these findings, this study aims to understand if there is a correlation between Nest smart thermostat usage for very low-, low- and moderate-income homeowners and an improvement in financial health.

DUTY TO SERVE RULE

Fannie Mae's mission is to provide liquidity, stability and affordability to all parts of the U.S. housing market. In 2008, Congress tapped Fannie Mae and Freddie Mac to provide leadership to facilitate a secondary market for mortgages and improve the availability of home financing for those families that have been hardest to reach. The final Duty to Serve Underserved Markets rule (Rule), issued in December 2016 by the Federal Housing Finance Agency (FHFA), provides guidance for how the Enterprises will serve very low-, low- and moderate-income households in three historically underserved markets:

- Manufactured housing: Exploring innovative financing options for one of the largest affordable housing opportunities
- Affordable housing preservation: Helping keep established properties available as low-cost housing alternatives
- Rural housing: Supporting the financing of housing for targeted high-needs rural regions and populations

AFFORDABLE HOUSING PRESERVATION

Energy or water efficiency improvements is a Regulatory Activity under the Affordable Housing Preservation market. According to the Rule, "Enterprise support for financing of energy or water efficiency improvements is eligible for Duty to Serve credit provided there are projections made based on credible and generally accepted standards that (1) the improvements financed by the loan will reduce energy or water consumption by the homeowner, tenant, or the property by at least 15 percent, and (2) the utility savings generated over an improvement's expected life will exceed the cost of installation."

1 U.S. Census Bureau; Campaign for Home Energy Assistance, "Investing in LIHEAP – Why Energy Assistance Is More Important Than Ever," March 2014
2 https://www.theatlantic.com/business/archive/2016/06/energy-poverty-low-income-households/486197/
3 https://www.nrdc.org/experts/khalil-shahyd/study-highlights-energy-burden-households-and-how-energy-efficiency-can-help
4 Ibid (footnote 2)
5 http://www.insidesources.com/green-energy-poverty/
6 "Energy Trust of Oregon Nest Thermostat Heat Pump Control Pilot Evaluation," Apex Analytics LLC, October 2014, p. 10. https://www.energytrust.org/documents/evaluation-nest-thermostat-heat-pump-control-pilot/

PROPOSED STUDY

Fannie Mae proposed, as part of its 2018-2020 Underserved Markets Plans to FHFA, to invest in research, data collection, and analysis in order to improve the market and Fannie Mae's understanding of consumer sentiment, needs and opportunities, future trends, business models, and factors driving Improvements and outcomes. Furthermore, Fannie Mae committed to publishing the information gathered to bring clarity to the marketplace.

As part of that research, Fannie Mae sought to study the effects of smart thermostats on homeowner energy and financial savings. If smart thermostats could save enough energy and provide enough financial benefit, Fannie Mae could have a basis for including smart energy products, such as smart thermostats, in new home loan products to make housing more affordable.

The study focuses on the impact of smart thermostats on financial health as measured by FICO scores. Initially, the proposed study considered additional financial health indicators, including delinquency rates, HELOC utilization, and revolving credit utilization, but these were ultimately not examined.

The research questions guiding the research were as follows:

RESEARCH QUESTIONS

1. Do smart thermostats have an impact on homeowner financial health?
2. Does that financial impact vary by geography (climate), financial position (income), or when the thermostat was installed (calendar month)?
3. Do smart thermostats have an impact on homeowner perceptions of financial and/or energy savings and related behaviors?

STUDY DESIGN

OVERVIEW

Fannie Mae hired the San Francisco-based, built-environment innovation and strategy firm, MKThink, to execute the study in partnership with Google Nest and Motili.

Fannie Mae designed the study to be a randomized, controlled study of very low-, low-, and moderate-income (< 100% Average Median Income, or AMI) HomeReady home loan borrowers[1].

Some of the borrowers received the opportunity to participate in a national energy-savings campaign featuring a Nest Thermostat E Smart home thermostat installation. Others did not receive the opportunity and were instead included in the randomized, control group.

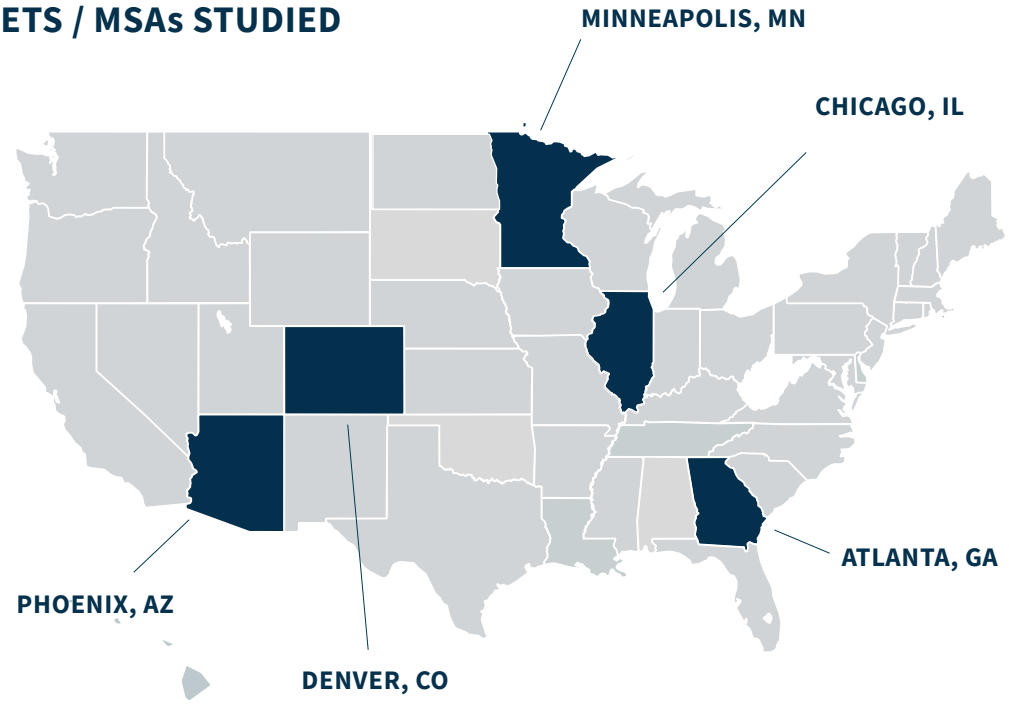
The Nest thermostats were installed between August 2018 and April of 2019. Each month, starting from August 2018, credit bureau data (CBD) was collected by Fannie Mae on selected research segments, which included month of year, AMI, and Metropolitan Statistical Area (MSA) as well as loan-level FICO differences. Additionally, quarterly, surveys were sent out to the treatment group to understand the self-reported impact of the thermostats on their energy and financial perceptions and behaviors.

The study estimates the Intent-to-Treat (ITT) effect of offering a free Nest Thermostat E on FICO scores by comparing the Offer group as a whole to the Control group. In this way, we avoid the pitfall of comparing outcomes across groups where households may have systematically "self-selected" in, on the basis of traits that may themselves be driving FICO migration. Where we find a significant ITT effect, we rescale the ITT estimate to infer the effect of the Treatment-on-Treated (TOT); i.e., effect of the Nest Thermostat E among those who accepted the offer. Where the ITT effect was not significant, no TOT analysis was conducted.

To maintain privacy and anonymity, no identifiable loan-level, financial information was ever shared and no study segment had fewer than fifteen loans.

1 HomeReady is Fannie Mae's affordable, low down payment mortgage product designed for creditworthy borrowers.

US MARKETS / MSAs STUDIED



STUDY SEGMENTS

Fannie Mae started with a goal of treating 1,000 HomeReady borrowers across 5 US markets. Over 15,000 borrowers were evaluated, and 1,000 were randomly set aside for the **Control** group (200 per MSA). Of that group, 757 were used in the final analysis.

The remaining borrowers were included in outreach and referred to as the **Offer** group. This group was given the chance to join a national energy savings study in which they could have a Nest Thermostat E professionally installed free-of-charge for both the device and installation. Fannie Mae conducted three waves of outreach over nine months, leading to 578 confirmed members of the treatment group referred to in this study as **Accepters**. Those that did not opt-in to the study and did not have a Nest Thermostat E installed were called **Decliners.** Both the Accepters and Decliners make up the Offer group as detailed in the table below.

Finally, there was attrition of 0-3% of the FICO records monthly during the study. All groups were affected but by no more than 20% in total.

Average start FICO per MSA across all AMIs, and the number of borrowers per MSA across each AMI segment

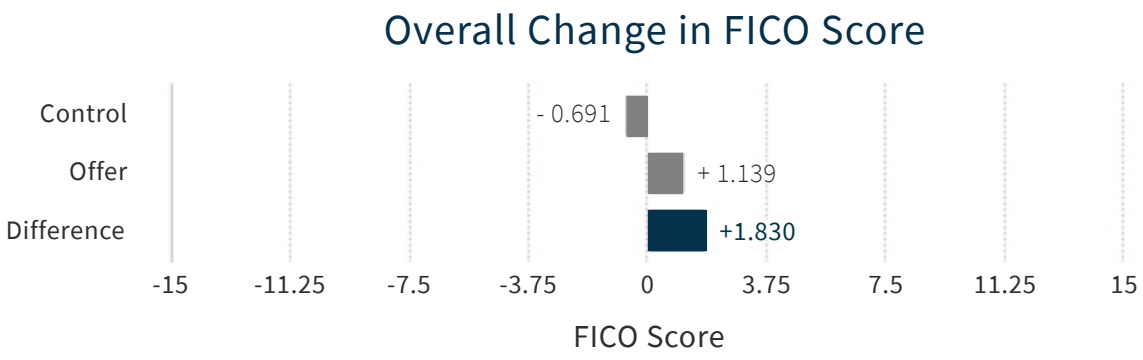
OFFERED (n)	FICO START	AMI81-100	AMI51-80	AMI <=50	Total
MSA Atlanta	719	652 (6%)	1,440 (13%)	363 (3%)	2,455 (22%)
MSA Chicago	717	682 (6%)	1,371 (12%)	398 (4%)	2,451 (22%)
MSA Denver	735	662 (6%)	863 (8%)	89 (1%)	1,614 (14%)
MSA Minneapolis	734	606 (5%)	1,650 (15%)	527 (5%)	2,783 (24%)
MSA Phoenix	725	636 (6%)	1,155 (10%)	275 (2%)	2,066 (18%)
Totals		**3,238 (28%)**	**6,479 (57%)**	**1,652 (15%)**	**11,369**
ACCEPTERS (n)	**FICO START**	**AMI81-100**	**AMI51-80**	**AMI <=50**	**Total**
MSA Atlanta	722	43 (7%)	94 (16%)	17 (3%)	154 (27%)
MSA Chicago	728	30 (5%)	43 (7%)	22 (4%)	95 (16%)
MSA Denver	754	40 (7%)	50 (9%)	8 (1%)	98 (17%)
MSA Minneapolis	739	31 (5%)	76 (13%)	23 (4%)	130 (22%)
MSA Phoenix	741	36 (6%)	56 (10%)	9 (2%)	101 (17%)
Totals		**180 (31%)**	**319 (55%)**	**79 (14%)**	**578**
DECLINERS (n)	**FICO START**	**AMI81-100**	**AMI51-80**	**AMI <=50**	**Total**
MSA Atlanta	719	609 (6%)	1,346 (12%)	346 (3%)	2,301 (21%)
MSA Chicago	717	652 (6%)	1,328 (12%)	376 (3%)	2,356 (22%)
MSA Denver	734	622 (6%)	813 (8%)	81 (1%)	1,516 (14%)
MSA Minneapolis	734	575 (5%)	1,574 (15%)	504 (5%)	2,653 (25%)
MSA Phoenix	724	600 (6%)	1,099 (10%)	266 (2%)	1,965 (18%)
Totals		**3,058 (28%)**	**6,160 (57%)**	**1,573 (15%)**	**10,791**
CONTROL (n)	**FICO START**	**AMI81-100**	**AMI51-80**	**AMI < 50**	**Total**
MSA Atlanta	722	36 (5%)	78 (10%)	20 (3%)	134 (18%)
MSA Chicago	713	47 (6%)	87 (11%)	20 (3%)	154 (20%)
MSA Denver	742	59 (8%)	88 (12%)	11 (1%)	158 (21%)
MSA Minneapolis	739	33 (4%)	87 (11%)	39 (5%)	159 (21%)
MSA Phoenix	726	39 (5%)	99 (13%)	14 (2%)	152 (20%)
Totals		**214 (28%)**	**439 (58%)**	**104 (14%)**	**757**

RESULTS

RESEARCH Q1: DO SMART THERMOSTATS HAVE AN IMPACT ON FINANCIAL HEALTH?

Those that were offered a smart thermostat, including 578 of whom participated in the treatment group, saw their FICO scores increase +1.83 points compared to the control group. (p-value = 0.38; not significant)

Based on the results from this study, smart thermostats ***may*** have an impact on financial health as measured by FICO score but the observed effect in this study was **not** significant.



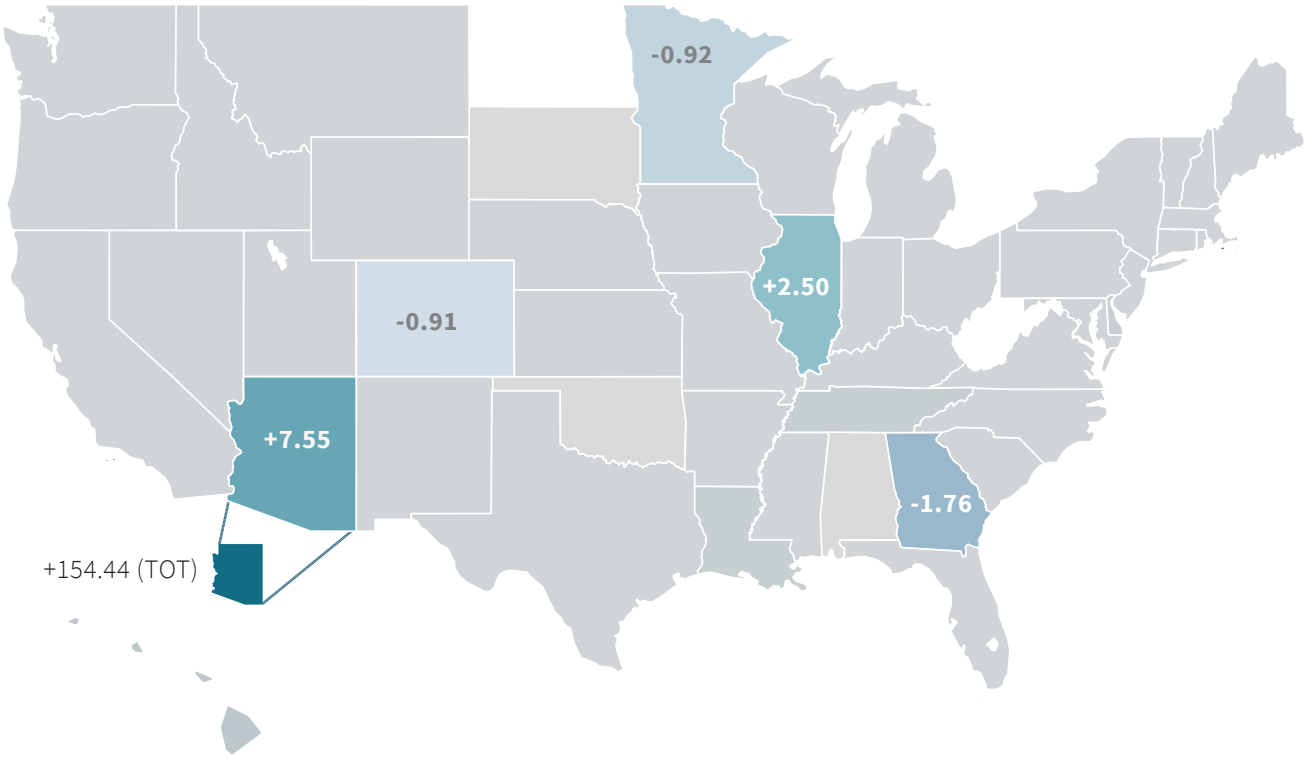
	Overall
Study Period	Sep 01, 2018 - Sep 30, 2019
Offered (n)	11,369
Control (n)	757
Accepters (n)	578
Test	1-way ANOVA
Alpha (significance level)	0.10
p-value	0.38
Significant? (yes/no)	no

RESEARCH Q2.1: DOES THE FINANCIAL IMPACT VARY BY GEOGRAPHY (CLIMATE)?

The Offer group in MSA Phoenix showed the greatest increase in FICO scores relative to Control at +7.55 points. This translates to an estimated effect of the Treatment on the Treated of +154.44 points. (p-value = 0.05; significant)

Based on the results from this study, geography had an impact on financial health as measured by FICO score. It is likely that climate played a role in these results with Phoenix having the highest number of Cooling Degree Days (CDD), a key factor in HVAC use.

Scaling the observed FICO increase in the Offered group by the ***treatment receipt rate*** (the ratio of the Accepters to Offered), implies a treatment effect on the treated portion of the sample (TOT) to be +154.44 points (Standard Error (SE)=79.57).



	Atlanta	Chicago	Denver	Minneapolis	Phoenix
Offered (n)	2,455	2,451	1,614	2,783	2,066
Control (n)	134	154	158	159	152
Accepters (n)	154	95	98	130	101
Test	**1-way ANOVA**				
Alpha (significance level)	0.10				
P-value	0.68	0.53	0.80	0.77	0.05
Significant? (yes/no)	no	no	no	no	yes
Weather Data					
Weather Station	KATL	KORD	KDEN	KMSP	KPHX
Heating Degree Days (HDD)	3,051	7,488	7,641	9,071	1,628
Cooling Degree Days (CDD)	2,339	850	963	704	4,738

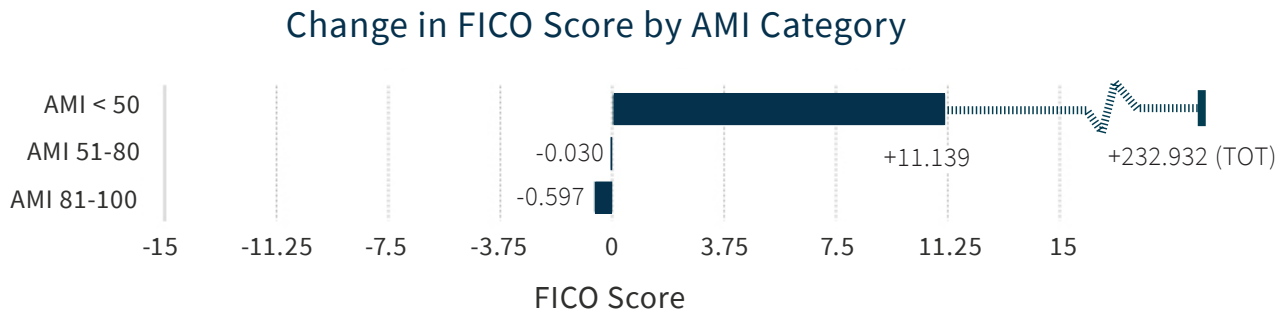
RESEARCH Q2.2: DOES THE FINANCIAL IMPACT VARY BY FINANCIAL POSITION (AMI)?

The very low-income borrowers (AMI < 50) had the greatest increase in FICO score +11.3 points (ITT). This translates to an estimated effect of the TOT of +232.932 points.

(p-value = 0.02; significant)

Based on the results from this study, the financial impact does vary by AMI. This suggests that those borrowers with least amount of income benefit the most from having an energy-saving device, like a smart thermostat, in their homes.

Since the effect observed in the ITT analysis was significant, scaling the FICO increase in the Offered group by the ***treatment receipt rate*** (the ratio of the Accepters to Offered), implies a treatment effect on the treated portion of the sample (TOT) to be +232.932 points (Standard Error (SE)=98.890).



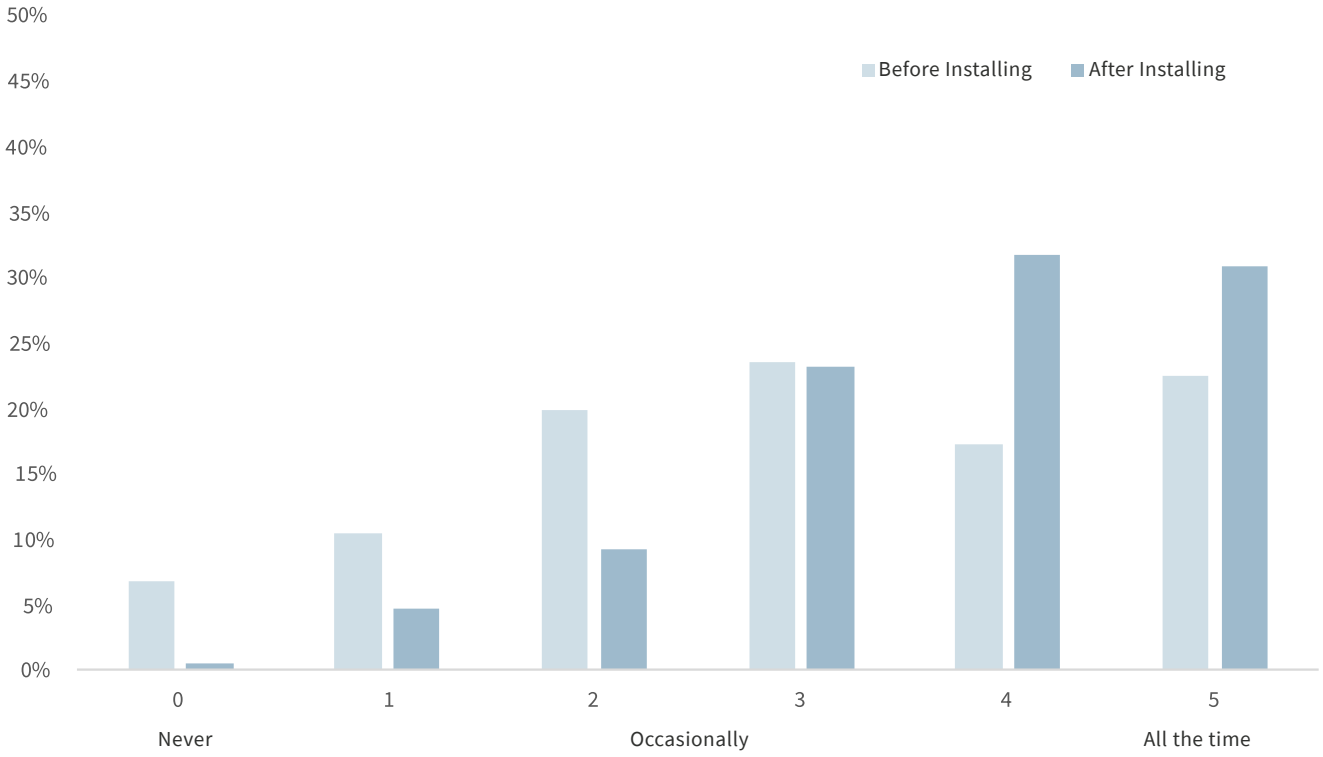
	AMI 81-100	AMI 51-80	AMI <=50
Offered (n)	3,238	6,479	1,652
Start FICO	725	727	721
Control (n)	214	439	104
Start FICO	731	727	730
Accepters (n)	180	319	79
Start FICO	743	734	724
Test	1-way ANOVA		
Alpha (significance level)	0.10		
p-value	0.86	0.93	0.02
Significant? (yes/no)	no	no	yes

RESEARCH Q3.1: DOES A SMART HOME THERMOSTAT IMPACT ENERGY-SAVINGS PERCEPTIONS?

After installing a Nest Thermostat E, 25% more borrowers reported "paying attention" to their energy use "Occasionally" to "All the time."

Based on the results from our surveys, the presence of a smart thermostat does seem to increase people's awareness of their energy use, which could potentially act as a leading indicator of future energy savings and subsequent financial health improvement. (Note: Surveys were only sent to Accepters.)

HOW OFTEN DID YOU PAY ATTENTION TO YOUR HOUSEHOLD ENERGY USE BEFORE AND AFTER INSTALLING?

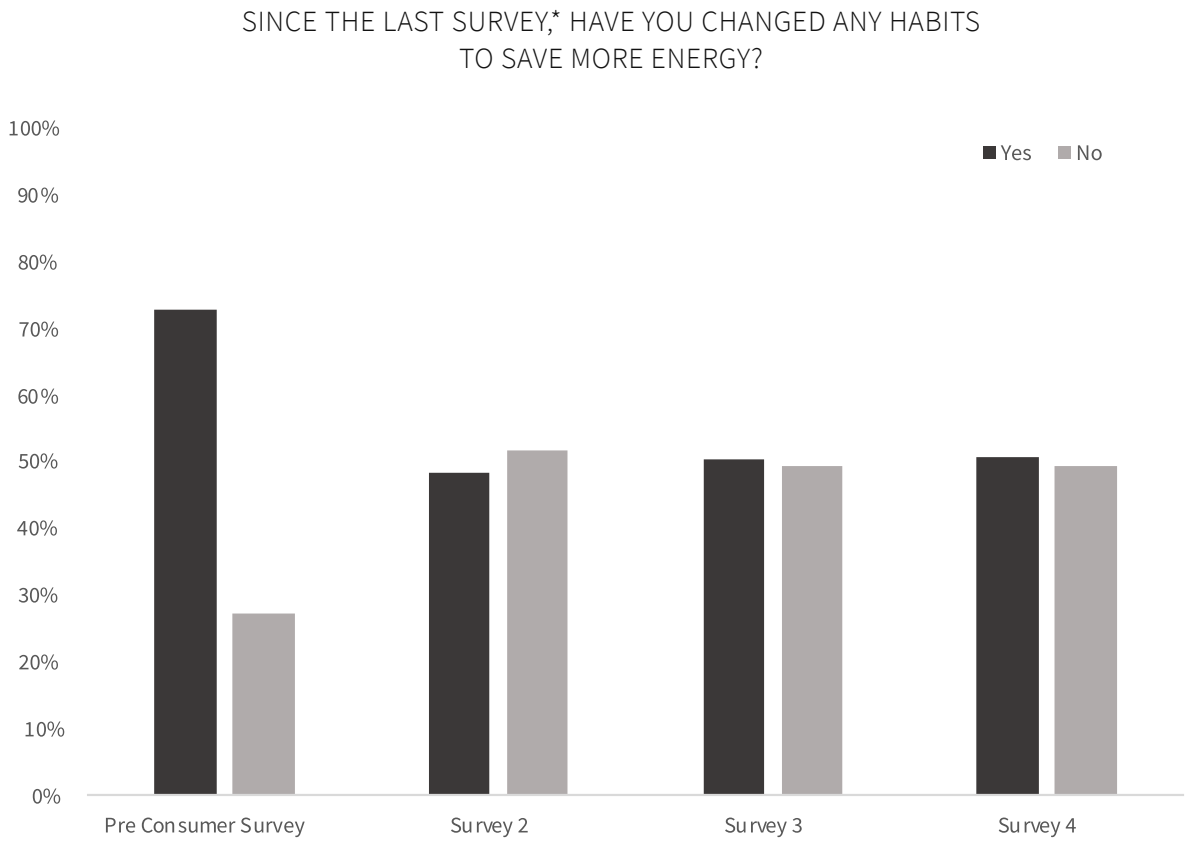


Respondents (n)	405
Survey Period	April 2019

RESEARCH Q3.2: DOES A SMART HOME THERMOSTAT IMPACT ENERGY-SAVINGS BEHAVIORS?

After installing a Nest Thermostat E, almost 70% of respondents self-reported changing habits to "save energy," which continued each month at a rate of approximately 50%.

Based on the results from our surveys, the presence of a smart thermostat does seem to lead to continued energy-savings behaviors in the home. However, since there is no control group for the surveys, and the surveys were only sent to the Accepters, it is impossible to know if these responses are significant.



*The first survey replaced the words "Since the last survey" with "After installing a Nest"

Respondents (n)	405	188	105	128
Survey Period	Apr 2019	Jul 2019	Nov 2019	Apr 2020

ADDITIONAL FINDINGS & THOUGHTS

In addition to the treatment findings revealed through data analysis and surveys, there were broader programmatic findings as well.

Outreach conversion was low (7%)

The research team was surprised by the low "open-rates" of the outreach emails and the overall low registration rates for a free program. Working with a homebuyer education provider that has had contact with the borrowers prior to their loan closing, the research team anticipated a higher open rate of emails sent by that group. However, the open rate averaged only about 6% across each wave of the email campaign, which included three to five emails per wave. It appears that once borrowers moved into their homes and were more than 6 months out from their last contact with the homebuyer education provider, they were much less likely to open emails.

Additionally, the research team was surprised that the "opt-in" rate (7%) wasn't higher given that the program was offering a free energy-savings device with a strong brand reputation. The team suspects this might have had to do with the perceived hassle of signing up and coordinating with an installer.

Self-Install rates were low one month after shipping (< 20%)

In the final months of outreach and deployment, the research team made a decision to ship 112 Nest Thermostat E devices directly to borrowers who had registered for the study but had had issues coordinating a professional install. These borrowers had not explicitly expressed that they no longer wanted to be included in the study, as some had. However, after one month from shipping the thermostats, less than 20% were showing up as "online" (connected to the internet) when an aggregate data request was issued to determine the "online" rate. This does not mean, definitively, that the thermostats were not installed; however, with the low certainty around installation completion, these borrowers were not included in the final analysis.

Update: As of November 17, 2020, 57% of those Nest Thermostat E devices were online. The research team learned that relying on self installation may delay the data analysis start time, as homeowners may need more than one month to complete installation.

LIMITATIONS

While the study resulted in several useful and even significant findings, there were certain limitations that are opportunities to be addressed in the future. Those limitations include:

- Uncertainty around confounding factors such as Nest devices previously installed, or installed in Control households during the study period
- Missing financial records, which increased as the study progressed (0-3% monthly), likely due to loan pay offs. We adjusted for this by removing the final 6 months from review to ensure >80% of records were intact. We cannot rule out that household attrition may itself be related to FICO migration.
- Fewer treatment loans than originally anticipated
- Rolling installation months that complicated analysis

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