

Picking Up the PACE: Loans for Residential Climate-Proofing*

Aymeric Bellon[†] Cameron LaPoint[‡] Francesco Mazzola[§] Guosong Xu[¶]
UNC Chapel-Hill Yale SOM ESCP Europe Erasmus RSM

April, 2024

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Abstract

Residential Property Assessed Clean Energy (PACE) loans are a new class of financial contract, whereby homeowners borrow to fund green residential projects and repay the loan via their local property tax payments. We assess equity-efficiency trade-offs of PACE using loan-level data from Florida merged to property transaction, tax, and permitting records. Consistent with the program’s objectives, borrowers are more likely to obtain permits related to disaster-proofing homes, and loan takeup is concentrated in areas with higher *ex ante* and *ex post* natural hazard risk. Such investments are capitalized into home values, but expansions of the property tax base are partially offset by an uptick in tax delinquency rates among borrowers. Although PACE loans are super senior to other debt, lenders expand their provision of mortgage credit in PACE-enabled counties. Enabling PACE loans increases the fiscal income of participating local governments while closing the investment gap in projects which improve the climate resiliency of the housing stock.

Keywords: PACE lending, property taxes, green retrofitting, home equity loans, delinquency, liens, securitization, natural disasters

JEL classifications: G21, G51, Q54, R21, R28

*We thank two large Florida residential PACE districts for providing us with loan-level data. We thank audiences at Peking University for helpful comments. We are grateful to Barbara Esty for assistance accessing the CoreLogic data through Yale University Library. We thank representatives from CoreLogic for answering our questions about their data products. This research was financially supported by the Yale International Center for Finance and Yale Tobin Center for Economic Policy. Farhan Baig, Logan George, Stevan Kamatovic, Jakob Reinhardt, and George Li Wang provided excellent research assistance. We are currently processing loan-level data from additional PACE lenders and counties across Florida and California.

[†]UNC Chapel Hill, Kenan-Flagler Business School. Email: aymeric_bellon@kenan-flagler.unc.edu; Web: <https://www.aymericbellon.com>

[‡]Yale School of Management. Email: cameron.lapoint@yale.edu; Web: <http://cameronlapoint.com>

[§]ESCP Europe. Email: fmazzola@escp.eu; Web: <http://www.francescomazzola.org>

[¶]Erasmus University, Rotterdam School of Management. Email: xu@rsm.nl; Web: <https://guosongxu.github.io>

1 INTRODUCTION

The operations of buildings accounted for 26% of global energy-related emissions in 2022 ([International Energy Agency, 2023](#)), and 1 in every 10 homes in the United States was impacted by some degree of natural hazards in 2021 ([CoreLogic, 2022](#)). To reduce the current and projected future costs of climate change, several states in the U.S. have enacted laws allowing residential Property Assessed Clean Energy (PACE) loans. PACE loans are a new class of financial contract designed to increase investment in projects aimed at improving residential energy efficiency and climate resiliency, such as solar panel and hurricane-proof window installations. Specialized lenders known as “administrators” partner with local jurisdictions (e.g., counties) that decide to opt into the PACE program, and borrowers pay off loans through their local property tax bill. The overall amount of residential PACE financing has grown more than sixfold since 2005, reaching approximately \$8.5 billion in originations by the end of 2022.

There is substantial disagreement about the economic merits of PACE loans among practitioners and policymakers. Anchoring the liability of green investment to local property tax payments could relax households’ financial constraints, as it offers a new method to pledge future savings coming from energy-efficient and climate-resilient investments, which have higher discount rates stemming from long payback periods ([Giglio et al., 2021](#); [Hovekamp and Wagner, 2023](#)). However, because they operate through the property tax system, PACE liens are super senior to other pre-existing and future debt liens such as mortgages and cannot be discharged through personal bankruptcy ([LaPoint, 2023](#)). Due to this super seniority and lax screening of applicants relative to Home Equity Lines of Credit (HELOCs), critics have argued that access to PACE financing could result in crowd-out of existing mortgage credit and higher mortgage delinquency rates ([Consumer Financial Protection Bureau, 2023](#)).

This paper provides the first micro-level empirical estimates of the pecuniary benefits and costs of offering PACE loans. We present four key findings. First, households are more likely to use PACE loans following major natural disasters and in places with historically large property damages incurred by natural disasters, consistent with the view that they are used more when households’ investment opportunities increase. Second, PACE-financed investments contribute to an increase in home values. Third, lenders increase their supply of traditional mortgages when a county opts into PACE, as higher home price growth increases their collateral recovery values. Fourth, despite an uptick in tax delinquency rates among borrowers, simple back-of-the-envelope calculations suggest that the PACE programs generate an increase in net fiscal income for local governments.

A key contribution of our paper is that we construct a dataset where we observe economic outcomes of PACE investments at the property owner level, which is rare in analyses of residential climate resilience and adaptation policies. We obtain a sample of over 16,000 PACE loans originated in Florida by a coalition of three large residential PACE lenders between

2015 and 2023.¹ Florida is particularly relevant for assessing the returns to climate-resilient home improvement projects given the increasing prevalence of severe storms in the state and resulting explosion in home insurance costs affecting residents.² We link each loan to borrower and property-level data from the CoreLogic database. The CoreLogic data allow us to observe household economic outcomes, such as housing transactions, home equity-secured loans, building permit issuance, tax delinquency, and other liens such as bankruptcy judgments. Home improvement project descriptions recorded by town clerks on permit applications allow us to classify PACE-funded projects into disaster-proofing vs. energy efficiency categories. The largest fraction of PACE permits are for impact-resistant window and door installations (22%) and roofing repairs or reinforcements (22%), with smaller percentages attributed to solar panel (15%) and modern Heating, Ventilation, and Air Conditioning (HVAC, 11%) installations. In contrast, for non-PACE residential permits over the same time period, over half fall outside these four categories of projects explicitly eligible for PACE financing.

A particular advantage of having detailed microdata is that we can leverage the staggered rollout of PACE across Florida counties and households over our sample period. We deploy a battery of modern difference-in-differences (DiD) estimators for staggered treatment to account for the fact that the treatment and control groups do not remain stable over time. In our PACE loan-level analysis we use two empirical approaches. In the first design, we compare early to late PACE borrowers via [Callaway and Sant’Anna \(2021\)](#)’s estimator, which, with the inclusion of neighborhood-specific time trends, helps us hold fixed the relative subprimeness of the PACE borrower pool. To bolster the validity of this research design, we show that properties of early vs. late cohorts of PACE borrowers are statistically similar on observable characteristics which proxy for property quality. In the second empirical approach, we compare delinquency rates for PACE borrowers to those for HELOC borrowers. This second comparison addresses concerns that later PACE borrowers are not similarly creditworthy to earlier borrowers. There is no never-treated or not-yet-treated group in this second comparison, because PACE access applies to the entire county, and homeowners can apply for PACE after obtaining a HELOC. Accordingly, in this second design, we estimate average treatment effects on the treated (ATT) via the stacked DiD estimator proposed by [Cengiz et al. \(2019\)](#).

We discipline our tests with a simple conceptual framework where PACE loans reduce households’ financial constraints. If PACE loans improve households’ ability to invest in projects that increase their net wealth, then we should observe greater participation when the cash flows associated with investments in climate-related projects are greater. PACE-financed home improvement projects that increase the home’s resistance to natural disasters may be positively capitalized into home values. This growth in home prices should lead to an expanded supply

¹There are no official data providers of PACE-financed investments. Administrators report loans into coalitions, called PACE districts or agencies, on a voluntary basis. Since PACE loans are implicitly backed by property tax revenues and municipal bond issues, counties and local courts retain basic information about the existence of PACE liens. However, complete information about loan contract terms is not part of the public record in the majority of counties.

²Annual premia for homeowners policies in Florida tripled between 2018 and 2023, increasing annually by 42% in 2023 alone ([Bloomberg, 2024](#)).

of traditional mortgages. As financially constrained households are at the margin riskier, we should observe higher *ex post* realized risks. We find empirical support for all these predictions.

We show that PACE loan takeup is stronger when the cash flows from investing in climate-related projects are greater in expectation. We use the historical distribution of county-level damages from natural disasters to proxy for higher returns to invest in climate-related resilience projects, such as hurricane impact-resistant windows. Using this proxy, we show that PACE loan participation increases faster in these areas. Next, we adopt an empirical design that isolates plausibly exogenous variation in the returns to invest in climate-related resilience projects. We focus on the sample of residential properties that adopted a PACE loan around Hurricane Irma in 2017. We find that PACE loan takeup increases by a factor of two at the individual level due to higher local property damage caused by Hurricane Irma. This finding provides evidence that households rely more on PACE loans when they experience an expansion of their investment opportunities, that is, when they have to reconstruct part of their home following a natural disaster.

These projects financed by PACE loans increase the house's value. Specifically, repeat sales properties undergoing PACE-funded home improvement projects experience an average appreciation in home sale prices of 35%. This implies that, holding fixed any time-invariant quality differences across homes, PACE projects generate an average return on investment of between 2x and 3x, with slightly lower returns after taking into account discounting, permitting fees, loan origination costs, and growth in households' property tax bills over time.

Financially constrained households are more likely to be riskier at the margin, which implies that we should observe more *ex post* default for these groups. We show that households taking up a PACE loan are more likely to be delinquent on their property tax bills by 1 p.p. (a 12% increase) within a year of origination, and by 2.5 p.p. (a 30% increase) within three years of origination, relative to HELOC borrowers with comparable properties. This rise in delinquency is driven by borrowers with long tenures in their home without an escrow account, for whom tax payments are not on autopilot (Cabral and Hoxby, 2012).

Mortgage lenders increase their credit supply for counties that opt into the PACE program. This is consistent with the view that increased home equity values due to investment in PACE-qualified projects improves lenders' recovery rates. To show this result, we use loan application information from Home Mortgage Disclosure Act (HMDA). Our identifying assumption is that counties passed, in a quasi-random fashion, formal legislation allowing PACE administrators to begin underwriting loans. Reassuringly, we uncover similar results pointing to increases in mortgage credit provision regardless of whether we use never-treated counties (Sun and Abraham, 2021) or not-yet-treated (de Chaisemartin and D'Haultfoeuille, 2020) counties as the control group. These effects are economically significant; PACE adoption in a county results in a 3 p.p. higher approval rate for both first-lien home purchase and refinance loans, representing a 4% increase in loan approvals. The lack of crowd-out in this context occurs because lenders increase their approvals of loans to higher loan-to-income (LTI) borrowers.

Our empirical estimates can be combined via a back-of-the-envelope calculations to determine the desirability of adopting PACE from the perspective of local governments. Subtracting our estimate of household tax delinquency rates – which results in losses of tax income for a county – from the expansion of the property tax base through capitalization into housing values translates to higher per capita tax revenue for a county of \$694 per PACE loan-year.³ Thus, although some PACE borrowers may be worse off from experiencing greater, and apparently unanticipated, annual tax burdens, local governments and prospective mortgaged homebuyers in PACE counties benefit from program adoption.

Our paper extends the literature that studies debt contracts aiming to improve energy efficiency and climate resilience by focusing on households rather than firms. Examples of financial contracts targeting corporate sustainable investment include corporate green bonds (Zerbib, 2019; Tang and Zhang, 2020; Flammer, 2021; Baker et al., 2022b), sustainability-linked bank loans (Kim et al., 2022), and blended financing structures (Flammer et al., 2023). We depart from this literature by studying a new class of loan contracts, namely PACE loans, which represent a public-private partnership in providing nudges which encourage households to internalize externalities of climate change adaptation.

We build on research documenting the energy efficiency gap, as described in Gerarden et al. (2017) and Jaffee et al. (2019), and on policies put in place to reduce it. Previous papers examine the role of efficiency standards (Hausman and Joskow, 1982; Clara et al., 2022), building energy codes (Jacobsen and Kotchen, 2013; Levinson, 2016), energy subsidies (Fowlie et al., 2015; Houde and Aldy, 2017; Fowlie et al., 2018; Hahn and Metcalfe, 2021), appliance rebate programs (Davis et al., 2014), as well as certification and labeling (Eichholtz et al., 2010; Myers et al., 2022; Lu and Spaenjers, 2023).⁴ Several papers document low participation in residential energy efficiency programs despite the environmental benefits and positive private returns (Fowlie et al., 2015, 2018). A key factor that affects household participation in environmental retrofit projects is credit constraints (Berkouwer and Dean, 2022).

Relative to work on the energy efficiency gap, our paper provides the first empirical evidence that residential PACE loan programs democratize household access to borrowing for green property retrofits, especially for individuals facing *ex ante* binding financing constraints. This, in turn, improves the value of real estate assets, leading to further expansions in household borrowing capacity (Favara and Imbs, 2015; Zevelev, 2020; Mazzola, 2022). Another defining feature of PACE is that unlike other green policy nudges, it operates through relaxed screening standards rather than by subsidizing credit, since PACE loans carry higher fees and interest rates than comparable home equity loans (Consumer Financial Protection Bureau, 2023).

Our findings provide the first policy evaluation of local PACE programs with estimates on both the costs and benefits side. Our work provides an empirical microfoundation for the

³We assume that 100% of the tax delinquencies are paid by the local government. This is a strong assumption, as PACE loans can be backed by municipal bond issues purchased by private investors (e.g. insurance companies), which attenuates our finding of a positive fiscal effect.

⁴A related literature studies mortgage markets and climate risks. See, for instance, Issler et al. (2020); Gete et al. (2024).

macroeconomic modeling simulations of commercial PACE loans in [Rose and Wei \(2020\)](#) by combining data covering the major stakeholders: governments, PACE borrowers, non-PACE homeowners, and lenders.⁵ We also provide a large-scale analysis of PACE loans, thus establishing the external validity of [Goodman and Zhu \(2016\)](#), who examine sale prices for a subsample of 773 California houses with a PACE lien. Other related work includes [Eichholtz et al. \(2010\)](#) and [Jaffee et al. \(2019\)](#), who study the energy performance of commercial real estate, whereas we examine the residential property market. [Millar and White \(2024\)](#) observe a slowdown in county-level house price growth when counties roll out residential PACE programs. We show that this result cannot be driven by houses with a PACE lien, as we instead observe an increase in prices for such properties sold after their owners takeout a PACE loan.

The results of our paper generally align with those in the literature on the capitalization of green investments into house prices ([Dastrup et al., 2012](#); [Aydin et al., 2020](#); [Gillingham and Watten, 2024](#)). A distinguishing feature of our analysis is that we leverage granular data on building permits that allows us to document home improvement projects motivated by disaster-proofing rather than only energy efficiency concerns. This is important given recent evidence that insurance markets in regions like coastal Florida are unraveling due to insurers exiting ([Sastry et al., 2024](#)), resulting in home and flood insurance premia rapidly rising in areas where PACE loans are also prevalent ([Keys and Mulder, 2020](#)). We provide evidence that private mortgage lenders respond by increasing credit supply, even though mortgages are junior to PACE liens and cannot be securitized through purchase by government-sponsored enterprises (GSEs). Consistent with our conceptual framework, this suggests the benefits of lower physical risk to collateral due to PACE-financed improvements may outweigh losses of liquidity due to lack of debt seniority and reduced securitization options.

Finally, our paper adds to the economics and finance literature on environmental liability by studying a new class of liens that applies to households instead of firms. Most papers in this literature have studied the impact of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) liens on firm investment and borrowing decisions. A CERCLA lien is a federal lien issued when a contaminated facility is cleaned up. Research has documented how the priority and responsibility of these clean-up costs affect firms' *ex ante* decisions. For instance, [Bellon \(2021\)](#) studies how the exposure of secured lenders to CERCLA clean-up costs affects firms' behaviors. [Akey and Appel \(2021\)](#) look at parent companies. [Chen \(2022\)](#) studies purchasers' liabilities, and [Ohlrogge \(2022\)](#) investigates different priority rules of environmental clean up claims under the Resource Conservation and Recovery Act. Our paper complements this literature by studying liens that back a different set of projects, namely resilience and energy efficiency investments in residential property, rather than clean-up activities.

The rest of the paper is structured as follows. Section 2 provides institutional background on the origins and structure of residential PACE programs. Section 3 describes our real estate

⁵There are large structural differences between our setting and that in [Rose and Wei \(2020\)](#). First, [Rose and Wei \(2020\)](#) is concerned with the California commercial PACE program while our focus is on residential environmental retrofits. Second, we focus on household participation and tax revenue implications, rather than the general equilibrium effects of the PACE program on local economies.

and PACE loan-level data and how we merge the two. Section 4 traces out the effects of PACE adoption at both the individual and county levels on natural disaster exposure, home values, delinquency, and mortgage credit access. In Section 5, we combine our estimates to conduct a cost-benefit analysis of the program. Section 6 concludes with a discussion of the implications of our analysis for unraveling home insurance markets in areas imminently exposed to climate change like Florida.

2 BACKGROUND ON PACE PROGRAMS

In this section, we provide institutional details and outline a conceptual framework indicating how PACE programs could theoretically impact the economy.

2.1 INSTITUTIONAL DETAILS

General background. Credit access is a crucial factor in climate change mitigation and adaptation (Rajan and Ramcharan, 2023). Over the last two decades, 38 states in the U.S. have passed legislation and enabled PACE to provide financing for energy efficiency upgrades and disaster resiliency improvements for property owners. While most PACE programs focus on commercial properties, in three states (California, Florida, and Missouri) PACE financing is available to residential property owners. Based on data provided by PACE Nation (pacenation.org), Figure 1 shows that the aggregate size of the residential PACE loan market has sharply increased since its introduction around 2010. By the end of 2022, the total amount of residential PACE financing reached approximately \$8.5 billion. PACE loans can be applied towards a wide range of environmental retrofit and/or climate adaptation projects. These include projects that aim to reduce the home’s energy consumption (e.g., modern HVAC installations), increase the use of daylight, solar panel installations, or impact-resistant roofing, windows, or door replacements and repairs.⁶

[Insert Figure 1 about here]

PACE financing does not create a liability for local governments because the credit is provided through private capital or municipal bonds. PACE loans can be administered by a local government or a private entity on behalf of the local government. The private entity can be either a non-profit or for-profit and is typically referred to as a “district.” Lenders operating within that district are called “administrators.” Districts can also issue private bonds backed by the PACE loan payments borrowers make.

⁶Other disaster-proofing projects enumerated as a use for PACE funds include creating a secondary water barrier to prevent water intrusion or those reinforcing roof-to-wall connections. To qualify for PACE, projects must be undertaken by a certified or registered contractor.

We focus on the Florida residential PACE program, for which we obtain a detailed sample of loans from one of the largest residential PACE administrators.⁷ In Florida, state legislation (Chapter 163.08) has regulated PACE loans since July 2014. The Act refers to Chapter 2008-227, Laws of Florida, which explicitly states the role of PACE in the state’s comprehensive plan to reduce reliance on energy-intensive carbon emissions and increase the energy efficiency and conservation of all end-use sectors. Given this goal, the Florida legislature has recognized the “compelling state interest” to provide additional financial means for property owners to undertake energy improvement projects attached to their homes.

County-level adoption. Figure 2 provides a map of counties classified by the current status of their residential PACE legislation. The figure highlights the prevalence of PACE programs across Florida, with most counties having enabled PACE financing at some point, except for a handful in the panhandle region. In 2011, Miami-Dade became the first Florida county to launch the program. The pace of adoption increased between 2015 and 2018, and by the close of 2020, the majority of large Florida counties implemented the program. Florida counties with PACE currently partner with four districts, each of which represents a coalition of administrators. There are currently six administrators operating in Florida.

[Insert Figure 2 about here]

To create Figure 2 and assign treatment date cutoffs, we track the progress of PACE adoption across all 67 Florida counties using a combination of local news stories about the entry of PACE districts, cross-referenced with LexisNexis links to the local property tax code and, whenever possible, by obtaining the dated list of PACE liens recorded with each county’s tax assessor’s office or the circuit court clerk, whichever is the applicable records custodian.⁸ This process also allows us to account for cases where PACE is in flux in a county due to legal challenges.⁹

Eligibility and rules. All homeowners are eligible for PACE loans, regardless of their credit score, as long as (i) the homeowner has paid all their property taxes and has not been delinquent over the preceding three years; (ii) there are no involuntary liens attached to the property, such as those imposed as a result of a bankruptcy court order; (iii) there are no notices of default or other property-based debt delinquency for the last three years; and (iv) the homeowner is the

⁷Compared to the Florida PACE program, the California PACE program has faced multiple statewide legal challenges, making it difficult to determine precise treatment statuses.

⁸For each county, the first PACE lien ever recorded occurs within the same year of statutory adoption. Most of our outcome variables come from local tax records or the public version of HMDA and are thus available at annual frequency, and so it makes no difference in our analysis whether we use the statutory adoption date or as the treatment date cutoff.

⁹In our main difference-in-differences analyses, we consider county-level PACE adoption to be an absorbing state even if there is a city or town within the parent county which attempts to nullify PACE. 10 counties have experienced such legal challenges, but all of them have continued recording new PACE liens, indicating that, from the lender’s perspective, there is continued legal ambiguity about which level of government has the ultimate authority to enable PACE. Our results are robust to simply excluding contentious PACE liens in such defector jurisdictions.

borrower for all mortgage debt secured by the property.¹⁰ Policymakers state that the unique design of PACE loans makes financing available to homeowners who are unable to obtain credit through traditional channels, such as home equity lines of credit (HELOCs), or to those who resist making investments due to the concern that they will have to repay the full loan amount when the property is sold or refinanced (Cox, 2011).

PACE loans provide qualifying home improvements with up to 100% financing.¹¹ Unlike other forms of financing, PACE credit is repaid in the form of property tax payments, and these payments are attached to the property rather than the borrower. Delinquent property tax payments with the PACE assessment take priority over other lienholders, such as a mortgage lender, making PACE loans super senior to other claims to the property used as collateral. Importantly, mortgage lenders cannot legally enforce a covenant related to a homeowner's decision to use a PACE loan. For example, they cannot demand payment in anticipation of the principal amount of the mortgage if the debtor obtains a PACE loan.

Single-family homes, condos, vacant residential land, and small multi-family buildings are all eligible for residential PACE loans. In our sample of PACE loans with permits, 91% are single-family homes, 5% are condos, and the remainder have a multi-family use. Properties also qualify for residential PACE loans if they start out with a non-residential land use and convert to residential through construction.¹²

Application process. Prospective PACE borrowers can apply directly through the website of a district or administrator (the lender) or indirectly through a registered contractor.¹³ If initiated through a contractor, the contractor forwards the quoted cost for the home improvement project and any permit information to the PACE lender operating in that area. Unlike traditional consumer credit products, under state guidelines lenders do not use credit scores to determine eligibility, which leads to lax screening compared to other home equity lines. However, lenders do perform a hard credit inquiry to determine whether the applicant satisfies the eligibility criteria, including whether they have a recent history of mortgage delinquency or bankruptcy.¹⁴

At the time of origination, the district involved in underwriting the loan sends the loan terms

¹⁰We find evidence of loose enforcement of the eligibility requirement that PACE borrowers not have a record of property tax delinquency in the three years preceding origination. Figure 3 shows that PACE borrowers are far more likely to have a recent local tax lien, despite there being no such requirement in place for HELOC borrowers.

¹¹Typically, the total PACE loan amount is limited to 20% of the (market) appraised property value by the county unless the mortgage lenders with a lien on the property consent to higher LTV loans. However, home improvements that show through an energy audit that the annual energy savings equal or exceed the annual repayment amount are not subject to this limit.

¹²Most counties offering residential PACE (R-PACE) also partner with districts and administrators specializing in commercial PACE (C-PACE) loans. The structure of C-PACE is very similar to R-PACE in that the owners pay back the loan through the local property tax assessment. Yet, since commercial properties are typically much greater in value there are multiple contributors to the capital stack. Hence, most PACE administrators specialize in either R-PACE or C-PACE loans.

¹³See, for example, the application tool from Florida PACE Funding Agency, one of the four districts: <https://floridapace.gov/apply/>.

¹⁴See, for instance, the PACE FAQs compiled by Palm Beach County's Office of Resilience: <https://discover.pbcgov.org/resilience/pages/pace-frequently-asked-questions.aspx>.

to the local tax assessor, who then generates a Notice of Assessment. The borrower is then CC'ed on this notice, which serves as a loan disclosure form. In many records offices, clerks attach to the loan contract a Notice of Commencement on the improvement resulting from the building permit, which mitigates the scope for fraud. Without this paper trail, borrowers might otherwise attempt to take out a PACE loan by listing an eligible project, but then use the funds for some other purpose. We show in Section 4.1 that the vast majority of PACE borrowers apply funds towards permitted projects within four major categories: HVAC, roofing, solar, and window and door upgrades.

Loan repayment. A defining feature of PACE is that the loans are government-backed. This means that the borrower repays through their annual local property tax assessment. Annual local property tax payments are based on an interest rate fixed at origination, and the payments fully amortize the loan, just like with a standard fixed rate mortgage.¹⁵ For single-family homes, the most common loan term is 30 years, the average origination amount is around \$25,000, and the average fixed interest rate is approximately 7%. This would imply an annual tax payment of \$2,014.66 towards the PACE loan balance.¹⁶ Local tax assessors separately itemize the PACE loan payment amount in each annual tax bill as a non-*ad valorem* assessment – in contrast to the property tax itself which is *ad valorem*. However, the *ad valorem* and non-*ad valorem* components are lumped together into a single tax liability. This means that if a primary mortgage lender requires the PACE borrower to submit a monthly payment into an escrow account, the total monthly mortgage payment will increase to cover the resulting increase in property taxes.

There are no prepayment penalties attached to PACE loans. Due to the super seniority of the PACE lien, lenders can require that borrowers pay off the PACE loan in full before refinancing or selling the property. In the event a borrower is overdue on their property tax bill, and thus becomes delinquent on the PACE loan, the only way they can remove the lien is by redeeming the tax debt. Because they follow the property (*in rem*) and not the individual (*in personam*), local tax liens cannot be discharged through personal bankruptcy (LaPoint, 2023).¹⁷ Hence, since the ultimate penalty for severe delinquency is tax foreclosure or forced sale of the property, strategic default motives are limited for PACE borrowers.

In Appendix A we offer examples of official PACE documents attached to recorded loans in Florida. We obtain these documents directly from local tax authorities, and they form the basis for the merged property-loan-level data we use in our empirical analysis of the program.

¹⁵See Appendix A for sample contracts.

¹⁶It is straightforward to compute the implied annual payment in Excel as $PMT(0.07, 30, -25000) = \$2,014.66$, where 30 is the loan term in years. Other common loan terms are 5, 10, 15, 20, and 25 years. The average interest rates rise and fall with overall economic conditions, with rates in 2023 averaging closer to 10%. There is no explicit index rate but the rates track 10-year Treasuries, just like a fixed rate mortgage.

¹⁷Tax liens cannot be discharged unless the house is abandoned. Moreover, only property taxes that are at least one year old can be discharged in personal bankruptcy.

2.2 CONCEPTUAL LINKS BETWEEN PACE AND PRIMARY MORTGAGE MARKETS

We present a highly stylized model in [Appendix B](#) that serves as a roadmap for our empirical tests. We summarize the economic intuition in this subsection. We build the framework on several features. First, PACE loans allow households to finance projects they would not have been able to finance otherwise because of credit constraints. A key characteristic of these projects is that, taken in isolation, they are illiquid. Households cannot sell the project financed with a PACE loan without selling the house. This characteristic is consistent with the type of projects allowed by PACE financing, such as a new roof or impact-resistant windows. Second, PACE loans are senior to mortgage debt. This seniority structure means that if the lender repossesses the house, then PACE liabilities are inherited by the lender. Third, without loss of generality, we assume that households default on their mortgage because of an exogenous income shock, consistent with the fact that pure strategic default is not a salient feature in the data. Households are strategic only to the extent that if they default, they do not repay their PACE and mortgage loans.¹⁸

PACE loans in the capital stack differentially influence lenders' recovery values and households' probability of default. On one hand, PACE loans increase the overall leverage of households. As income shocks are assumed to be exogenous, this higher leverage exposes households to a (weakly) higher default probability. On the other hand, PACE loans increase lenders' recovery value by allowing households to invest in projects that increase the home's value.

The supply of mortgages depends on these two opposite forces. Which of these two forces dominates, and ultimately, how PACE loan affects mortgage supply, depends on the project's net present value. If this value is high, then it means that the recovery value effects dominate the increased probability of default coming from higher leverage. While highly stylized, the conceptual framework's main prediction is that mortgage supply increases with the presence of a PACE loan if the project's net impact on the house price is high. We present evidence for this mechanism by showing that PACE liabilities increase household default, create large house price appreciation, and lead to a higher *ex ante* supply of mortgage lending.

3 DATA SOURCES AND DESCRIPTIVE STATISTICS

In this section, we describe how we link loan-level data from the Florida PACE market to property characteristics, building permits, mortgages, liens, and local damages caused by natural hazards. We compare property and borrower characteristics for PACE loans vs. home equity lines of credit (HELOCs), where the latter is the most similar alternative home equity loan contract which is typically used by borrowers to finance home improvement projects.

¹⁸While we assume the income shock as exogenous, we could easily interpret this exogenous income shock as correlated with a drop in house price, which would generate empirical predictions consistent with "double-trigger" models ([Ganong and Noel, 2023](#))

3.1 DATA SOURCES

We use four datasets in our main analysis. The first is residential PACE loan information between 2015 and 2023. The second is the suite of products from CoreLogic that we merge together to obtain detailed information on deeds transactions, bankruptcy and tax liens, and permit information. The third dataset is loan applications and approvals from the Home Mortgage Disclosure Act (HMDA) covering private lending. Fourth, the Spatial Hazard Events and Losses Database for the United States (SHELDUS) consists of information on the geographic span and severity of severe weather events for Florida during our PACE loan sample period.

PACE loan data. We obtain loan-level data from a large Florida PACE district representing three lenders. The data include 16,141 unique PACE loans originated in Florida since 2015. For each loan, we observe the property Assessor Parcel Number (APN), the signing date of the loan, and the origination amount. A property may be associated with multiple PACE loans. In our sample of PACE projects, we observe 15,266 unique properties (or APNs). For our analysis, we aggregate PACE loans at the year level for properties with multiple PACE loans to build a property-year panel dataset.

CoreLogic Data. We match the loan dataset to the CoreLogic *Owner Transfers* and CoreLogic *Tax* data using the APN of each property.¹⁹ *Owner Transfers* is a transaction-level dataset that includes information on house prices, buyers and sellers, and information about the use (e.g. single vs. multi-family) and location of the property. It also provides details on when properties are traded. We focus on arms-length transactions of single-family and small multi-family properties (i.e. those with fewer than 10 units) in our house price analysis. To eliminate the impact of extreme outliers, we winsorize transaction values at the 1st and 99th percentiles.²⁰

To obtain observable property characteristics, such as location and physical structure (size, bedrooms, age, etc.), we merge CoreLogic *Owner Transfers* to CoreLogic *Tax* using the CLIP ID, which is the concatenation of the APN, parcel sequence number, and geolocation. CoreLogic *Tax* contains the tax assessment record for each property, including properties which are ultimately exempt from paying property tax. This allows us to continuously track valuations and recorded improvements to the property for both PACE and non-PACE properties. An advantage to studying the Florida PACE market is that under state law, properties in Florida are revalued by the local assessor each year. This is in contrast to many other states which feature long intervals between mass revaluation of the property stock (e.g. every two years in Missouri).

We also obtain tax and bankruptcy lien data from CoreLogic’s *Involuntary Liens* database. We calculate tax delinquency rates by pooling together all local tax liens, including property tax

¹⁹CoreLogic recently renamed their legacy Deeds data product to *Owner Transfers*. The structure of the two datasets is the same, except the latter now has the unified panel identifier, a “CLIP,” which can be linked across CoreLogic datasets to construct a property-level panel.

²⁰We identify arms-length transactions in the CoreLogic *Owner Transfers* data as those which have the internal flag `PRI_CAT_CODE` set to “A,” indicating arms-length transfers. Our sample differs immaterially when we instead construct our own arms-length transaction flag by eliminating from the sample any REO or foreclosure transactions, any transactions involving two family members, and any instances where the owner and seller share a surname.

liens and liens placed for overdue user or impact fees, which might include sewer, trash, or public utilities fees. *Involuntary Liens* also contains information on liens resulting from bankruptcy judgments, although these are far more rare occurrences. A bankruptcy lien is placed on an asset after the personal bankruptcy declaration goes through the courts. In contrast, under property tax law, a tax lien is active on the property if its owner is in arrears on their tax bill one day after the due date for the prior tax year’s liability (LaPoint, 2023).

One limitation to the *Involuntary Liens* dataset is that it is not possible to construct a lien-level panel, since there is no way to link to two lien events to the same underlying delinquency spell. This means that we cannot track the performance of PACE liens or the severity of a delinquency event by accounting for when the lien is removed from the property.²¹ For this reason, we define delinquency as an absorbing state, meaning in our analysis we consider a property to be “delinquent” in a given year if under the same ownership it has ever had a tax lien placed on it.

We merge in information on any for-purchase mortgage, refinancing, and home equity loans or lines of credit from CoreLogic Mortgage.²² CoreLogic Mortgage reports the loan amounts, recording dates, contract details such as the loan maturity, rate type (fixed vs. floating), and the contract rate at origination, and lender and borrower names. We use the CoreLogic Mortgage data for three purposes. First, for some of our difference-in-differences analyses, we compare outcomes for properties with PACE loans to the outside option of financing via home equity lines of credit (HELOCs), which are the most common source of non-PACE financing for home improvement investments. In what follows, we define HELOCs as open-end home equity loans, as opposed to home equity loans which are traditionally closed-end and carry a fixed rate; our definition consists of 80% of traditional, non-PACE home equity loans.²³ However, our difference-in-differences results are materially unchanged if we instead pool closed and open-end home equity loans into the HELOC control group.²⁴

Second, we use CoreLogic Mortgage to compute combined loan-to-value (CLTV) ratios. This allows us to adjust for selection across the PACE and HELOC segments of the home equity loan market by matching the two borrower types on the basis of their equity stake in the property.²⁵ Third, we use mortgage contract terms, together with any history of refinancing activity tied to

²¹In FOIA requesting PACE records from individual counties participating in the program, we found that local governments usually do not separately log property tax payments towards the “normal” tax liability and the portion that goes towards amortizing the PACE loan. In some cases, information on the amortization schedule is available from the local court system which records details on the loan contract at the time of origination and termination. We discuss how we compiled the data obtained through these FOIA requests in the Appendix.

²²The legacy version of CoreLogic Deeds used to contain much of the information which is now contained in the more detailed, but separate CoreLogic Mortgage dataset.

²³We do not include cash-out refinancing loans in this definition due to the fact that such loans combine rate refinancing with equity extraction, whereas PACE loans are a pure equity extraction. Cash-out refinancing loans are also less likely to be used for home improvement projects (Hurst and Stafford, 2004), which is the purpose of our treatment group of PACE loans.

²⁴Borrowers of closed-end home equity loans are more likely to use the funds to smooth consumption in response to negative income shocks rather than to invest in home improvement projects (Agarwal et al., 2006).

²⁵Generally, HELOCs have higher LTVs than PACE loans, but this is partially a function of the maximum principal drawdown limit set by the lender for the former.

a property-owner combination, to back out the implied mortgage amortization schedule. Beyond relying on rough proxies for the presence of escrow such as tenure in the house, this allows us to determine whether an individual would likely have an escrow account in place at the time they take out a PACE loan. We show in [Section 4.3](#) that the spike in delinquency rates we observe following PACE loan origination is entirely driven by homeowners without an escrow account, or those who have remained in the house throughout our full sample period, pointing to the lack of salience of the property tax amongst long-time homeowners ([Cabral and Hoxby, 2012](#)).

The final component in our CoreLogic database is *Building Permits*, which tracks the universe of any building permit applications tied to APNs appearing in the other CoreLogic datasets. Like the other files, we merge the set of building permits tied to PACE and non-PACE properties using the CLIP id. Permits includes the text description of the work tied to each permit application, the projected costs of the work stipulated by the contractor on file, and the names of the contractor and applicant.²⁶ We restrict our sample of permits to those pertaining to residential applications with three or fewer separate projects attached to the same permit, to those not pertaining to newly constructed homes, and to permits which have a final status of either “approved” or “completed.”²⁷

Crucially, the memo attached to each application provides information that allows us to isolate permitted projects with a PACE-approved use. Using standard string parsing methods, we divide up the permits into five mutually exclusive categories: HVAC, Roofing, Solar, Windows and Doors, and Other. Other includes any non-PACE home improvement projects such as interior remodelings, kitchen renovations, property expansions, and landscaping. We are careful to separate solar installations (Solar) which happen to be on the roof from roof repairs and reroofing (Roofing); the former are energy efficiency PACE projects, while the latter deal with climate-proofing. We present the full list of keywords and methods we use to categorize permits in the Appendix.

HMDA mortgage lending data. Next, we use Home Mortgage Disclosure Act (HMDA) data for our analysis of the mortgage market effects of PACE adoption in [Section 4.4](#).²⁸ We focus on 2010-2022 HMDA datasets, and use the FFIEC mapping files to harmonize lenders’ names pre-2017 with those from 2018 onwards.²⁹ The public HMDA data cover nearly the universe of mortgage applications in the U.S. For each applicant, we observe applicant demographic information – including their gender, income, and co-applicant status – as well as the lender’s acceptance/rejection decisions. Our ability to separate out lenders’ acceptance decisions for each borrower application allows us to tease out whether the super seniority of PACE loans incentivizes lenders to stop offering primary mortgages in counties where the local government

²⁶Depending on the application format in a jurisdiction, the text description of the project reflects either information reported by the applicant or by the town clerk filing the permit application.

²⁷For some counties, there is no meaningful distinction between the two, as the contractor is not always required to confirm with the town planning office that the work has been completed.

²⁸Note that because PACE lenders offer specialized non-mortgage loan products, they are not required to report PACE loans into HMDA. We confirmed that the coalitions of lenders (districts) or the lenders themselves (administrators) originating Florida PACE loans do not appear in HMDA during our sample time period.

²⁹See here <https://ffiec.cfbp.gov/documentation/faq/identifiers-faq>.

has enabled PACE. Contrary to this hypothesis, we find in Section 4.4 that lenders increase their approval rate of for-purchase and refinancing mortgages.

SHELDUS natural hazards data. Finally, we rely on the Spatial Hazard Events and Losses Database for the United States (SHELDUS). We download the complete hazard-level data extract covering all Florida counties from 2010 onward. The database contains most natural disasters, such as thunderstorms, hurricanes, floods, wildfires, and tornadoes. It reports the date of the natural hazard event, the affected counties, and various measures of direct losses caused by the event based on insurance claim payouts (indemnities).

Using this dataset, we construct two main variables. The first variable aims to capture *ex ante* risk exposure to natural disasters. To that end, we calculate the value (in real 2021 dollars) of average property damage at the county level between 1960 and 2021. This variable ranks counties based on their historical exposure to natural disasters. Under rational expectations, this measure should be monotonically increasing in the expected probability of natural disaster risks at the county level.

Second, we calculate a proxy for an unanticipated and realized natural disaster shock: the landfall of Hurricane Irma in Florida in 2017. This storm event is informative for our analysis for several reasons. This natural disaster was extremely powerful and created widespread destruction. It was also unanticipated. Moreover, the Hurricane took place in 2017, which is during our sample period. We use the county-level property damages per capita due to this hurricane to calculate households' geographical exposure to it.

3.2 DESCRIPTIVE STATISTICS

We begin our analysis by studying the economic and demographic factors that drive PACE program adoption at the county level. Table 1 reports statistics for Florida counties that have legalized a PACE program and those that have not. Participation in a PACE program is not entirely random. Counties with a PACE program are more likely to have a larger population; on average, they have 310,000 more individuals. Adoptor counties also have a more educated population, and the median household is richer, earning 11% greater income.

[Insert Table 1 about here]

To formally assess whether economic, demographic, and political factors explain counties' introduction of PACE programs, we use a predictive regression and report the results in Table 2. The dependent variable, $Adopted_{j,t}$ is an indicator variable that equals one if a county has adopted PACE in a given year. We find that higher household income, lower unemployment rates, Demographic leaning, and the number of (lagged) natural disasters are positively correlated with the introduction of PACE programs. However, the predictive power of these factors is only significant in the cross section; when we include county and year fixed effects (in columns 4 through 6), none of the economic, demographic, and political factors

significantly predict PACE adoption. This evidence suggests that the *timing* of PACE adoption is plausibly random. Although we cannot rule out unobserved characteristics that drive PACE adoption and the possibility of selection bias at the county level, in our empirical analyses, we perform many of our tests using the sample of counties that have enabled PACE. Endogenous selection of counties into the PACE program is unlikely to bias the point estimates in our house price capitalization and borrower delinquency analyses due to our within-county approach which compares early to late cohorts of PACE borrowers.

[Insert Table 2 about here]

We also assess the characteristics of properties with a PACE loan. To establish a counterfactual benchmark, we compare properties financed through PACE with those financed through HELOCs. A HELOC is a plausible alternative to a PACE loan, since both instruments carry low origination fees relative to alternative equity extraction products like cash-out refinancing options, and HELOCs are commonly used to fund home improvement projects.³⁰ Figure 3 conducts a balance test for characteristics of properties with an attached PACE loan vis-à-vis HELOC. Properties with a PACE loan are smaller than properties with a HELOC, both in total square feet and number of bedrooms. PACE properties consist of fewer residential units (i.e. they are more likely to be single-family homes). Moreover, properties with a PACE loan are significantly older, and trade at a lower value. Overall, this evidence is consistent with the view that PACE loans provide credit to households with lower wealth, who are potentially more financially constrained than households with HELOC loans.

[Insert Figure 3 about here]

4 MAIN EMPIRICAL RESULTS

We present our main empirical results in this section. We analyze at the loan-level how access to PACE financing results in building permit activity. We then show that the demand for PACE loans is higher following hurricanes, a proxy for the cash flows of climate-related projects. Next, we show the impact of PACE loans on loan delinquencies and how the projects they back are capitalized into home sale prices. Finally, we show that counties formally enabling PACE districts to originate loans do not result in mortgage credit rationing.

4.1 PACE BORROWERS' BUILDING PERMIT DECISIONS

As mentioned in Section 2, to obtain PACE financing borrowers are required to state on the application their intended use of funds (e.g. asphalt shingle roof, as in the sample contract in

³⁰HELOCs and closed-end home equity loans are also tax-advantaged in that interest paid on the credit line balance can be deducted from the borrower's taxable income. During tax years 2018–2025, HELOC interest is tax-deductible if the proceeds are used to “buy, build, or substantially improve the residence.” For years prior to 2018, HELOC interest is generally tax-deductible regardless of the use of funds. See [IRS Publication 936](#) Home Mortgage Interest Deduction.

Appendix A), and the town clerk attaches a notice of commencement to the loan disclosure. However, our loan-level data from lender districts and counties do not consistently report the home improvement project type, leading us to use permits from CoreLogic matched to the parcel to obtain this information.³¹ Examining homeowners' permitting decisions around the time of PACE loan origination is important for two reasons. One is to rule out systemic fraud – that is, cases where borrowers take out a PACE loan for a qualified green project only to instead use the proceeds exclusively towards other uses. The second is that we can gauge the timing of home improvement investments to guide our interpretation in Section 4.3 of the capitalization effects of PACE into home prices.

One challenge we face is that multiple projects can be filed under the same permit application, leading to instances in which the permit filing describes both PACE-eligible and PACE-ineligible projects. Households might lump different projects together under the same contractor given fixed costs (e.g., receiving a quote and scheduling the job) leading to complementarity between PACE investments and non-PACE investments and other sources of home improvement financing, whether internal (cash) or external (HELOCs). 52.2% of permits on PACE loan properties feature multiple projects.³² To address this measurement problem, we impose several restrictions on our sample of building permits:

- (i) We restrict to properties listed on the permit application with a land use of either single-family or small multi-family with fewer than 10 units.
- (ii) We parse the text of the clerk's memo for each permit application to classify permits into five major categories: HVAC, Roofing, Solar, Windows and Doors, and Other. These categories reflect the vast majority of projects attached to PACE loans (Consumer Financial Protection Bureau, 2023). We then drop permits for which the categories are not mutually exclusive (e.g., the memo mentions undertaking a solar panel installation and window replacement). This results in us dropping only 1% of permits. We present in the Appendix the full list of keywords we text mine to define these categories.
- (iii) We drop instances of duplicate permits, where duplicates are defined as a permit with the same effective date issued in the same jurisdiction to the same APN with the same permit project type.³³ Such duplicates arise due to instances of mis-recording, or in a small number of cases, because properties receive multiple PACE loans with a common project attached to each lending contract.

³¹Much of the information from the scanned copies of notices of commencement we obtained from the counties matches the permit information from CoreLogic. This includes the name and address of the registered contractor executing the project.

³²Consequently, we show in Section 4.5 that there is an ambiguous effect on demand (i.e. applications) for home improvement loans following a county's enrollment into PACE. PACE acts as a substitute for HELOCs for relatively small permit values, but as a complementary source of financing for larger jobs, and these two forces can cancel each other out, on average.

³³Permit project type is a variable field created by CoreLogic, and there are almost 1,900 unique project types listed in our sample of PACE loans. Therefore, our definition of duplicate permits is fairly stringent.

After applying these restrictions, our resulting sample consists of 17,094 unique permits tied to 15,031 distinct PACE properties.

[Insert Figure 4 about here]

Figure 4 illustrates that the composition of permits issued to owners of properties with a PACE loan is strongly stilted towards projects with a clear PACE-qualified home improvement. Over our full sample period (Panel A), we classify 70.8% of permits approved on PACE properties within a 6-month symmetric window around loan origination as green projects.³⁴ Of these, the majority (44.9%) fall under hurricane-proof improvements, including impact-resistant window and door installations (22.5%) and re-roofing (22.4%). For permits approved on non-PACE properties over the same time period, only 46.3% have a PACE-eligible use, and hurricane-proof permits make up only 26.4% of the total. Panel B shows how this decomposition of permit types attached to PACE vs. non-PACE properties evolves over time as more counties adopt the program. In the early stages of counties’ PACE adoption, permits for impact-resistant improvements dominate, with roofing and solar panel installations becoming more prevalent in recent years; by contrast, for non-PACE properties there is virtually no variation in the breakdown of permit types over time. Figure 4 thus provides initial evidence of a clear first stage effect of PACE borrowing on green home investments.

[Insert Figure 5 about here]

In Figure 5 we run event studies in which the outcome is an approved permit for a specific project type and compare current PACE borrowers to future PACE borrowers using the Callaway and Sant’Anna (2021) estimator. We estimate the event study over an unzipped panel in which we have a dummy $Permit_{i,t}$ for each parcel APN indicating permit approval in a time t relative to PACE loan origination.

$$Permit_{i,t} = \sum_{t=-3, t \neq -1}^{+3} \beta_t \cdot PACE_{i,t} + \eta_i + \theta_{z,t} + \varepsilon_{i,t} \quad (4.1)$$

Following Roth (2024), we estimate equation 4.1 in long-differences for the pre-PACE and post-PACE coefficients, so that we can visually interpret pre-trends on the $\hat{\beta}_t$ coefficients relative to the reference period $t = -1$. We follow this convention throughout the paper for research designs where we apply the Callaway and Sant’Anna (2021) estimator. In all event study specifications in Figure 5, we include 5-digit zip code \times tax year fixed effects $\theta_{z,t}$. Doing so helps us hold fixed features of the locality such as the stringency of rules set by the town building code division, which might affect whether borrowers decide to apply for a permit

³⁴Varying the length of the time window around PACE origination yields intuitive results. As we shorten the window around origination, the fraction of permits classified as “other” declines almost linearly. There is no consistent timeline for filing a permit relative to applying for a PACE loan, and in many towns retroactive permitting carries limited or no fines and fees.

or whether the town approves the project. Note that we do not include a vector of property characteristics, because the property’s size and physical structure might be altered by permitted activities. Including characteristics $\mathbf{X}_{i,t-k}$ recorded from the property’s assessment history as of k years ago would result in that vector being absorbed by the parcel fixed effects η_i .³⁵

For each PACE-qualified project category, the permitting probability increases by between 2 and 3 p.p. within a year of origination, with noticeably stronger effects for window and door permits. Borrowers are less likely to permit in the years prior to and directly following PACE takeup. This observed timing helps validate our approach to constructing Figure 4 in which we focus on permits approved within the same year as PACE origination. We also find that the probability of permitting within the “other” (non-PACE) category spikes by a similar magnitude within a year of origination. Again, this points to the complementarity of PACE and non-PACE projects given fixed costs of home investment decisions.

4.2 DOES DEMAND FOR PACE LOANS RESPOND TO NATURAL DISASTER RISK?

We next investigate whether household demand for PACE loans responds to changes in investment opportunities after the program becomes available in the area. We posit that the demand for projects that enhance housing storm resilience increases following a natural disaster, because disaster risk becomes more salient after a storm. Another reason for a potential uptick in demand is the higher likelihood of property damage during a storm, necessitating more housing-related renovations that can be financed through PACE loans. Cortés and Strahan (2017) show using nationwide SHELDUS data that homeowners supplement monetary support from FEMA with for-purchase mortgages from banks following disasters. Moreover, households have higher liquidity needs following a natural disaster (Morse, 2011; Cookson et al., 2023).

To test the relation between natural disasters and PACE demand, we first plot in Figure 6 the binscatter between new PACE loans and historical average per capita property damages (in logs). Specifically, the dependent variable is the first year the PACE loan is taken out. We estimate the binscatters among people who end up having a PACE loan to avoid the selection caused by the strategic development of the Florida PACE company. We observe a positive correlation between the two variables. Hence, takeup of PACE loans has evolved much faster in counties with a history of substantial property damages.

[Insert Figure 6 about here]

While the results are informative, other variables could affect the probability of taking a PACE loan earlier in an area previously experiencing severe natural disasters. To better isolate the impact of natural disasters on individual PACE borrowing decisions, we next examine an exogenous natural disaster event: Hurricane Irma in 2017. Irma is the largest (Category 4)

³⁵Still, even though they are potentially bad control variables, when we include lagged characteristics $\mathbf{X}_{i,t-1}$ on the RHS of (4.1), our results hardly change.

hurricane that hit Florida during our sample period, causing an estimated \$50 billion in total damages.³⁶ We estimate the effect of Hurricane Irma on PACE loan demand via the following regression specification:

$$PACE_{i,j,t} = \sum_{n=2015, n \neq 2017}^{2020} \beta_n \cdot \mathbb{1}\{t = n\} \times DMG_j + \delta_t + \eta_i + \varepsilon_{i,j,t} \quad (4.2)$$

where the variable DMG_j denotes per capita property damages incurred during Hurricane Irma (in logs) in county j . The variable is set to zero if there are no property damages in the county j . The indicator $\mathbb{1}\{t = n\}$ is a time (year) indicator that equals one if t is equal to n and zero otherwise. Our reference year is 2017. Because Hurricane Irma occurred in 2017 and the PACE program started in 2015, we focus on a seven-year event window of $[-2, +3]$ around the natural disaster event, that is, from 2015 to 2020. δ_t represent year fixed effects, and η_i represent property fixed effects. The dependent variable, $PACE_{i,j,t}$, is a dummy variable that takes the value of one if property i received a PACE during year t .

In the event study, we set the reference year to be 2017, as Hurricane Irma made landfall in Florida in September of that year. We cluster standard errors at the property level to account for the possibility that loan demand may be autocorrelated over time. Doing so ensures that the number of clusters is large enough to estimate the standard errors. The results are robust to clustering at the county-level.

Figure 7 plots the estimated coefficients ($\hat{\beta}_n$). Before the Hurricane, there is no pre-trend and the coefficients are economically small and close to zero. There is a significant increase in the probability of taking out a PACE loan for places more affected by Hurricane Irma. Supporting a causal interpretation, the take-out peaks the year after the Hurricane and diminishes gradually before becoming quantitatively lower and turning statistically insignificant three years later. Overall, the graph supports the idea that households rely more on PACE loans when they face plausibly exogenous financing needs.

[Insert Figure 7 about here]

Table 4 shows the economic magnitude of the impact of Hurricane Irma on PACE loan take-up. Column (1) shows the net effect over the following two years. Column (2) decomposes the post-period effect year by year. Most of the effect is driven by the response in the first and second year, while the effects in the third year are quantitatively small and statistically insignificant. Finally, columns (3) and (4) replicate the baseline specification, but replace DMG_j with a dummy variable $Irma_j > 0$ that takes a value of one if the average property damages in a county is strictly positive and zero otherwise. Overall, the effects remain robust.

[Insert Table 4 about here]

³⁶Source: National Hurricane Center Tropical Cyclone Report, Hurricane Irma (March 2018) [\[link\]](#).

4.3 CAPITALIZATION OF PACE LOANS INTO HOUSE PRICES

Counties introduce PACE programs primarily to stimulate investment in residential energy efficiency and climate resiliency. These investments might be capitalized into higher house prices for at least three non-mutually exclusive reasons. First, the project financed by a PACE loan can reduce the costs associated with the house, such as the electricity fees, or the insurance premia. Second, the future value of the house might be more certain if the house becomes more resilient to natural disasters.³⁷ Third, there could be a non-pecuniary benefit from a homeowner living in a house that is more energy efficient.

To evaluate the effect of PACE financing on house prices, we collect transaction data for houses that received a PACE loan over the period 2015 to 2023 from CoreLogic *Owner Transfers*. We find that approximately 20% of properties with a PACE loan have a transaction record in this timespan. Because household demand for PACE loans is endogenous, comparing the market prices for the homes of PACE borrowers to those of houses without PACE loans would be problematic. Our balance test in Figure 3 points to PACE properties being negatively selected relative to the counterfactual of HELOC properties. However, even if we controlled for these observable quality dimensions, PACE-financed properties may also be of unobservably lower quality, which would bias upward estimates in pricing regressions where we pool sales of properties with and without PACE financing.

To minimize this form of selection bias, we adopt a within-treatment group comparison approach. Specifically, we restrict our sample of house transactions to properties with a PACE loan. For each treated unit (i.e., a property with a current PACE loan), we set not-yet-treated units (i.e., properties that will receive a PACE loan in subsequent years) as the control group. We estimate the average treatment effect on the treated (ATT) using the estimator proposed by Callaway and Sant’Anna (2021). The regression equation takes the following form:

$$\log(\text{Price}_{i,t}) = \beta \cdot \text{PACE}_{i,t} + \gamma' \cdot \mathbf{X}_{i,t} + \theta_{z,t} + \varepsilon_{i,t} \quad (4.3)$$

where the dependent variable $\log(\text{Price}_{i,t})$ is the log transaction price of property i in year t . The main independent variable $\text{PACE}_{i,t}$ is an indicator variable that equals one for transactions occurring in year t after property i receives a PACE loan and zero for transactions before PACE loan is taken out. The vector of property characteristics $\mathbf{X}_{i,t}$ includes log square footage (winsorized at the 1st and 99th percentiles), bedrooms, units, and property age proxied by years built in 10-year bins. Additionally, we include zip code \times year fixed effects, $\theta_{z,t}$, to control for common factors such as local economic prospects that affect house prices in a narrowly defined geography.³⁸

We report results in Table 5 and Figure 8 from estimating dynamic versions of equation 4.3. Panel A of Table 5 reports the ATT coefficient estimates pooled over the pre-PACE

³⁷A house whose value is more certain would have a higher price through a discount rate channel.

³⁸Our results are nearly identical if we instead redefine the outcome variable as log price per square foot.

and post-PACE periods without controlling for property characteristics. After PACE-financed retrofitting, properties are sold at a significant premium, as shown in the second row of Table 5, Panel A. The first row shows that the average difference in transaction prices between a comparable non-PACE property and a not-yet PACE property is statistically significant and positive before the treatment. However, specific features of the properties may bias the estimate. To address this potential issue, we report results from a specification including property controls in Panel B of Table 5. The average pre-PACE coefficient is slightly positive but not statistically significant. In contrast, the post-PACE coefficient is positive and statistically significant at the 1% level. The economic magnitude is larger than the estimates produced in Panel A which are not adjusted for property covariates.

[Insert Table 5 about here]

Our DiD event study approach identifies the plausibly causal effect of PACE financing under the assumption that the house prices of treated and not-yet-treated properties would follow parallel trends in the absence of the PACE loan. Although this assumption cannot be directly tested, to get a clearer view of how the point estimates evolve over the term of the PACE loan, we include a set of lead and lag indicators around the loan origination year. In Panel B of Table 5, and in Panel B of Figure 8, we observe that the treatment effect becomes significant only after the PACE loan, and there is no evidence of pre-existing trends after controlling for property characteristics. This evidence supports the parallel trends assumption underlying our identification strategy.

[Insert Figure 8 about here]

On average, a PACE property has a sale price appreciation of $(\exp(0.298) - 1) \approx 35\%$ higher than a non-PACE property. To give a sense of the economic magnitude, this average capitalization value is approximately three times the average value of the loan origination amount, plus average permit filing fees, suggesting that the treatment effect is economically sizeable.

Overall, these results are broadly consistent with the policy goal of capitalizing environmental retrofitting into house prices through increased credit access. When combined with the fact that most PACE loans are taken up by households that face *ex ante* higher financing constraints, we highlight a potentially important benefit of publicly-backed financing programs that facilitate the green transition.

4.4 THE EFFECT OF PACE LOANS ON BORROWER DELINQUENCY

The preceding analysis highlights a statistically significant and rather large premium in market value for PACE-financed houses. But a major critique of the residential PACE program is that repayments through property taxes could lead to increased tax delinquency. This concern is

particularly relevant given that a large fraction of PACE loans are extended to lower-income households, who may struggle to afford the property tax increases or face higher attention constraints when signing the financing contract. The average annual non-*ad valorem* payment of \$2,014.66 towards a PACE loan balance represents a 56% increase in the total combined property tax bill for the average borrower.

We assess the impact of PACE loans on tax delinquency in this section. Our regression specification is similar to the previous equation, but with the dependent variable capturing local tax delinquency at the property level:

$$Delinquent_{i,t} = \beta \cdot PACE_{i,t} + \gamma' \cdot \mathbf{X}_{i,t} + \eta_i + \theta_{z,t} + \varepsilon_{i,t} \quad (4.4)$$

where the outcome variable $Delinquent_{i,t}$ equals one in cases where property i has a local tax lien involuntarily placed on it, indicating delinquency. We measure delinquency as an absorbing state, since lien removals are not systematically recorded in the CoreLogic *Involuntary Liens* data. Our results remain materially unchanged if we instead examine delinquency at the property-by-owner level, using the name(s) recorded on the title for assessment purposes matched to the name(s) listed on the lien flag.³⁹ $PACE_{i,t}$ is a dummy variable equal to one if property i has a PACE lien in year t and zero otherwise. The estimation sample underlying equation (4.4) is an unzipped panel of properties, meaning we set $Delinquent_{i,t} = 0$ as long as the property does not have a tax lien recorded.

We estimate different variations of this equation by including or excluding $\gamma' \cdot \mathbf{X}_{i,t}$, which contains the control variables of property characteristics as described in Section 4.3. We also run separate specifications with neighborhood \times year fixed effects $\theta_{z,t}$ at different levels of geographic granularity, including the Census tract (defined according to 2010 decennial Census boundaries), county FIPS, 5-digit zip code levels, and tax code area (TCA). Including TCA fixed effects conditions on both a common statutory property tax rate and access to any amenities financed through the local property tax base (Amornsiripanitch, 2023). One can think of a TCA as a small neighborhood defined by the intersection of tax jurisdictional boundaries (e.g., the intersection of a school district and tax assessor's neighborhood), which allows us to isolate the behavioral aspects of PACE loan default from increases in the tax burden. Our results are largely impervious to the geographic unit defining the neighborhood \times time fixed effects $\theta_{z,t}$.

As with the house price analysis in the preceding subsection, we estimate equation (4.4) using the Callaway and Sant'Anna (2021) estimator. To avoid selection bias into PACE loans, we continue to compare tax delinquencies of properties with a PACE loan (treated group) to those that have not yet received a PACE loan (control group). Figure 9 Panel A plots the results of the dynamic event study. Across all specifications, we observe an abrupt jump in the probability of delinquency within the first tax year after a PACE lien is attached to a property. The period

³⁹Using the property-by-owner combination as the unit of analysis rather than individual properties helps isolate cases where a property may have been in arrears on its taxes, after which the previous owner sold the property, extinguishing the initial lien, and then the new owner who became a PACE borrower subsequently defaulted on their property tax bill.

$t = 0$ estimates are all statistically significant at the 1% level and correspond to an additional 1 percentage point increase in the probability of being tax delinquent within the same tax year after the household takes up a PACE loan. Moreover, the figure shows that (i) there are no pre-trends in local tax delinquency probability before PACE origination for the property; and (ii) the estimated ATT increases over time due to our definition of $Delinquency_{i,t}$ as an absorbing state – or what is called an “ever-delinquent” flag in the literature.

[Insert Figure 9 about here]

To probe the robustness and mechanism underlying these results, we construct an alternative control group consisting of properties with HELOC-financed retrofitting projects. We isolate HELOC loans associated with a permit issued within 6 months of origination and use those loans as the control group to re-estimate equation 4.4. As with the previous analysis, in Panel B of Figure 9 we find that following a PACE lien, tax delinquencies again increase significantly within the same tax year of origination. Since in this comparison the control units comprise properties with similar retrofits financed by HELOCs, the treatment effect is driven by PACE liens rather than undertaking the project itself. Therefore, our results support the view that PACE program adoption could lead to higher tax default rates.

How quantitatively important are these PACE-driven delinquency rates for the collection of property tax revenues? Answering this question is key to determining the net fiscal costs local governments incur by enacting PACE within their jurisdiction. Our baseline effect obtained from comparing current vs. not-yet PACE borrowers in Panel A of Figure 9 represents a 12% increase in tax delinquency in $t = 0$ relative to $t = -1$. The same effect for the HELOC vs. PACE borrower comparison in Panel B represents a 20% increase relative to the baseline $t = -1$ gap in delinquency rates between the typical (home improvement) HELOC and PACE borrower.

For our HELOC vs. PACE event study, we find a 2.5 p.p. increase in delinquency probabilities within three years of treatment ($t = 2$ full tax years post-PACE); this forms an upper bound estimate of the effect of PACE on tax default.⁴⁰ In Section 5, we combine our estimates for the property-level capitalization and delinquency effects of PACE to show that even using our upper bound estimate of a 2.5 p.p. uptick in delinquency rates – and assuming no partial default on the tax bill – PACE generates net fiscal gains for adoptor counties.

4.5 EFFECTS OF LOCAL PACE ENROLLMENT ON MORTGAGE LENDING

One potential concern about the public-private partnership aspect of the PACE program is that repayment through local taxes creates a super senior lien, which breaches the priority rules of either pre-existing or future claimants such as mortgage lenders. Due to this concern, Fannie Mae and Freddie Mac refuse to purchase mortgages with PACE liens. In a 2015 announcement,

⁴⁰We cautiously interpret our event study point estimates at horizons $t > 2$, as PACE is a relatively new program amongst the largest counties in our sample where the bulk of PACE loans occur. The point estimates at $t > 2$ are identified off of a subset of borrowers located in early adoptor counties.

the Department of Housing and Urban Development intended to require PACE liens to remain subordinate to loans guaranteed by the Federal Housing Administration (White House, 2015). More broadly, publicly-backed energy retrofit programs may substitute for private financial sources such as home improvement loans underwritten by banks. At the same time, public finance policies may contribute to “green gentrification” by expanding the size of the tax base, thereby improving neighborhood amenities and the value of properties (as we show in Section 4.3). Private lending can be a natural complement to such green gentrification.

We evaluate the effect of PACE adoption on private credit supply in the housing market by comparing mortgage approval rates in counties that have enacted PACE with those in counties where PACE has not been adopted at a given point in time. We draw on borrower application-level data from 2010 to 2022 from HMDA. By focusing on loan approval decisions, we disentangle credit supply from credit demand. To avoid confounding effects of policies applied to secondary mortgage loans, we restrict the sample to mortgage applications for houses intended to be occupied as a principal dwelling, being for either one-to-four-family home purchases or refinancing. The identifying assumption underlying this test is that counties that passed PACE legislation early are not fundamentally different from counties that passed PACE legislation. Table 2 supports the assumption that counties adopted PACE with quasi-random timing. For our baseline approach, we use the DiD estimator proposed by Sun and Abraham (2021), for which we designate never-treated counties as the control group. Our choice of estimator does not qualitatively affect the estimates. Figure 12 demonstrates that our results are robust to using the stacked DiD approach proposed by Cengiz et al. (2019) and Baker et al. (2022a).

Our regression equation for estimating the effects of county-level PACE adoption on mortgage lending is:

$$Accept_{i,l,c,t} = \beta \cdot PACE\ adoption_{c,t} + \gamma \cdot \mathbf{X}_{i,c,t} + \alpha_c + \delta_t + \eta_l + \varepsilon_{i,l,c,t} \quad (4.5)$$

where the dependent variable $Accept_{i,l,c,t}$ measures lending decisions, such as lender l 's approval rates for borrower i in county c of year t . The variable of interest is $PACE\ adoption_{c,t}$, a dummy variable that equals one for county c in year t following formal legal enactment of PACE and zero otherwise. The vector $\mathbf{X}_{i,c,t}$ includes borrower characteristics such as dummy variables indicating Loan-to-Income ratio, co-applicants, ethnicity, and gender. Finally, we include geography (e.g., Census tract) fixed effects, α_c , lender fixed effects, η_l , and year fixed effects, δ_t , to account for unobservable differences across regions, among lenders, and over time.

We are mainly interested in β , which captures an intent-to-treat (ITT) effect of PACE access on mortgage lending decisions. This is an ITT effect in the sense that statutory PACE access in a county poses a credible threat to the priority of the lender's capital stake in the house, but not all prospective mortgage borrowers will also eventually seek PACE financing. A positive estimate of β would indicate a positive effect of PACE programs on lenders' willingness to originate mortgages. In contrast, a negative β would suggest borrowers' access to PACE crowds-out private lending.

[Insert Table 6 about here]

We present results from estimating 4.5 in Table 6. The first column reports the coefficient of interest controlling for county fixed effects and borrower and loan characteristics. The coefficient is positive and statistically significant, suggesting that banks increase lending in PACE-enabled counties. Column 2 adds Census tract fixed effects to account for more granular economic characteristics. The coefficient estimate is barely affected and remains statistically significant. Column 3 includes lender fixed effects to account for differences across lenders (e.g., funding, size, etc.), and the coefficient halves in magnitude, but remains statistically significant. In column 4, we add year fixed effects to absorb time trends, and the coefficient is still positive (0.027) and, importantly, statistically significant. Next, in column 5 we focus on refinancing mortgage applications. The non-rationing of credit results holds for refinance loans as well, representing a 2.5 p.p. increase in loan approvals. Therefore, PACE positively affects credit supply not only for new homeowners, but also for existing homeowners.

[Insert Figure 10 about here]

Baseline estimates (Column 4 and 5) are plotted in Figure 10. Overall, the figure shows that following PACE adoption, mortgage approval rates for home purchase financing (panel A) and loan refinancing (panel B) increase significantly (i.e., $\beta > 0$). In fact, the coefficient estimates are positive and statistically significant only in the post period, that is for $t > 0$. These effects are economically meaningful; PACE adoption in a county results in a 3 p.p. higher average approval rate for first-lien home purchase. This estimate represents a 4% increase, which is economically sizable. Therefore, the results are consistent with the fact that PACE credit availability raises the prospects of valuable home improvement projects, which would be capitalized into property values (as we find in Section 4.3). As a result, banks may earn a higher internal rate of return due to higher loan origination values – which are proportional to upfront fees – and lower loss given default for mortgages in PACE counties. This evidence is perhaps surprising given concerns raised by policymakers about super senior PACE liens crowding out other forms of private lending. Important for the validity of our research design, in all of our specifications the estimated $\hat{\beta}_n$ coefficients display no pre-trend and are statistically insignificant. This bolsters our identifying assumption that mortgage approval rates or credit demand would have trended similarly between PACE and non-PACE counties if the loan program had never been enacted.

Taken together, the above evidence is consistent with the interpretation that PACE loans complement private primary mortgage lending and increase lenders' expected returns by accelerating environmental retrofitting and house price appreciation. Two channels can explain these findings. The first explanation is that the value of a property with an active (ongoing) PACE loan increases. When an improved PACE property is sold, banks are more likely to extend credit to the borrower for purchasing a new, nearby property, due to the increased proceeds the borrower receives from the sale. The second explanation is that the adoption of the PACE program raises *expected* climate-proofing investment, prompting banks to be more willing to

lend regardless of the number of actual PACE-financed properties in a given county (i.e., an anticipation effect).

We are unable to disentangle these two channels because HMDA application data do not contain the APN of a property and thus cannot be linked to the PACE loans directly. However, there are good reasons to believe that an anticipation effect exists, because we observe an immediate effect on bank lending at $t = 1$ (i.e. in the first year after program adoption), when PACE takeup and transaction volume for PACE-improved properties is low. On the other hand, Figure 10 shows that the treatment effect is increasing over time, consistent with more households taking advantage of the program acquiring PACE loans over time. The time path of the $\hat{\beta}_n$ obtained from the dynamic version of (4.5) supports the first explanation.

To shed light on the mechanism of (actual or expected) house value appreciation underlying our private lending results, we explore heterogeneity in borrower risk profiles for post-PACE mortgage originations. Our framework predicts that the positive effect on mortgage approvals is more pronounced for borrowers exhibiting a greater *ex ante* risk of default. To capture borrower risk, we use the applicant’s loan-to-income (LTI) ratio. Our choice of LTI as a proxy for risk is guided by the fact that households with a higher loan-to-income ratio are more likely to default on their mortgage following a negative income shock. We compare each applicant’s LTI ratio with the annual median LTI value within a Census tract. If an applicant’s LTI is above the median value in a given Census tract, we classify that applicant as high-risk. Similarly, low-risk applicants are those with a below-median LTI value. We then estimate equation (4.5) for high- and low-risk applicants separately. Columns 6 and 7 of Table 6 show the results of this sample-split exercise. The coefficient in column 6 (high-LTI) is positive and significant, while the one in column 7 (low-LTI applications) is not. This evidence suggests the PACE effect on lending is most pronounced for high-risk borrowers.

Visually, Figure 11 shows a clear divergence in approval rates for the two groups of applicants. We find that the ITT effect on mortgage approvals is driven by the high-risk group (red points) as the estimates of β are both statistically and economically larger than those for the low-risk group (black points). This points to lenders reallocating mortgages after the PACE introduction towards borrowers who appear *ex ante* riskier. Our proposed mechanism is that green installations increase the collateral value of homes, which is consistent with our separate tests documenting the positive impact of PACE loan takeup on house values (as shown in Section 4.3). This increase in collateral value is particularly valuable from the perspective of preventing the downside risk of short sales forced on riskier borrowers who default with negative equity (Gerardi et al., 2018).

[Insert Figure 11 about here]

There are three non-mutually explanations for why projects financed by PACE loans increase home values. First, the costs of operating the house could decrease following the PACE-related investment, which increases buyers’ willingness to pay. For instance, prospective buyers may

be willing to pay more for a house with solar panels because their electricity bill is expected to be lower. Second, the home’s value is more certain in the future, which leads to a higher price. This is likely to happen for wind-proof projects (e.g., impact-resistant windows and doors or asphalt shingle roof installations), because these projects increase the resistance of the home to hurricanes. Third, non-pecuniary benefits of living in the house may increase given the existence of buyers with a taste for sustainable houses.

In general, we are not able to quantify precisely the contribution of each of these three margins. That said, our results on permitting in Section 4.1 show that PACE loans extended towards energy efficient property improvements, like solar or HVAC installations, are relatively uncommon, and together represent just 27% of all permits associated with PACE loans. Further, energy audits conducted by some Florida counties in partnership with PACE districts indicate that even for the small fraction of loans originated towards solar installations, projected energy savings are minimal.⁴¹ Moreover, energy savings do not usually start accruing in the first few years, but rather accumulate over the long-term. In contrast, we document the predominance of wind-proof projects (e.g., impact-resistant windows and doors or asphalt shingle roof installations) favored by PACE applicants.

5 DISCUSSION OF LOCAL COST-BENEFIT IMPLICATIONS

By contrasting the benefits of capitalizing PACE loans into house prices with the potential costs of increasing delinquency rates, the evidence presented above highlights the tension surrounding the introduction of PACE programs, as raised by policymakers and regulators. We perform a simple back-of-the-envelope calculation to get a sense of the direct net benefit (cost) of PACE from the perspective of the local tax office:

$$\Delta R_{t,t+1} = \underbrace{\tau_{t+1}}_{\text{local tax rate}} \times \left(\underbrace{\Delta P_{t,t+1}}_{\text{capitalization effect}} - \underbrace{\Delta D_{t,t+1} \cdot P_t}_{\text{revenue lost from delinquency}} \right) \quad (5.1)$$

where $\Delta R_{t,t+1}$ is the change in local property tax revenue. The first term in (5.1) represents the benefit of PACE, which is the positive change in revenue due to an increase in average home values. We subtract for the capitalization effect revenues lost from an uptick in the delinquency rate $\Delta D_{t,t+1}$ on the prior year’s tax bill. We suppress the county subscript, although, in principle, both the local tax rate $\tau_{j,t+1}$ and the ATT effect could vary by jurisdiction.

Evaluating equation (5.1) using our ATT estimates from Section 4.3 and 4.4, we derive an estimated net tax benefit of \$694 per borrower-year. We assume the prevailing property tax rate of 0.9%.⁴² Based on our estimates in Section 4.3 and Section 4.4, the direct net effect on local tax income is $0.9\% \times (\$86,892 - 0.025 \times \$389,325) = \$694$ where \$389,325 is the average taxable property value over our sample period.

⁴¹We obtained these quarterly summary reports of greenhouse gas (GHG) emissions and kilowatt (KWh) hours saved in response to FOIA requests submitted to individual tax assessor’s offices.

⁴²Source: <https://smartasset.com/taxes/florida-property-tax-calculator>. Accessed April 4, 2024.

There are at least three reasons to believe that this estimate represents a lower-bound fiscal benefit of PACE programs to local governments. First, we rely on the strong assumption that 100% of the fiscal costs induced by tax delinquencies are paid by the local government. In reality, many PACE loans are backed by private investors, who would at least partially absorb tax losses in the case of default. Second, we do not directly model the spillover effect of PACE programs on the local economy, including potential employment creation and related investment spending. Research on the macroeconomic benefits of PACE in California suggests that a \$4 million increase in PACE financing leads to a \$10 million increase in local gross output (Rose and Wei, 2020). Therefore, on average, local governments are likely to benefit from program adoption and face strong incentives to enroll if the property tax base is a sufficiently large fraction of revenues. Third, PACE loans finance projects that aim at reducing negative externalities. We do not quantify the pecuniary value of the potential reduction in negative externalities, such as carbon emissions, or the mitigation of unraveling home insurance markets, coming from the projects financed by PACE loans.

6 CONCLUSION

This paper offers the first systematic evidence on the trade-offs of the PACE program to assess its effectiveness towards improving the resilience of the housing capital stock in the face of climate change. We build a new loan-level dataset linked to property tax, transaction, and permit records to present four main results.

First, PACE loan takeup is substantially higher in counties with historically high property damages and is sensitive to the incidence of natural disasters such as major hurricanes. Second, PACE-financed properties experience a significant increase in market value compared to otherwise similar properties that have not yet received a PACE loan. On average, the appreciation in house prices is over twice the amount of the PACE loan. Third, we show that tax delinquency rates increase by 1–2.5 percentage points after PACE borrowers take out the loan. This effect is driven by older property owners without an escrow account for whom property tax bills are less salient. Finally, we find no evidence supporting the concern that PACE financing crowds out private mortgage lending. In fact, private mortgage approvals increase in counties that have opted into the PACE program, consistent with our evidence that PACE-financed retrofits enhance the property’s collateral value.

Our results together suggest that PACE loans are an effective financing method for encouraging green home investments. The local government backing of PACE loans through the property tax base helps solve the market failure of under-investment in climate-resilient home improvement projects – due, in part, to the presence of *ex ante* liquidity constraints – but without leading to an unraveling of mortgage markets. While we do not assess other potential positive externalities of PACE, such as local physical capital investment and job creation, a simple cost–benefit analysis based on our estimates indicates that the net fiscal benefit to local tax offices amounts to \$694 per borrower per year. Therefore, our results support the view that

the PACE program is a cost-effective initiative for fast-tracking the climate-resilience of the housing stock.

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TABLE 1. Descriptive Statistics: Balance Tests at the County Level

	Counties with PACE programs	Counties without PACE programs	Difference
Fraction w/high school diploma or less (2017-2021)	11.28	17.13	5.86***
Fraction w/bachelor's degree or higher (2017-2021)	27.22	18.74	-8.48***
Population (Census 2020)	446,460	136,288	-310,172***
Declared natural disasters (since 2015)	14.25	13.86	-0.40
Unemployment rate (2021)	4.45	4.52	0.08
Median household income (2021)	60,102	53,927	-61,745**
White fraction of population (2020)	0.64	0.68	0.04
Black fraction of population (2020)	0.13	0.13	-0.00
Latino fraction of population (2020)	0.16	0.13	-0.03

Note: This table reports descriptive statistics for counties with at least one approved PACE program vs. those without any PACE program. The data come from FEMA, the decennial Census, and the American Community Survey (ACS). *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 2. Determinants of PACE Adoption at the County Level

	(1)	(2)	(3)	(4)	(5)	(6)
Population	-0.043 (0.066)	-0.052 (0.072)	-0.041 (0.074)	-0.411 (0.964)	-0.618 (0.991)	-0.776 (0.956)
Household median income	0.602* (0.320)	0.728** (0.335)	0.559 (0.378)	-0.228 (0.335)	-0.179 (0.352)	-0.220 (0.364)
% Bachelor degree or higher	-1.611** (0.721)	-1.820** (0.754)	-1.678** (0.791)	1.281 (1.276)	1.830 (1.251)	1.769 (1.228)
% Black	0.360 (2.267)	0.471 (2.439)	0.719 (2.438)	-0.536 (2.611)	0.545 (2.601)	0.987 (2.609)
% Latino	0.636 (1.982)	0.815 (2.096)	1.048 (2.099)	-1.712 (5.767)	-4.375 (6.944)	-5.358 (7.303)
% White	0.160 (2.011)	0.316 (2.138)	0.630 (2.150)	-4.525 (3.864)	-6.663 (4.709)	-7.263 (4.798)
Unemployment rate	-4.306*** (1.251)	-4.259*** (1.391)	-5.033*** (1.574)	-0.786 (1.142)	-0.266 (1.244)	-0.265 (1.423)
Democratic leaning	1.199* (0.601)	1.454** (0.653)	1.443** (0.685)	-0.641 (1.104)	-0.882 (1.139)	-0.837 (1.200)
Neighbor PACE	0.074 (0.104)	0.023 (0.104)	0.013 (0.104)	0.007 (0.086)	0.033 (0.086)	0.054 (0.092)
#Declared disasters	0.059*** (0.020)			-0.003 (0.030)		
#Declared disasters L1		0.133*** (0.026)			-0.015 (0.029)	
#Declared disasters L2			0.120*** (0.031)			-0.000 (0.029)
Observations	504	466	430	504	466	430
R-squared	0.325	0.325	0.286	0.693	0.705	0.714
County FE	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes

Note: This table examines whether a county's economic, political, or demographic conditions predict the adoption of PACE programs. The dependent variable in each column is an indicator equal to one ($Adopted_{j,t}$) if a county j has adopted PACE in that year t . In columns 4 through 6, county fixed effects and year fixed effects are included. Standard errors are reported in parentheses and clustered at the county level. County population is from the Census; the fraction of Black, Latino, and White population, household median income, education attainment, and unemployment rate are from the American Community Survey; Democratic leaning comes from Florida Department of State's Election Reporting System and measures the county-level voting share for the Democratic presidential candidate in the most recent presidential elections; Neighbor PACE is a dummy variable equal to one if one or several neighboring counties have an effective PACE program in year t ; # Declared natural disasters come from FEMA. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 3. Summary Statistics for House Price and Lending Samples

	N	Mean	Std. Dev.	p5	p95
Panel A: House Price Analysis (CoreLogic-PACE Repeat Sales)					
$SaleAmount_{i,t}$	2,858	322,011.5	170,957.6	120,000	659,000
$\log(Price_{i,t})$	2,858	12.55	0.52	11.70	13.40
$Bedrooms_{i,t}$	2,858	3.02	0.83	2	4
$\log(square\footage_{i,t})$	2,858	9.04	0.81	7.74	10.78
$AgeDec_{i,t}$	2,858	5.24	2.87	1	10
Panel B: Private Lending Analysis (HMDA)					
$Approval_{i,l,c,t}$	1,575,159	0.828	0.377	0	1
$PACE_{i,c,t}$	1,382,195	0.306	0.461	0	1

Note: This table reports some descriptive statistics between the counties with at least one approved PACE programs and those without any PACE program. The data come from FEMA, the decennial Census, and the American Community Survey (ACS).

TABLE 4. Impact of Irma on Individual PACE Loan Takeup

Dep. variable: $PACE_{i,j,t}$	(1)	(2)	(3)	(4)
Post Irma $_{i,t} \times DMG_j$	0.013*** (0.001)			
1 year after Irma $\times DMG_j$		0.018*** (0.001)		
2 years after Irma $\times DMG_j$		0.009*** (0.001)		
3 years after Irma $\times DMG_j$		0.000 (0.001)		
Post Irma $_{i,t} \times Irma_j > 0$			0.070*** (0.005)	
1 year after Irma $\times Irma_j > 0$				0.099*** (0.007)
2 years after Irma $\times Irma_j > 0$				0.038*** (0.005)
3 years after Irma $\times Irma_j > 0$				-0.007 (0.007)
Observations	78,432	78,432	78,432	78,432
R-squared	0.17	0.17	0.17	0.17
Property FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Mean Dep. Var.	0.069	0.069	0.069	0.069

Note: This table reports the impact of Irma on PACE loan participation by estimating equation (4.2). $PACE_{i,j,t}$ is a dummy variable that takes the value one if the property i has a PACE loan in the year t . The variable DMG_j denotes property damages per capita incurred during Hurricane Irma (in logs) in county j . The variable is set to zero if there are no property damages in the county j . $Irma_j$ is a dummy variable that takes a value of unity if the county j has some exposure to Irma and zero otherwise. The regressions are estimated on the sample of properties with an originated PACE loan.

TABLE 5. ATT Estimates for PACE Loan Effects on Log House Prices

Dep. variable: $\log(\text{Price}_{i,t})$ Panel A: without property controls				
	ATT	SE	95% Confidence Bands	
Pre-PACE	0.111***	0.028	0.055	0.166
Post-PACE	0.187***	0.030	0.128	0.246
$t = -3$	0.179***	0.038	0.105	0.253
$t = -2$	0.043	0.031	-0.019	0.104
$t = 0$	0.119***	0.038	0.045	0.192
$t = 1$	0.407***	0.045	0.319	0.495
$t = 2$	0.035	0.051	-0.064	0.134
Panel B: with property controls				
Pre-PACE	0.063	0.172	-0.273	0.399
Post-PACE	0.298***	0.116	0.070	0.525
$t = -3$	-0.011	0.180	-0.364	0.342
$t = -2$	0.137	0.219	-0.292	0.565
$t = 0$	0.222	0.175	-0.121	0.565
$t = 1$	0.305**	0.146	0.019	0.591
$t = 2$	0.366**	0.147	0.078	0.654

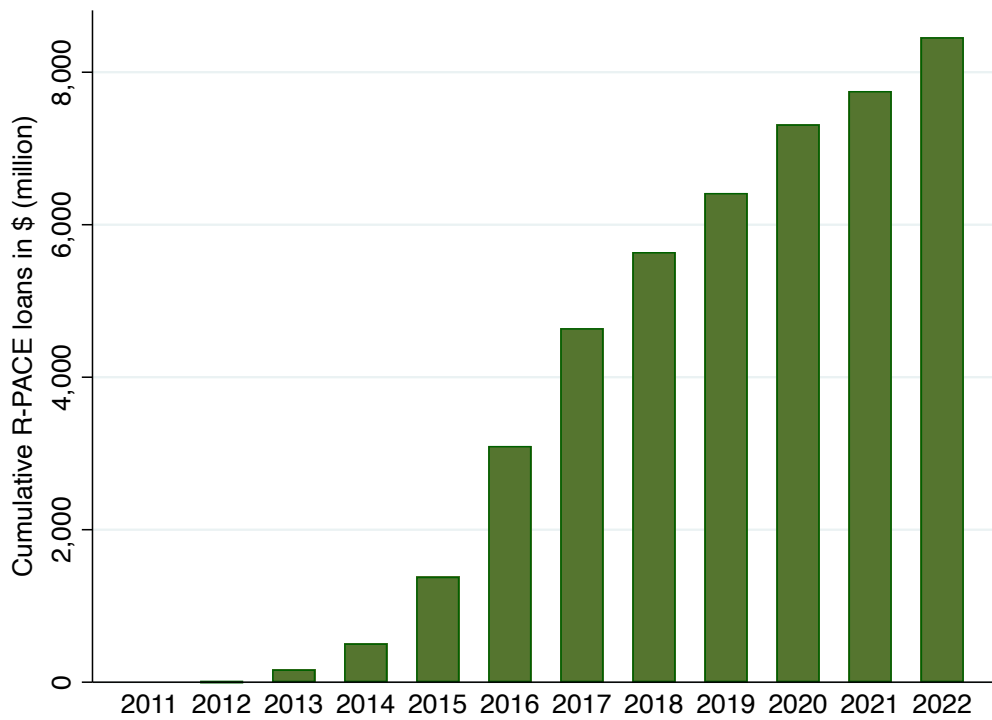
Note: This table presents the aggregated group-time average treatment effects on the treated (ATT) regression coefficient estimates using Callaway and Sant'Anna (2021)'s estimator. Following Roth (2024), we use long-differences for the pre-treatment and post-treatment coefficients, so that we can easily interpret pre-trends relative to the reference period $t = -1$. The dependent variable in each panel is the log sale amount of a property. Treatment is a PACE loan attached to the property, and the control group is composed of not-yet-treated properties. Coefficients in Panel A are estimated in a regression without property controls. Those in Panel B includes property controls (number of bedrooms, units, size, age deciles). Zip code-times-year fixed effects are included in the regressions. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 6. Impact of PACE Adoption on Mortgage Credit Supply

Borrower Sample:	All					High-risk	Low-risk
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PACE_{adoption}_{c,t}$	0.062*** (0.001)	0.063*** (0.001)	0.029*** (0.002)	0.027*** (0.004)	0.025*** (0.006)	0.036*** (0.004)	0.002 (0.005)
Loan type	Purchase	Purchase	Purchase	Purchase	Refi	Purchase	Purchase
Observations	1,566,109	1,563,990	1,563,456	1,563,456	1,412,543	1,015,202	547,811
R-squared	0.023	0.036	0.094	0.094	0.185	0.096	0.107
Borrower Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County FE	Yes	No	No	No	No	No	No
Census tract FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Lender FE	No	No	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes	Yes
Mean Dep. Var.	0.829	0.829	0.829	0.829	0.683	0.819	0.847

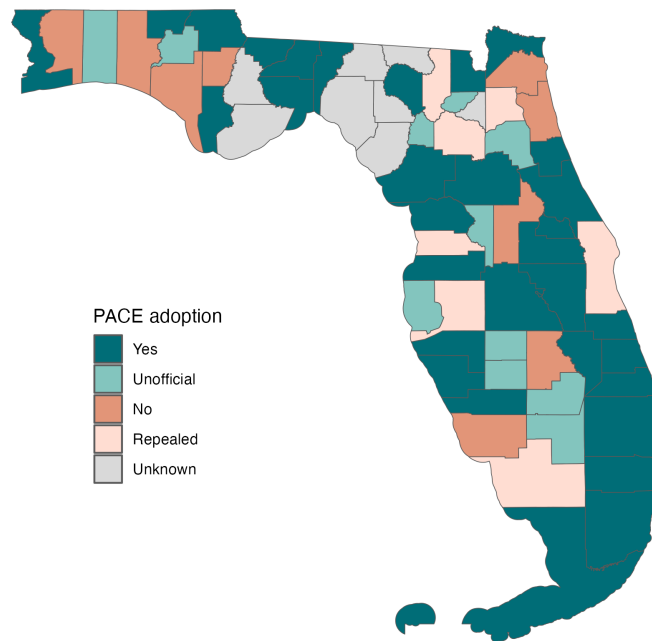
Note: This table reports the impact of county-level PACE adoption on mortgage application approvals. We restrict the sample to mortgage applications for one-to-four-family home purchases (columns 1-4 and 6-7) or for loan refinancing (column 5). Both sets of exercises focus on applications for houses intended to be occupied as a principal dwelling. The outcome variable across all specifications is a dummy variable $Accept_{i,l,c,t}$ taking value one if lender l approves mortgage application i for a house in county c in year t . $PACE_{adoption}_{c,t}$ is a dummy variable that takes the value one if county c has introduced R-PACE in year t , and zero otherwise. Borrower controls include Loan-to-Income ratio, ethnicity, gender, and presence of co-applicant. In the final two columns we report results separately for applicants with above-median LTI (high risk) vs. below-median LTI (low risk). We produce each estimate by taking a pooled difference in means via [Sun and Abraham \(2021\)](#)'s estimator. Robust standard errors clustered at the county-level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

FIGURE 1. Total Amount of PACE Loans Originated



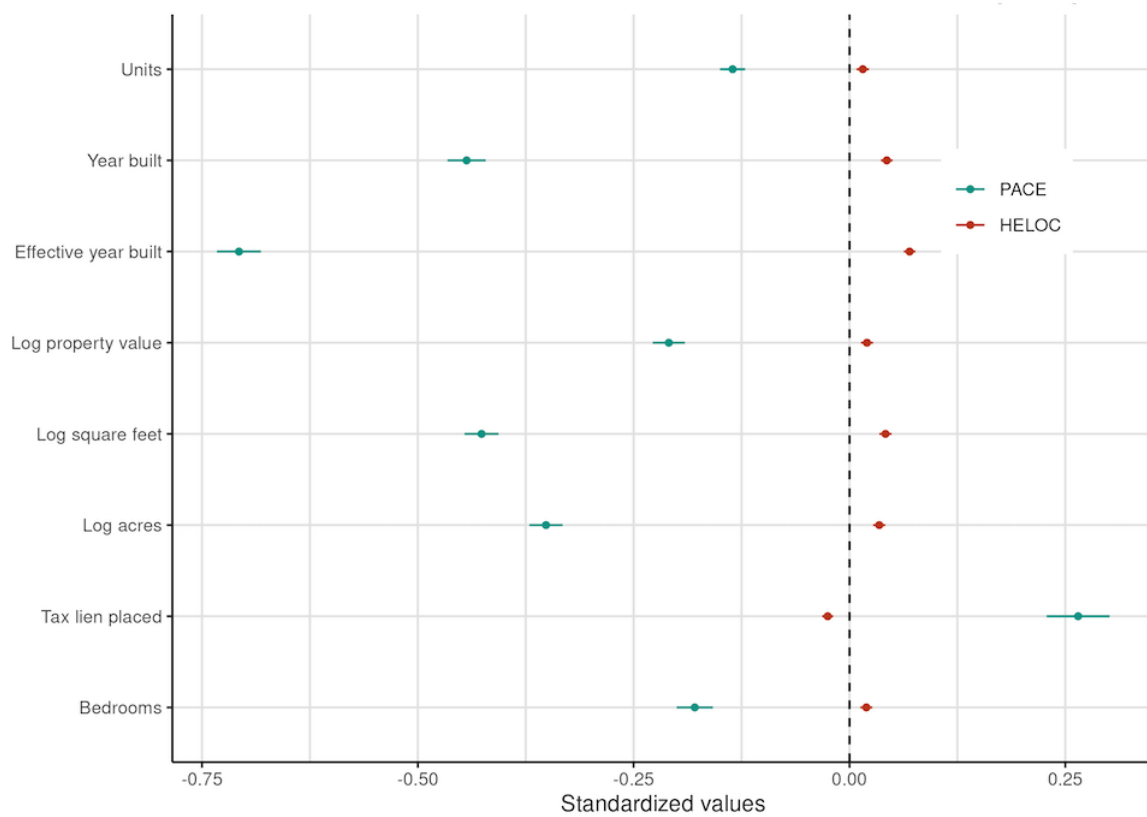
Note: This graph plots the cumulative amount of loans (in millions of nominal U.S. dollars) originated from the residential PACE programs between 2011 and 2022. Residential PACE programs are available in California, Florida, and Missouri. Source: <https://www.pacenation.org/pace-market-data/>.

FIGURE 2. County-Level Adoption of Florida Residential PACE Programs



Note: Panel A provides a map of Florida counties that have adopted residential PACE programs as of December 2023. We classify counties into five categories: “Yes” if PACE is adopted and currently enabled; “Unofficial” if there is no official adoption of PACE but PACE lenders have originated loans to properties in that county; “No” if PACE has not yet been adopted; “Repealed” if the county adopted PACE at one point but lenders withdrew due to legal challenges; “Unknown” if adoption information is not yet available and we have no record of PACE loans originated in those counties.

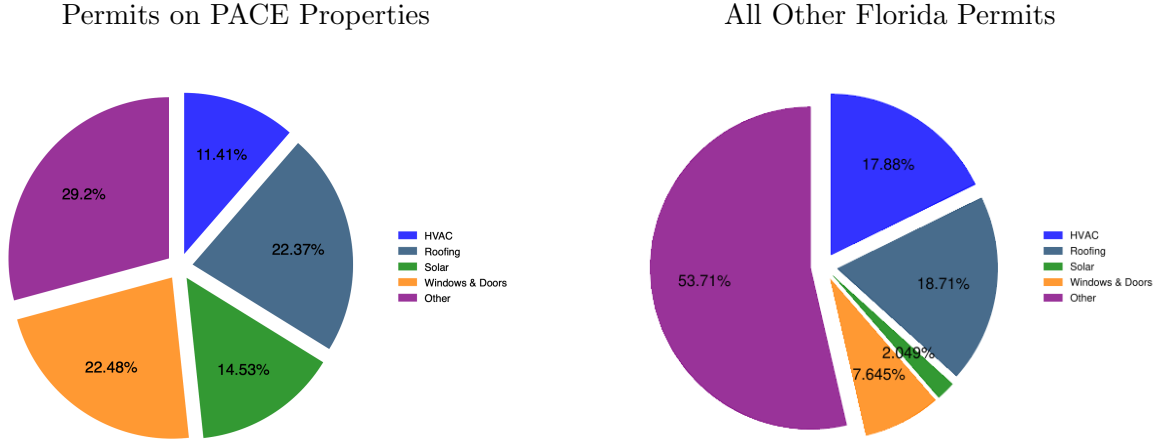
FIGURE 3. Balance Test: Property Characteristics for PACE Loans vs. HELOCs



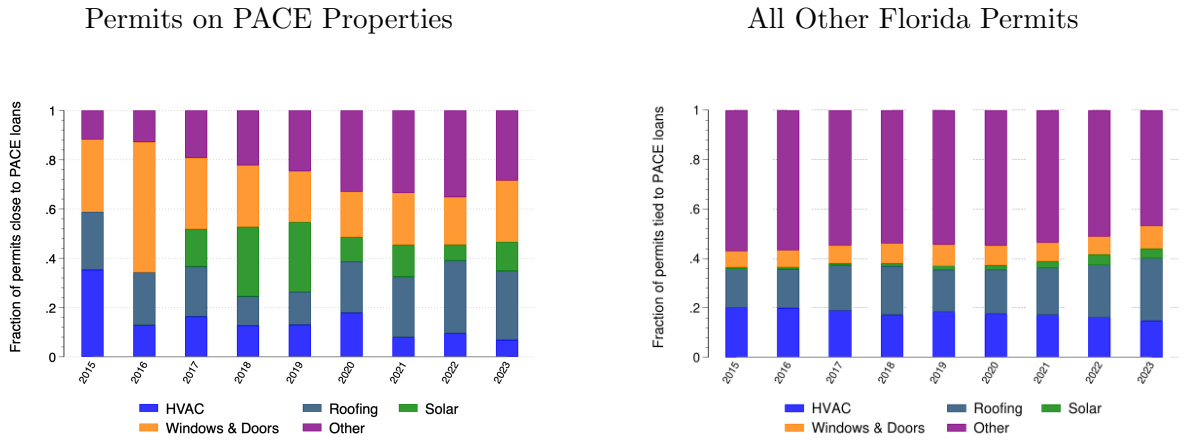
Note: This graph shows the characteristics balance between properties with a PACE loan and properties with a home equity line of credit (HELOC). Overall, properties with a PACE loan are smaller, older, and trade at a lower price than properties with a HELOC.

FIGURE 4. Composition of Permitted Home Improvement Projects

A. Pooled over Sample Period



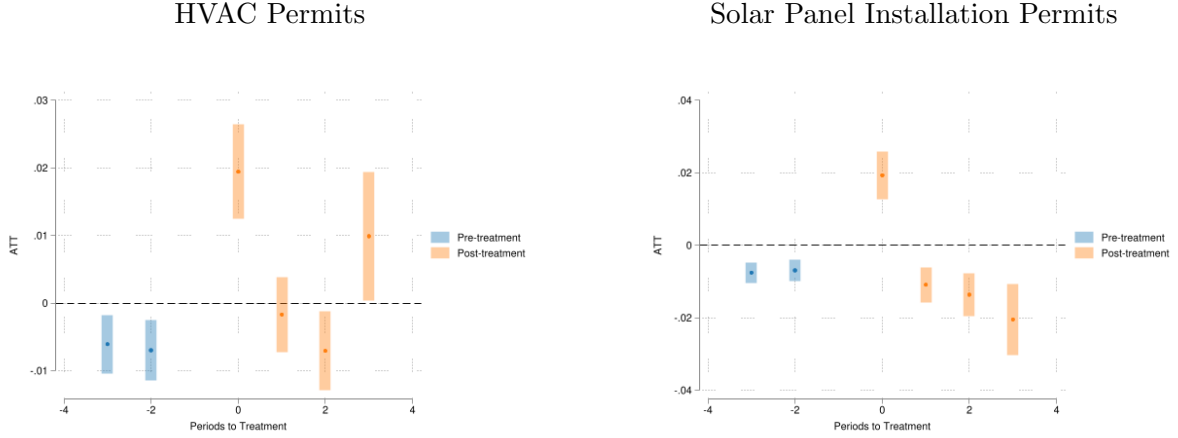
B. Evolution of Permit Activity over Time



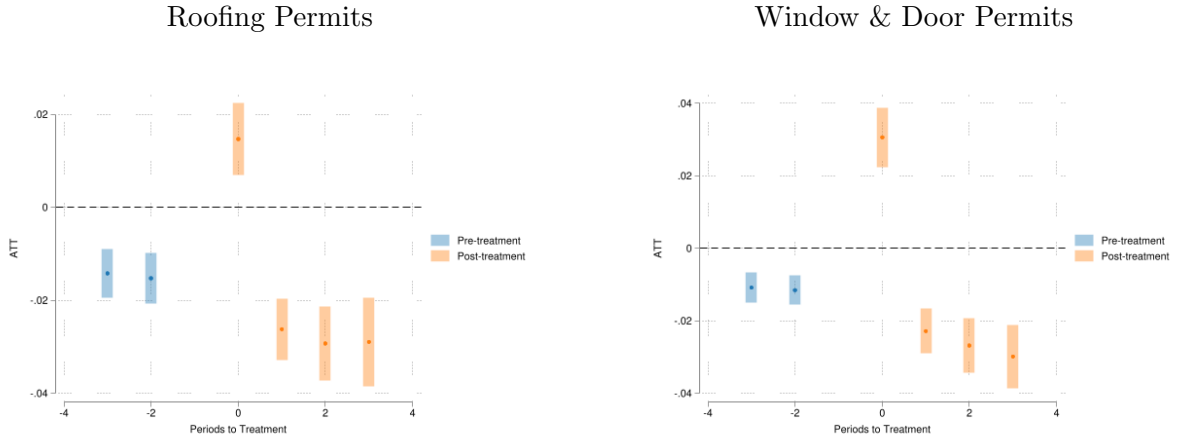
Note: We classify building permits tied to residential properties with a PACE loan by string parsing the description of the home improvement project filed with the town clerk as part of the permit application. The five mutually exclusive categories are: HVAC, roofing, solar, windows and doors, and other. We define roofing as replacing the roof of the house, which distinguishes permits involving solar panel installations on the roof. “Other” includes any permits which would not qualify for PACE based on the project description, such as kitchen or other cosmetic renovations. Panel A shows the breakdown of permits into these categories over the full sample time period, 2015 – 2023 for only residential PACE properties (left) and for all single-family homes in Florida (right). Panel B. shows how the proportions of permits evolve over the sample period. For permits associated with a PACE property, we tabulate only for permits issued with an effective date within six months of loan origination. See text for further details on the CoreLogic building permits data and how we sort permits into these categories.

FIGURE 5. Dynamic Event Studies: Building Permits Issued around PACE Origination

A. Energy-Efficient Projects

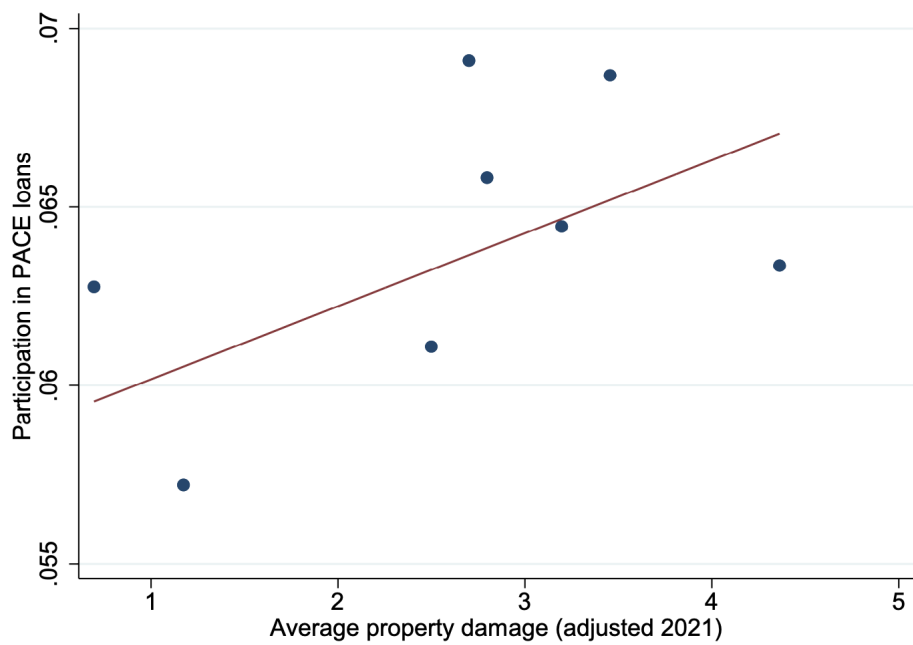


B. Disaster-Proofing Projects



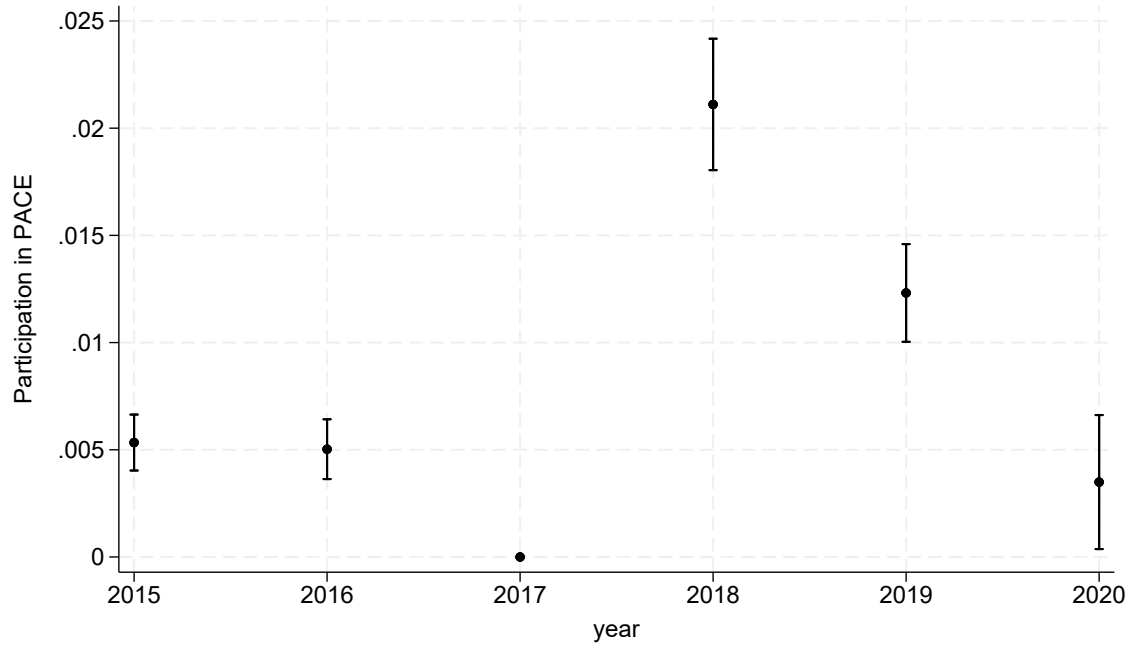
Note: This figure presents the aggregated group-time average treatment effects on the treated (ATT) event study coefficient estimates using Callaway and Sant’Anna (2021)’s estimator in which properties receiving a PACE loan at a later date serve as the control group. Following Roth (2024), we use long-differences for the pre-treatment and post-treatment coefficients, so that we can easily interpret pre-trends relative to the reference period $t = -1$. The dependent variable in each graph is an indicator equal to one if within t years of receiving a PACE loan a permit is issued within one of four climate-adaptation categories. Panel A displays results for the energy-efficient adaptations (HVAC and solar), while Panel B shows results for disaster-proofing adaptations (roofing and window and door installations). Each regression includes a full set of 5-digit zip code \times year fixed effects. Time on the x-axis is measured in years relative to PACE loan origination ($t = 0$). See text for further details on the CoreLogic building permits data and how we sort permits into these categories. We restrict the sample to permits on residential properties. Bars indicate 95% confidence intervals with standard errors clustered by 5-digit zip code and obtained through wild bootstrap with 1,000 replications.

FIGURE 6. Relationship between County-Level PACE Takeup and Property Damages from Natural Disasters



Note: This graph plots the bin-scatter between the average property damages due to natural disasters and the usage of PACE loans. Specifically, the y-axis is the dummy variable $PACE_{i,t}$ that takes the value one if property i has an attached PACE loan originated in year t , and zero otherwise. The x-axis is the county-level log average property damage per capita between 1960 and 2021, measured in real 2021 dollars.

FIGURE 7. Dynamic Event Study: PACE Loan Takeup Following Natural Disasters



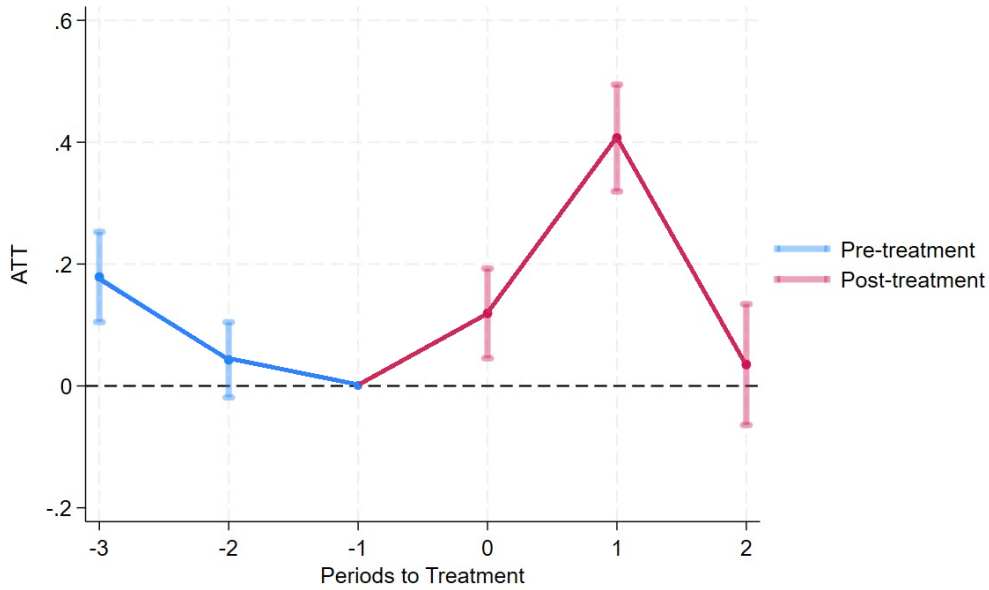
Note: This figure plots the dynamic event study window of PACE loan adoption following Hurricane Irma within the sample of the residential units that adopted a PACE loan. Specifically, we estimate the following equation by OLS:

$$PACE_{i,j,t} = \sum_{n=2015, n \neq 2017}^{2020} \beta_n \cdot \mathbb{1}\{t = n\} \times DMG_j + \delta_t + \eta_i + \varepsilon_{i,j,t}$$

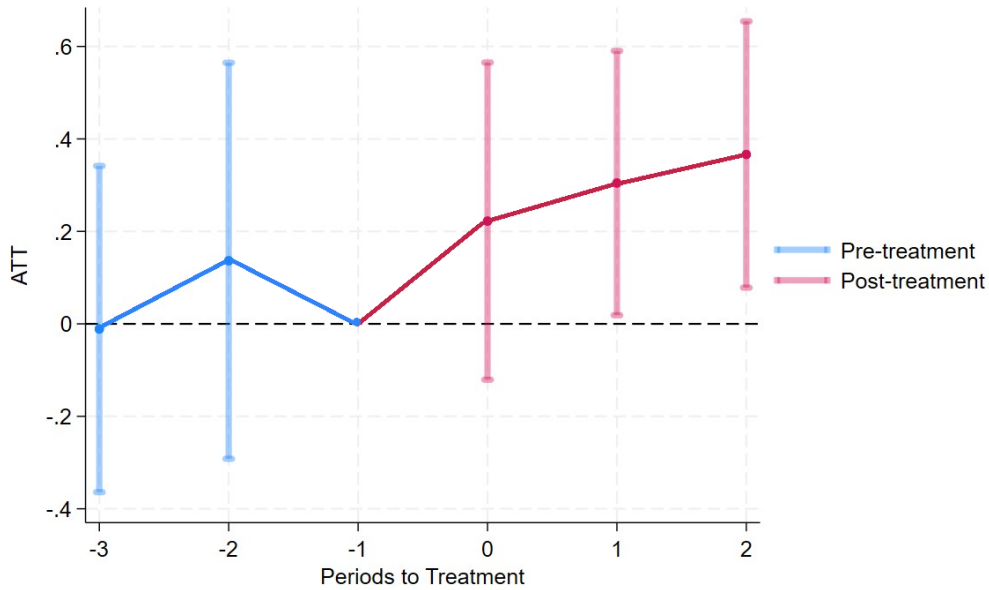
Where the variable DMG_j is the log of average property damages per capita incurred during Hurricane Irma in county j . $\mathbb{1}\{t = n\}$ is a dummy variable that takes the value one if t is equal to n and zero otherwise. δ_t is a full set of year fixed effects, and η_i are property fixed effects. $PACE_{i,j,t}$ is a dummy variable that takes a value of one if the property i acquired a PACE loan during the year t and 0 otherwise. The reference year is 2017, which is the year Hurricane Irma struck the Florida coast in September. Bars indicate 95% confidence intervals with standard errors clustered by property APN.

FIGURE 8. Dynamic Event Studies: Capitalization of PACE Lending into House Prices

A. Without Property Controls

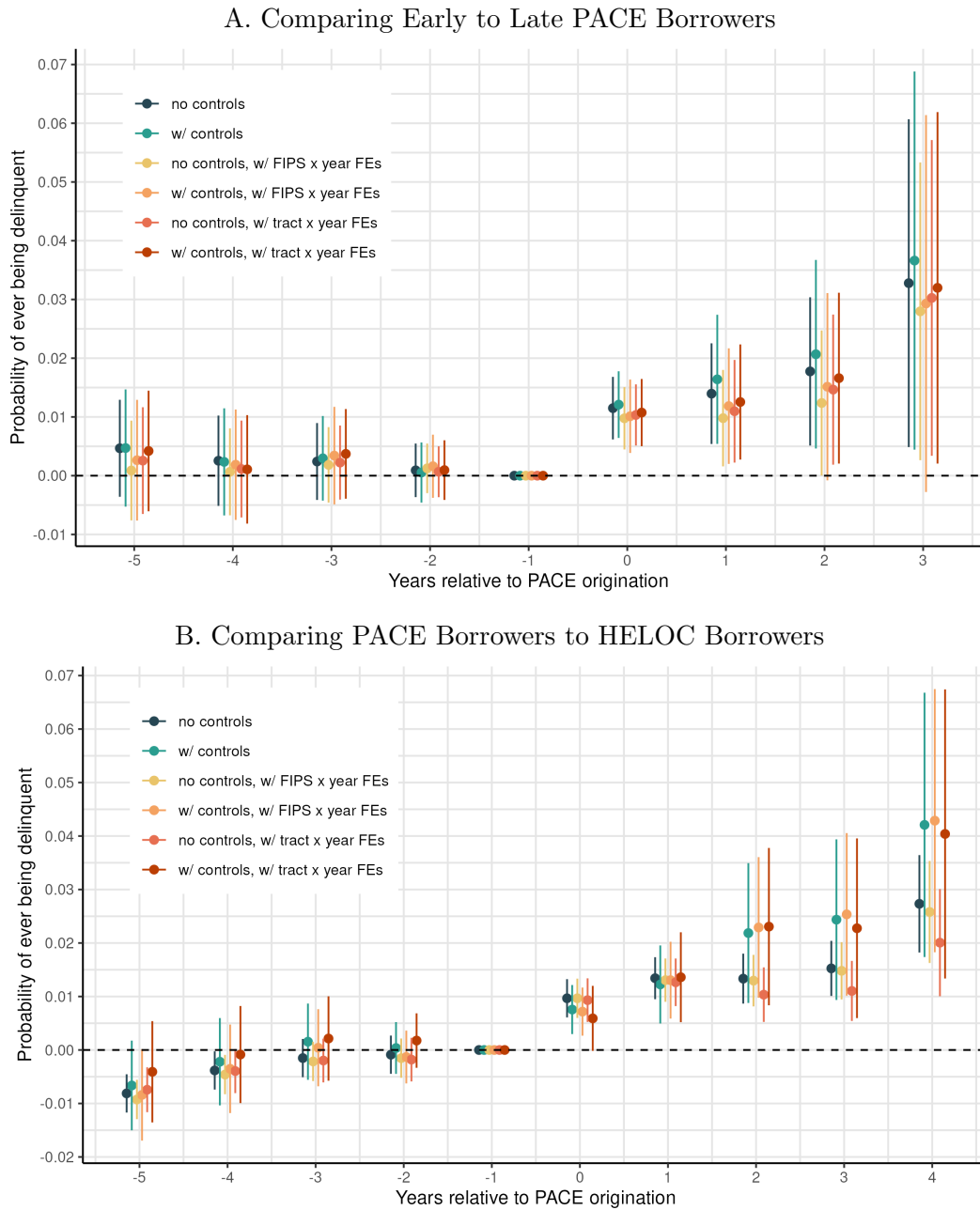


B. Controlling for Property Characteristics



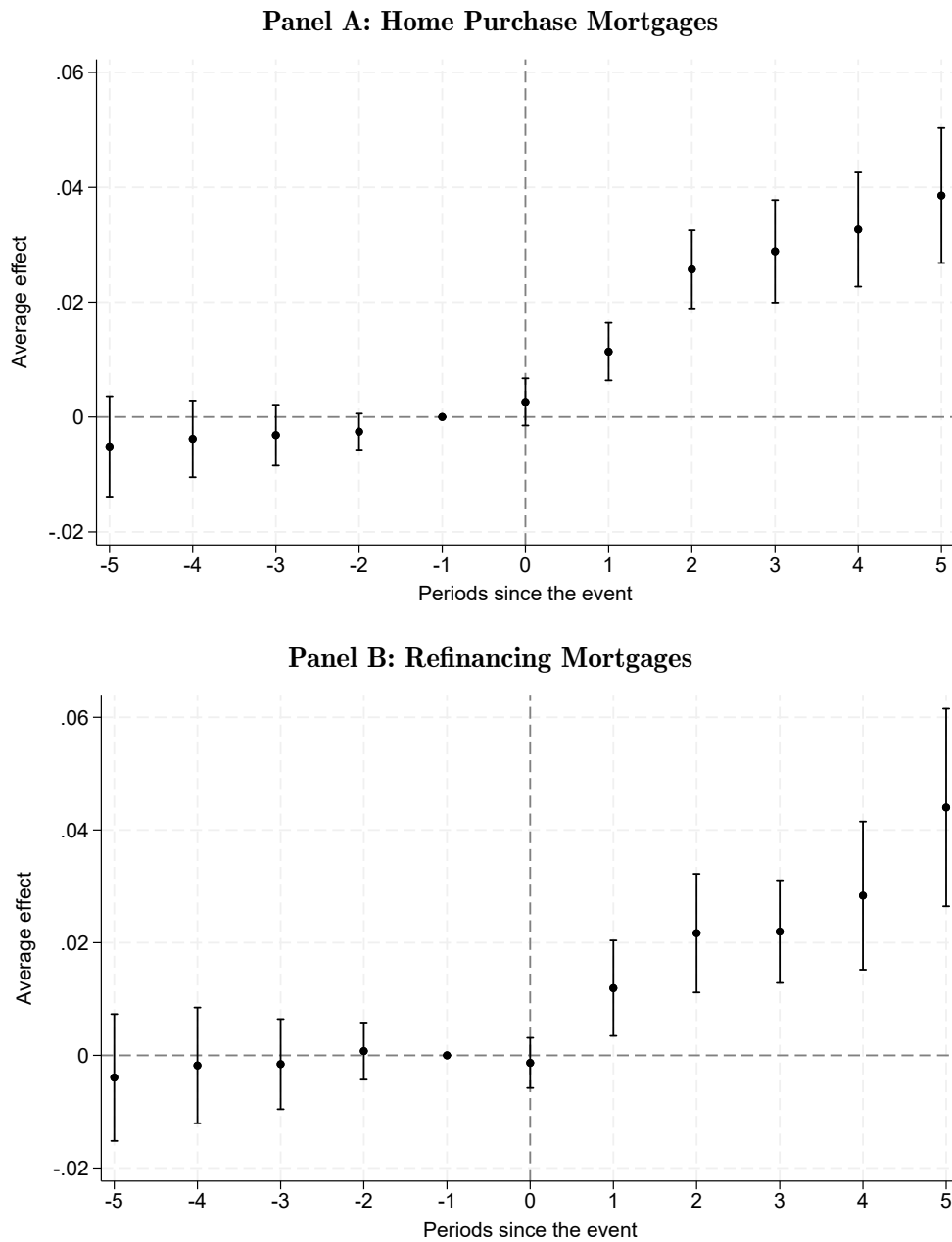
Note: This figure plots the Average Treatment Effects on the Treated (ATT) from event study specifications estimated via [Callaway and Sant'Anna \(2021\)](#)'s estimator with home transaction prices winsorized at the 1st and 99th percentiles as the outcome variable. Following [Roth \(2024\)](#), we use long-differences for the pre-treatment and post-treatment coefficients, so that we can easily interpret pre-trends relative to the reference period $t = -1$. The dependent variable is the sale amount of a property transaction. We restrict our sample to repeat sales of residential properties which both receive a PACE loan at some point during our sample period, 2015 – 2023. Specifications with property controls (Panel B) include Census tract \times year fixed effects, winsorized log square footage, bins for number of bedrooms and bathrooms, and deciles of property age. Time on the x-axis is measured in years relative to PACE loan origination ($t = 0$). Bars indicate 95% confidence intervals with standard errors clustered by property APN and obtained through wild bootstrap with 1,000 replications.

FIGURE 9. Dynamic Event Studies: PACE Origination and Property Tax Delinquency



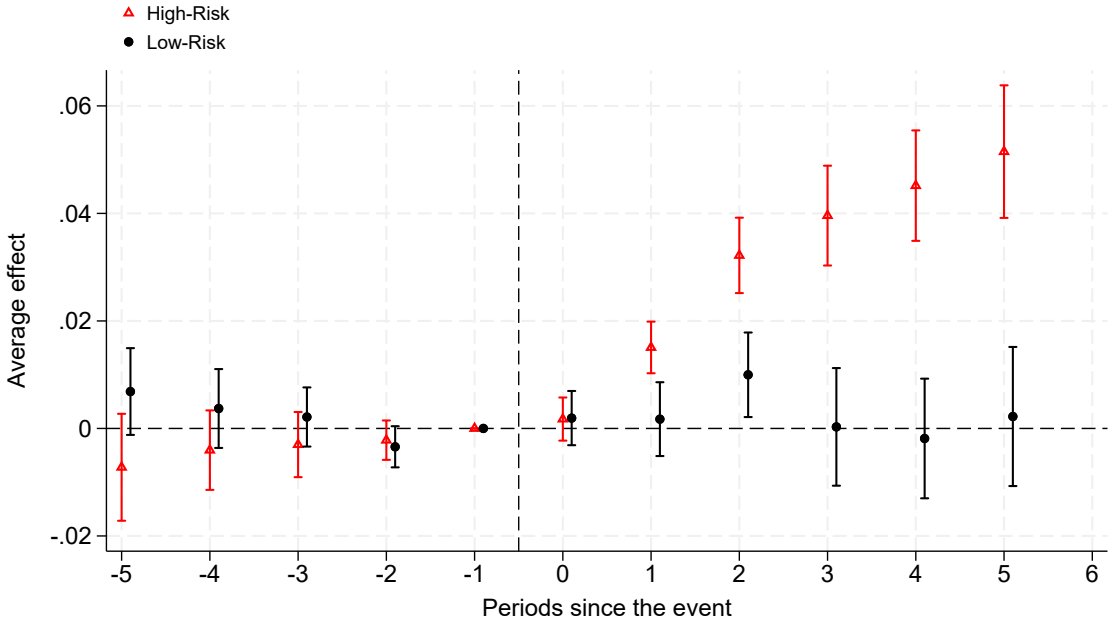
Note: This figure plots local property tax delinquency probabilities for PACE borrowers around the year of loan origination. The outcome is a dummy equal to one if the property has ever been delinquent as of that point in time. In Panel A, we compare early PACE borrowers to late (i.e. not-yet-treated) PACE borrowers using [Callaway and Sant’Anna \(2021\)](#)’s estimator. Following [Roth \(2024\)](#), we use long-differences for the pre-treatment and post-treatment coefficients, so that we can easily interpret pre-trends relative to the reference period $t = -1$. In Panel B, we compare PACE borrowers to HELOC borrowers. Since the never-treated and not-yet-treated control groups are not well-defined for the comparison of PACE to HELOC borrowers, for the treatment/control split in Panel B, we instead use the stacked difference-in-differences estimator proposed by [Cengiz et al. \(2019\)](#). Specifications with property controls include winsorized log square footage, bins for number of bedrooms and bathrooms, and deciles of property age. In some specifications, we include county FIPS \times year fixed effects. For specifications with tract \times year fixed effects, we impose boundaries according to the 2010 decennial Census. In each graph, we estimate the event study specification over an unzipped annual panel of tax delinquency statuses for each single-family property in our sample. Bars indicate 95% confidence intervals obtained from standard errors clustered by property APN.

FIGURE 10. Dynamic Event Study: Lenders' Credit Supply Response for First-Lien Mortgages



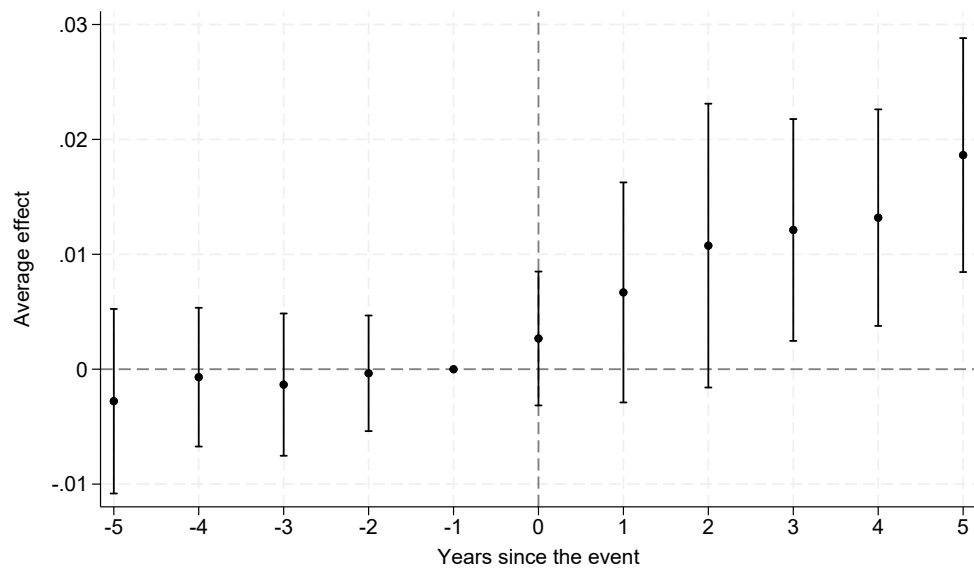
Note: The graph plots the coefficient estimates of regression equation 4.5 using Sun and Abraham (2021)'s estimator focusing on mortgage applications for home purchase (Panel A) and for loan refinancing (Panel B). Time on the x-axis is years relative the introduction of the PACE program in a county in Florida.

FIGURE 11. Dynamic Event Study: Heterogeneous Mortgage Credit Supply Responses by Borrower Loan-to-Income



Note: The graph plots the coefficient estimates of regression equation 4.5 on two different borrower risk samples using Sun and Abraham (2021)’s estimator. We measure borrower risk based on the annual median value of Loan-to-Income ratio of applicants in a Census tract, and define “high-risk” applications those with a LTI above the median (red triangles), whereas “low-risk” applications those with a LTI below the median (black dots). Time on the x-axis is years relative the introduction of the PACE program in a county in Florida.

FIGURE 12. Dynamic Event Study (Stacked DiD): Lenders' Credit Supply Response for First-Lien Home Purchase Mortgages



Note: The graph plots the coefficient estimates using the "stacked" difference-in-differences approach of [Cengiz et al. \(2019\)](#) which adds stacked cohort fixed effects to the regression equation 4.5. Time on the x-axis is years relative the county's introduction of the PACE program.

Online Appendix to
**Picking Up the PACE:
Loans for Residential Climate-Proofing**

by Aymeric Bellon (UNC Chapel-Hill), Cameron LaPoint (Yale SOM), Francesco Mazzola (ESCP Europe), and Guosong Xu (Rotterdam School of Management)

A SAMPLE PACE LOAN DOCUMENTS

In this appendix, we offer examples of recorded PACE loan contracts and accompanying documents, including local property tax bill stubs and home improvement permit filings. Some jurisdictions – mostly less-populated ones – do not maintain digitized records of PACE assessments. For such counties, our FOIA requests for information on PACE loans tied to property APNs yielded a combination of PDF scans of the “Notice of Assessment” (Figure A.1) confirming the loan details and the “Notice of Commencement” (Figure A.2) confirming the improvement being financed by the PACE loan. The document fields and formatting are standard across all Florida counties. As discussed in Section 2.1, the Notice of Commencement renders it difficult for the borrower to apply PACE funds towards consumption of goods or services other than the project listed on the assessment notice.

The format of property tax bills is also standard across counties, although the particular line items comprising the total local tax bill will vary due to overlapping sub-county jurisdictions (i.e. the tax code area described in Section 4.4) and the existence of any non-*ad valorem* assessments specific to the property (like a PACE loan). For instance, in the sample tax bill pictured in Figure A.3, the borrower received a PACE loan from the Green Corridor PACE District operating in the county, and this annual payment towards the loan balance represents about one-third of the property owner’s overall property tax bill. Property owners are responsible for paying both *ad valorem* and non-*ad valorem* tax bills according to the same calendar schedule, meaning that failing to pay the full balance due for a tax year (payment deadline of March 31 in Florida)

Figure A.1. Sample PACE Contract and Property Lien Recording

GADSDEN COUNTY NICHOLAS THOMAS
Instrument: 230005183 Recorded: 07/17/2023 1:47 PM

OFFICIAL RECORDS: 1 of 4
Book: 937 Page: 241

Recording Fee: \$35.50

**This instrument prepared by and executed
by a public office of the Florida PACE
Funding
Agency and after recording return to:
Home Run Financing
750 University Ave #140
Los Gatos, CA 95032**

SPACE ABOVE THIS LINE RESERVED FOR RECORDER'S USE

NOTICE OF ASSESSMENT

GADSDEN

THIS NOTICE OF ASSESSMENT ("Notice") provides a summary memorandum of a Financing Agreement entered into by and between the FLORIDA PACE FUNDING AGENCY (the "Agency") and the record owner(s) of the Assessed Property (the "Property Owner"), both as described hereinafter. This Notice is executed pursuant to such Financing Agreement in substantially the form appended to Agency Resolution #2016-0809-3, a certified copy of which is recorded in the Official Records at 160008599; a Final Judgment, a certified copy of which is recorded at 140007031; a Final judgment, a certified copy of which is recorded at 220010257; all in the Public Records of GADSDEN, Florida, and all of the terms and provisions thereof are incorporated herein by reference. Agency has levied and imposed a non-ad valorem assessment as a lien of equal dignity to taxes and assessments, and as more particularly described herein and in such Financing Agreement, on the Assessed Property in conformance with Section 163.08, Florida Statutes (the "Supplemental Act").

1. Property Owner: XXXXXXXXXX
2. Assessed Property: See Legal Description in Attachment I. OR 873 P 138 OR 579 P 1338 OR
3. Street Address of Assessed Property: 388 Charlie Harris Loop, Quincy FL 32352
4. Property Appraiser Parcel Identification Number: 2-17-3N-3W-0000-00244-0100
5. Qualifying Improvements:
Energy Efficiency Improvement:
Roof - Asphalt Shingle
6. Financed Amount (pursuant to the Financing Agreement; this amount may be reduced WITH SUCH REDUCED AMOUNT REFLECTED IN A SUPPLEMENTAL NOTICE OF ASSESSMENT): \$22,777.37
7. Interest Rate (to be applied to the principal amount of the Financed Amount): 9.99%
8. Assessment Installment (pursuant to the Financing Agreement; this amount may be reduced WITH SUCH REDUCED AMOUNT REFLECTED IN A SUPPLEMENTAL NOTICE OF ASSESSMENT): \$2,992.92
9. Period of years (number of Annual Payments): 15 years
10. The Annual Payment of the Assessment will appear on the same bill as for property taxes, and will include the Assessment Installment, plus any annual costs of administration and charges associated with the Assessment, annual collection costs, and annual charges required by the local property appraiser and tax collector.
11. The Assessment is NOT due on sale or transfer of the Assessed Property. Payoff and release

Notice of Assessment ES
Application ID No.: 5293401
County: GADSDEN
Generated on: July 06, 2023

information may be obtained by contacting the Florida PACE Funding Agency at:
www.floridapace.gov or Home Run Financing, 750 University Ave #140, Los Gatos, CA 95032;
Telephone: (844) 873-7223; Email operations@homerunfinancing.com; Websites:
www.homerunfinancing.com and www.floridapace.gov.

12. NOTE: Prepayment information must be requested ten (10) business days prior to any prepayment. Prepayments must be in immediately available funds.
13. Suggested ALTA, Schedule B exclusion to coverage for title insurance professionals: *"Non-ad valorem assessment, which by its term is not due upon sale, evidenced by notice recorded in Official Record Book____, at Page____,"*
14. The following caveat is intended to be supplemental, constructive notice provided in writing to any prospective purchaser as required by the Supplemental Act. So long as the Assessment provided for hereunder has an unpaid balance, at or before the time Property Owner enters into a contract to sell the Assessed Property, the Property Owner gives any prospective purchaser by law a written disclosure statement in the following form:

QUALIFYING IMPROVEMENTS FOR ENERGY EFFICIENCY, RENEWABLE ENERGY, OR WIND RESISTANCE - The property being purchased is located within the jurisdiction of a local government that has placed an assessment on the property pursuant to s. 163.08, Florida Statutes. The assessment is for a qualifying improvement to the property relating to energy efficiency, renewable energy, or wind resistance, and is not based on the value of the property. You are encouraged to contact the county property appraiser's office to learn more about this and other assessments that may be provided by law.

THE DECLARATIONS, ACKNOWLEDGMENTS AND AGREEMENTS CONTAINED AND INCORPORATED HEREIN SHALL RUN WITH THE LAND DESCRIBED HEREIN AND SHALL BE BINDING ON THE PROPERTY OWNER (INCLUDING ALL PERSONS OR ENTITIES OF ANY KIND), AND ANY AND ALL SUCCESSORS IN INTEREST. BY TAKING SUCH TITLE, PERSONS OR ENTITIES WHO ARE SUCCESSOR SHALL BE DEEMED TO HAVE CONSENTED AND AGREED TO THE PROVISIONS OF THIS NOTICE AND THE REFERENCED FINANCING AGREEMENT TO THE SAME EXTENT AS IF THEY HAD EXECUTED IT AND BY TAKING SUCH TITLE, SUCH PERSONS OR ENTITIES SHALL BE ESTOPPED FROM CONTESTING, IN COURT OR OTHERWISE, THE VALIDITY, LEGALITY AND ENFORCEABILITY OF THIS AGREEMENT.

OFFICIAL RECORDS: 2 of 4
Book: 937 Page: 242

Figure A.2. Sample Notice of Improvement Commencement for PACE Loan

GADSDEN COUNTY NICHOLAS THOMAS
Instrument: 230004789 Recorded: 06/30/2023 8:41 AM

OFFICIAL RECORDS: 1 of 1
Book: 936 Page: 705
Recording Fee: \$10.00

NOTICE OF COMMENCEMENT

The undersigned hereby gives notice that improvements will be made to certain real property, and in accordance with Chapter 713, Florida Statutes, the following information is provided in this Notice of Commencement.

1. Description of Property
Legal Description Lot 1 / Block 2-17-3N-3W-6000-00244-0100 / A/c 2-17-3N-3W-6000-00244-0100
Street Address 388 Charlie Harris loop City Quincy FL Zip 32351
2. General description of improvement RE-ROOFING (REMOVE + REPLACE SHINGLES)
3. Owner information
A. Name [REDACTED]
B. Address 388 Charlie Harris loop City Quincy St FL Zip 32351
C. Interest in Property _____
D. Name & Address of Fee Simple Title Holder (Other than Owner) _____
4. Contractor Name and Address
Kevin Krueger 8936 Western Way Jacksonville FL 32256
5. Surety Name _____
Bond amount: \$ 19,500
6. Lender's Name and Address _____
7. Person within the State of Florida designated by owner upon whom notices or other documents may be served as provided in Section 713.13(1)(a)7 of the Florida Statutes. _____
8. In addition to self, the Owner designates the following person to receive a copy of the Lienor's Notice as provided in Section 713.13(1)(b) of the Florida Statutes. Give name and address. _____
9. Expiration date of Notice of Commencement. The expiration date is one (1) year from the date of recording unless a different date is specified.

Signature of Owner/ Agent: [Signature]
This foregoing instrument was acknowledged, sworn to and subscribed before me this 30th day of June, 2023.
PREPARED BY: _____

State of: Florida
County of: Gadsden
Notary Signature: [Signature]
Printed Name: Allison Owens
Known personally/ID shown: GA DC
Cora Andrew Jaramillo
*physically present.

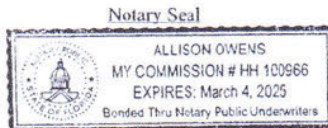



Figure A.3. Sample Property Tax Bill after PACE Loan Originated

	Sam C. Steele C.F.C. Monroe County Tax Collector	Monroe County 2019 Paid Individual Tax Certif NOTICE OF AD VALOREM TAXES AND NON-AD VALOREM ASSESSMENTS					
ACCOUNT NUMBER	ESCROW CODE	MILLAGE CODE					
1610844		500K					
PROPERTY ID #							
1610844							
MUST PAY BY CASH, CREDIT CARD OR CERTIFIED FUNDS							
205 Pirates Dr Key Largo, FL 33037-2323	NEW OWNER DUP BILL MAILED	0049468000000326139 205 PIRATES Dr BK 13 LT 14 AND 15 PIRATES COVE PB3-18 KEY LARGO OR502-826 OR672-82D/C OR1170-621AFF OR1170-622 OR117					
Paid 06/22/2020 \$7,106.47 Receipt # 116-19-0001470 Paid By CMAFL/CJAC							
AD VALOREM TAXES							
TAXING AUTHORITY	TELEPHONE	ASSESSED VALUE	EXEMPTION AMT	TAXABLE VALUE	MILLAGE RATE	TAXES LEVIED	
SCHOOL STATE LAW	305-293-1400	401,428	0	401,428	1.5550	624.22	
SCHOOL LOCAL BOARD	305-293-1400	401,428	0	401,428	1.7880	717.75	
GENERAL FUND	305-292-4473	401,428	0	401,428	0.7697	308.98	
F&F LAW ENFORCE JAIL	305-292-7017	401,428	0	401,428	1.7747	712.41	
HEALTH CLINIC	305-296-4886	401,428	0	401,428	0.0437	17.54	
GENERAL PURPOSE	305-292-4473	401,428	0	401,428	0.1725	69.25	
MOSQUITO CONTROL	305-292-7190	401,428	0	401,428	0.4508	180.96	
M C LOCAL ROAD PATROL	305-292-7017	401,428	0	401,428	0.3484	139.86	
SFWM DIST	800-432-2045	401,428	0	401,428	0.1152	46.24	
OKEECHOBEE BASIN	800-432-2045	401,428	0	401,428	0.1246	50.02	
EVERGLADES CONST PR	800-432-2045	401,428	0	401,428	0.0397	15.94	
K L FIRE RESC & EMERG I	305-743-6586	401,428	0	401,428	1.0000	401.43	
AD VALOREM TAXES:					8.1823	\$3,284.60	
NON-AD VALOREM ASSESSMENTS				LEVYING AUTHORITY	TELEPHONE	UNITS	AMOUNT
				MO CO SOLID WASTE	305-295-4323	1.000	402.00
				KEY LARGO WASTEWATER #4	305-451-4019	0.000	340.23
				GREEN CORRIDOR PACE	866-807-6864	1.000	2,198.84
NON-AD VALOREM ASSESSMENTS:						\$2,941.07	
TOTAL COMBINED TAXES AND ASSESSMENTS:							\$6,225.67

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B CONCEPTUAL FRAMEWORK

B.1 BASIC FRAMEWORK

Framework The model has two periods. In the first period $t = 1$, a representative household buys a house at price H_0 . The household makes a deposit of A at time 0 and takes out a mortgage $H_0 - A$ with repayment amount D . The household discount rate is equal to β .

In the second period, $t = 2$, the household takes out a PACE loan to finance an eligible house improvement project. The project increases the value of the house by ΔH . Moreover, the value of the house in the second period is equal to H , which is not necessarily equal to H_0 . The PACE loan requires a repayment of ℓ . At time $t = 2$, the household receives an income equals to \tilde{R}_2 . Income received in period $t = 2$ is random and follows well-defined probability distribution $f(\cdot)$. The household defaults if total income falls below total liabilities, namely $D + \ell$, and the lender then recoups losses by foreclosing on the house. As a result, the household will default if: $R_2 < D + \ell$. Borrowing through PACE increases the probability of bankruptcy for households because the total repayment amount is higher.

As a result, the household's utility function across the two periods is then equal to the following:

$$\begin{aligned}
 U(A, D) = & - \underbrace{A}_{\text{down payment}} + \underbrace{\beta \int_{\underline{R}}^{D+\ell} R_2 dF(R_2)}_{\text{Expected utility if default}} \\
 & + \underbrace{\beta \int_{D+\ell}^{\bar{R}} R_2 - D - \ell dF(R_2)}_{\text{Expected utility if no default}}
 \end{aligned}$$

An important friction is that PACE loan finances projects that, taken in isolation, are *illiquid*. The inability to keep the house and sell the PACE-backed project implies that the household cannot simply sell the PACE-financed project following a negative income shock. An important statistic is the net present value of the PACE financed project, that is, how much the house value appreciates, net of its discounted costs, if the PACE project is realized.

We assume lenders are more patient than borrowers. Lenders' discount rate satisfies $0 < \beta < \delta < 1$ to allow for gains from trade. As a result, lenders' profit function is given by:

$$\begin{aligned}
 \Pi(A, D) = & \underbrace{-(H_0 - A)}_{\text{Loan amount}} + \delta \underbrace{\int_{\underline{R}}^{D+\ell} H + \Delta H - \ell dF(R_2)}_{\text{Expected profit if borrower defaults}} + \delta \underbrace{\int_{D+\ell}^{\bar{R}} D dF(R_2)}_{\text{Expected profit if the borrower does not default}}
 \end{aligned}$$

PACE loans have an ambiguous effect on lenders' profit. The default region increases when a PACE loan is taken. However, the recovery value can be higher if the PACE loan increases the house value $\Delta H - \ell > 0$.

Lending markets are competitive, so lenders have zero rent: $\Pi(A, D) = 0$. The representative household maximizes his utility subject to the zero profit condition. We obtain the following first-order condition:

$$\begin{aligned}
& \underbrace{\beta \int_{D+\ell}^{\bar{R}} dF(R_2) - \beta(D + \ell)f(D + \ell)}_{\text{Marginal utility cost of a higher debt repayment}} = \\
& \underbrace{\delta(H + \Delta U - \ell)f(D + \ell) + \delta \int_{D+\ell}^{\bar{R}} dF(R_2) - \delta Df(D + \ell)}_{\text{Marginal utility of higher savings in the downpayment}}
\end{aligned}$$

This first-order condition characterizes a key tradeoff. Marginally increasing debt outstanding is costly for the household because it increases future debt repayment in non-defaulting states. It also weakly increases the probability of default. However, an increase in mortgage debt carries a utility benefit because it decreases downpayment. The extent to which the downpayment amount is reduced depends on the participation constraint of lenders. Downpayments will be reduced more if the collateral recovery value of lenders is higher, which depends on the net present value of the PACE-financed project.

B.2 PREDICTIONS

Comparative statics depend on $f(\cdot)$, which we do not observe. To make the results more tractable and without loss of generality, we assume that $f(\cdot)$ comes from a uniform distribution and repayment amount D^* is between $[\underline{R}, \bar{R}]$. Given the previous first-order condition, we can derive the following propositions:

Proposition 1: The supply of mortgage lending D is increasing in the payoffs of PACE loans (ΔH) but decreasing in the loan amount ℓ of the PACE contract.

Intuition/proof: If ΔH increases, then the recovery value of lenders in the event of default increases, reducing the risk of a short sale in which the value of the house falls below the outstanding debt. As lenders make zero profit, they have to increase the probability of default by increasing D in order not to make any profit. Increasing D also increases households' utility, as they are more impatient ($\beta < \delta$). With a uniform distribution $f(\cdot)$, the second order condition becomes $\beta < \delta$ and the optimal D can be expressed as an increasing function of (ΔH) and a decreasing function of ℓ .

Proposition 2: The probability of default is weakly higher with a PACE loan.

Intuition/proof: The default boundaries are determined by $D + \ell$, which increases with ℓ .