

PICKING UP THE PACE: LOANS FOR RESIDENTIAL CLIMATE-PROOFING

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HOW TO ACCELERATE THE CLIMATE TRANSITION OF HOUSING?

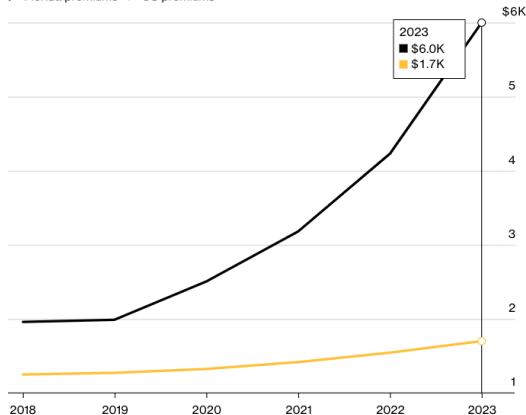
- Greater investments are necessary for climate change **mitigation** [▶ IEA Report](#)
 - ▶ Homes accounted for 16% of global energy-related emissions in 2022 (IEA, 2023)
 - ▶ Total global investment in mitigation alone is currently \$28.7 bil./year for RE [▶ CPI report](#)
 - ▶ Yet, \$827.1 bil./year needed to reach net zero emissions by 2050 (CPI, 2023)
- Greater investments also necessary for climate change **adaptation** (World Bank 2016)
 - ▶ 1 in every 10 homes in the US was impacted by natural hazards in 2021 (CoreLogic 2022)
 - ▶ Insurance markets unraveling in areas exposed to many climate risks (e.g. Florida)
 - ▶ Cities' losses from natural disasters could cost an estimated \$314 billion annually by 2030
- **In practice, green home improvements (HIs) can help on both margins** →
impact-resistant windows offer better insulation and storm protection [▶ DP ratings](#)

REAL EFFECTS OF UNRAVELING HOME INSURANCE MARKETS

Homeowners Policies Surging in Florida

Average homeowners insurance rates in Florida have tripled this decade

Florida premiums US premiums

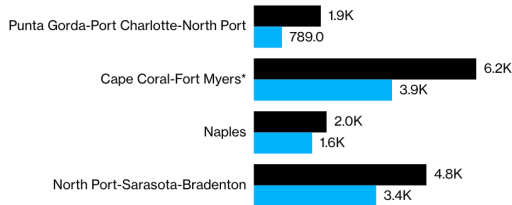


Source: Insurance Information Institute

Surge in Existing Homes for Sale

Southwest Florida is seeing a spike in active listings of single-family homes

December 2023 listings December 2022 listings



Source: Realtor Association of Sarasota and Manatee; Royal Palm Coast Realtor Association; Naples Area Board of Realtors; Realtors of Punta Gorda-Port Charlotte-North Port-DeSoto Inc.

Note: Cape Coral-Fort Myers data are for Jan. 2023-Jan. 2024

Source: Bloomberg, "In Southwest Florida, High Home Insurance Rates Are Driving Away Would-Be Buyers," February 14, 2024.

► Storm projections

► Map

PACE: AN INNOVATIVE HOME IMPROVEMENT LOAN PROGRAM

We study a new class of loans designed to help close these investment gaps

- **Residential Property Assessed Clean Energy (PACE) loans**
 - Key innovation: borrowers pay off debt through local property tax bill
 - Property tax implementation creates a super senior claim (LaPoint 2023)
- Under Modigliani–Miller, issuing a new senior claim should not create value
 - ▶ Govt.-backing allows constrained subprime borrowers to obtain home equity credit
 - ▶ Project is not pledgeable, so underlying collateral held fixed
- **Question:** does PACE financing enable otherwise unrealized (green) investments that increase property values?
- How is surplus distributed across households, insurers, lenders, govt.?

DUE TO THEIR STRUCTURE, PACE LOANS ARE CONTROVERSIAL

Increase in risk: Lax screening and potential predatory lending practices. Breaches the priority of traditional mortgages (**super seniority**).



Efficiency: Allows financially constrained households to invest in (**green**) projects that improve their home equity value by **lowering homeowners insurance costs**.

- Ultimately an empirical question which forces dominate!

SUMMARY OF OUR EMPIRICAL FINDINGS

① PACE **relaxes financing constraints and expands home improvement investment**

- ▶ PACE borrowers are 45% are subprime vs. 7% for HELOC borrowers
- ▶ Sharp increase in PACE-eligible projects around origination

② PACE borrowers pay a **large interest rate premium**

- ▶ Prime borrowers pay 240–270 bps more than comparable HELOC borrowers
- ▶ Premium is another 30–40 bps higher for subprime borrowers

③ PACE **increases household financial distress**

- ▶ Property tax delinquency rises by 0.2 p.p. (11%) after origination

④ PACE-financed investments **create and capitalize substantial value**

- ▶ Sale prices increase by 5.8%, with larger gains for climate-proofing projects
- ▶ Homeowners insurance premia fall by 3–5% $\Rightarrow$ implied discount rates of 2.7–3.6%
- ▶ **No evidence that PACE reduces households' ability to refinance**

PACE EXPANDS NET FISCAL POSITION OF LOCAL GOVT.

- Simple back-of-envelope calculation combining our DiD estimates

$$\Delta R_{t,t+1} = \underbrace{\tau_{t+1}}_{\text{effective tax rate}} \times \left(\underbrace{\Delta P_{t,t+1}}_{\text{capitalization effect}} - \underbrace{\Delta D_{t,t+1} \cdot P_t}_{\text{short-run tax revenue loss}} \right)$$

- Even after netting out delinquencies, **revenues grow by \$180–\$250 per PACE loan-year** in counties participating in program
- Lower-bound estimate of the increase in revenue from PACE adoption because...
 - ▶ Assumes 100% of the delinquency costs are borne by local govt.
 - ★ Municipal bond investors bear some of incidence when coupons backed by PACE payments
 - ▶ Ignores spillover effects on local employment (e.g. through contractors) or investment spending (e.g. through peer effects)

CONTRIBUTIONS & RELATED LITERATURE

① Household credit constraints & home equity extraction

Lustig & Van Nieuwerburgh, 2005; Liberti & Mian, 2010; Benmelech & Bergman, 2011; Vig, 2013; Corradin & Popov, 2015; Keys et al., 2016; Campello & Larrain, 2016; Melzer, 2017; DeFusco, 2018; DeMarzo, 2019; Chen et al., 2020; DeFusco & Mondragon, 2020

→ PACE expands borrowing capacity by changing claim seniority, holding collateral fixed

② Consumer credit pricing & lender market power

Agarwal et al., 2017; Gete & Zecchetto, 2018; Bachas et al., 2021; DeFusco et al., 2022; Erel & Liebersohn, 2022; Granja et al., 2022; Argyle et al., 2023; Yannelis & Zhang, 2023; Bhutta et al., 2026

→ Higher premia for households with weaker outside options point to market power

③ Green financial contracts & barriers to environmental investment

Fowlie et al., 2018; Flammer, 2021; Berkouwer and Dean, 2022; Kim et al., 2025

→ PACE shows how contract design relaxes barriers to household green investment

④ PACE, climate adaptation & property markets

Kirkpatrick and Benneer, 2014; Goodman and Zhu, 2016; Bernstein et al., 2019; Baldauf et al., 2020; Murfin and Spiegel, 2020; Rose and Wei, 2020; Bakkensen and Barrage, 2022; Ge et al., 2022; Sen, 2023; Millar and White, 2024; Hu, 2026; Oh et al., 2026; Sastry, 2026

→ Microdata show that adaptation investments capitalize into house values via insurance costs ↓

INSTITUTIONAL BACKGROUND ON PACE PROGRAMS

LEGAL BACKGROUND ON PACE CONTRACTS

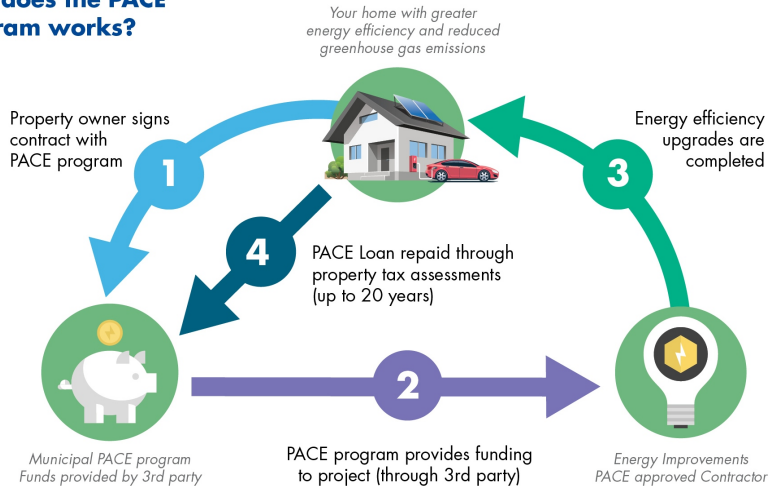
Property Assessed Clean Energy (PACE) Program

Loans for qualified energy efficient and climate-proofing home improvement projects where borrowers pay back debt through annual local property tax bill.

- Qualified uses are fairly expansive: solar panels, HVAC upgrade, **(re)roofing**, **impact-resistant windows/doors**, generator, water conservation, etc. ▶ DP vs. U-Factor
- Local govt. as the loan servicer means that lien on the property is **super senior** to all other forms of debt $\implies$ dominates mortgage lender or bankruptcy claims (LaPoint 2023)
- In practice, a public-private partnership: local govt. issues bonds backed by tax payments and outsources underwriting to private lenders (“administrators”)
 - ▶ Municipal backing keeps fixed interest rate lower than other subprime debt products

How PACE WORKS IN PRACTICE

How does the PACE program works?



Source: City of Miami Beach.

HOW DO BORROWERS OBTAIN PACE FINANCING?

- **Two application methods:**

- ① Apply directly through district or underwriter's website
- ② Work with PACE-qualified registered contractor on home improvement project, and contractor forwards your application to district operating in that area

- **Screening process:**

- ▶ Lender may perform a hard credit inquiry but cannot use FICO score in approval decision
- ▶ Credit inquiry used to uncover DTI, payment delinquency, and bankruptcy history
- ▶ PACE loan can't exceed 10% of income or 20% LTV, and property CLTV $\leq$ 100%

- **At origination:**

- ▶ Notice of assessment lists the loan terms $\rightarrow$ filed with town clerk (borrower CC'ed)
- ▶ Notice of commencement attached to loan details the home improvement project
 $\Rightarrow$ difficult to commit fraud using loan proceeds towards unqualified 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: [REDACTED]
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 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-0000-00244-0100 / A/c 2-17-3N-3W-0000-00244-0100

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

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 8934 Western Way Jacksonville FL 32256

5. Surety Name

Bond amount: \$ 19,500



Sam C. Steele C.F.C.
Monroe County Tax Collector

Monroe County 2019 Paid Individual Tax Certifi

NOTICE OF AD VALOREM TAXES AND NON-AD VALOREM ASSESSMENTS

ACCOUNT NUMBER	ESCROW CODE	MILLAGE CODE	PROPERTY ID #
1610844		500K	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 OR672-820/C OR1170-621AFF
OR1170-622 OR117

Paid 06/22/2020 \$7,106.47
Receipt # 116-19-0001470
Paid to: CHARTER

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

BILL EXPRESS
SCAN TO PAY ONLINE!

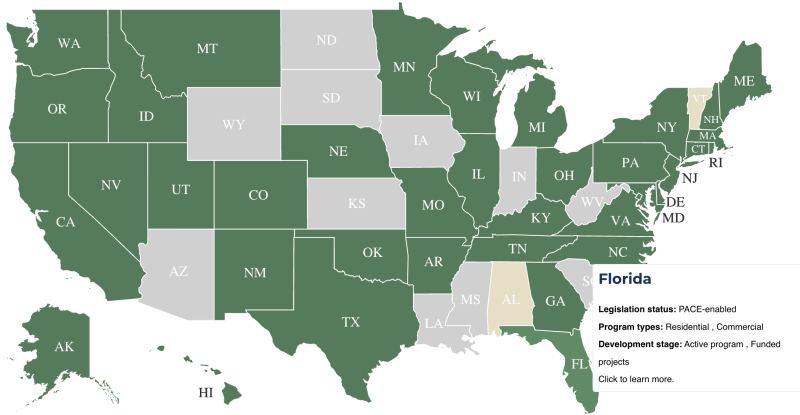
WWW.MONROETAXCOLLECTOR.COM
GET BILLS BY EMAIL

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

PACE LOANS OFFERED IN 36 STATES + D.C. AND GROWING

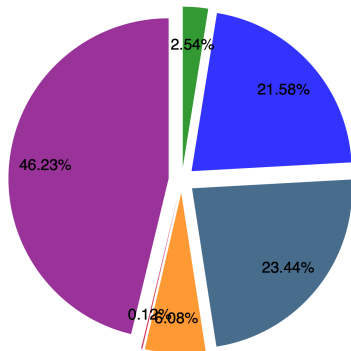


- 4 additional states have proposed C-PACE legislation (pacenation.org) ▶ R-PACE
- R-PACE only available in California, [Florida](#), and Missouri → 71% growth since 2020

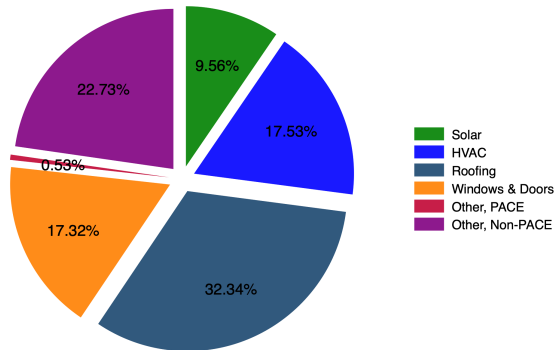
FL PACE LOANS MAINLY USED FOR STORM PROOFING

► EVENT STUDY

All Non-PACE FL Residential Permits



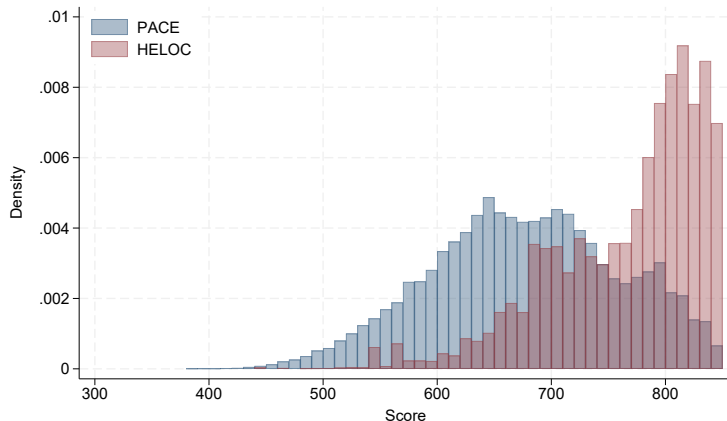
Permits Tied to FL R-PACE Properties



- Over half of FL PACE permits related to storm-proofing
- “Other” non-PACE projects far less common among PACE borrowers ► Dynamic
 - Underestimate true fraction of PACE projects due to permit exemptions after storms

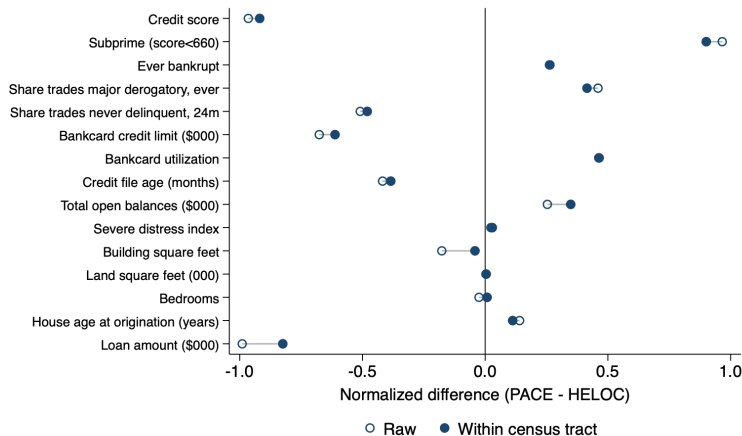
HOW ARE PACE LOANS PRICED?

PACE HHs FAR MORE LIKELY TO BE SUBPRIME THAN HELOCs



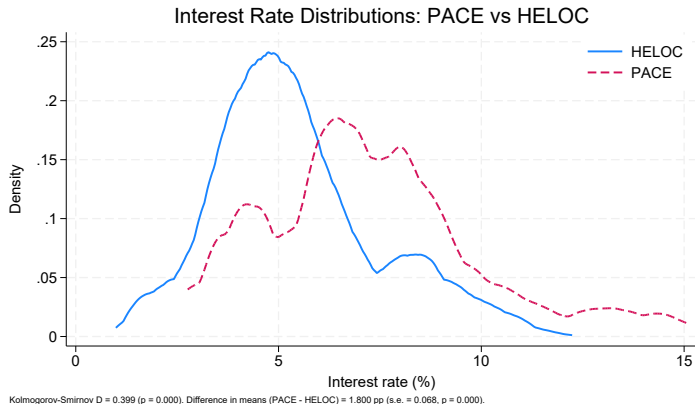
- HELOCs main source of financing for HI projects (Hurst & Stafford 2004)
- **45% of PACE borrowers are subprime** (score < 670), compared to 7% for HELOCs

PACE PROPERTIES NEGATIVELY SELECTED RELATIVE TO HELOCs



- PACE borrowers more likely to exhibit markers of **financial constraints**
- Selection suggests that HELOCs would not be a good control group for PACE

PACE HHs PAY A PREMIUM RELATIVE TO HELOC BORROWERS



- Unconditional average premium of 180 bps.
- HELOCs indexed to U.S. Prime Rate; PACE maturity matched to Treasury rate based on project lifespan

PACE HHs PAY A PREMIUM RELATIVE TO HELOC BORROWERS

$$\text{Rate}_{\ell,c,t} = \beta \cdot \text{PACE}_{\ell} + \gamma' \mathbf{X}_{\ell} + \theta_c + \delta_t + \varepsilon_{\ell,c,t}$$

- PACE borrowers pay a covariate-adjusted interest rate premium of **262 to 289 bps.** relative to HELOCs [▶ Results](#)
 - ▶ Implies an \$780 additional annual interest payments relative to HELOC
- Premium captures PACE lenders' market power, or borrowers' limited outside options, rather than risk or contract design
 - ▶ PACE premium is 27–41 p.p. larger for subprime borrowers [▶ Results](#)
- Fees explain at most 66 bps. of the gap
 - ▶ Assumes maximum of 5% fees fully rolled into principal (CFPB 2023)
 - ▶ Fees include admin fees to assessor's office which are statutorily capped
 - ▶ Permitting fees can also be rolled in, but are small ($\approx$ \$100–\$200)

CONCEPTUAL FRAMEWORK: ASSUMPTIONS & PREDICTIONS

- **Basic setup:** ▶ Details

- ▶ Households differ in **credit quality**
- ▶ Home improvements can be financed with a **junior HELOC** or a **super senior PACE loan**
- ▶ PACE lenders have **greater market power**
- ▶ PACE financing is restricted to **eligible projects and approved contractors**

- **Prediction #1: PACE reaches riskier households ✓**

- ▶ Junior HELOC lenders bear more default risk
- ▶ PACE seniority protects the lender $\Rightarrow$ constrained households can borrow

- **Prediction #2: Riskier households pay more for PACE ✓**

- ▶ Riskier households have no outside option, PACE lenders have market power

WHAT DO WE PREDICT FOR DELINQUENCY AND VALUATION?

- **Prediction #3: PACE increases delinquency (?)**

- ▶ Additional debt service increases financial distress

- **Prediction #4: PACE increases property values (?)**

- ▶ PACE finances projects that otherwise would not occur and restricts funds toward higher-value improvements $\Rightarrow$ greater capitalization into house prices
- ▶ Testable implication: larger effects for investments that generate greater flow utility to homeowners (e.g., climate-proofing in storm prone areas)

- **Why are these results not obvious?**

- ▶ PACE could instead *reduce* distress by substituting for more expensive credit, such as unsecured credit card debt, and freeing up cash flow
- ▶ Such is the case with subsidized natural disaster loans (Collier et al. 2024, 2025)
- ▶ Under M&M, seniority of the claim should merely redistribute value across creditors, and could reduce liquidity of underlying collateral (Millar & White 2024)

DATA & EMPIRICAL STRATEGIES

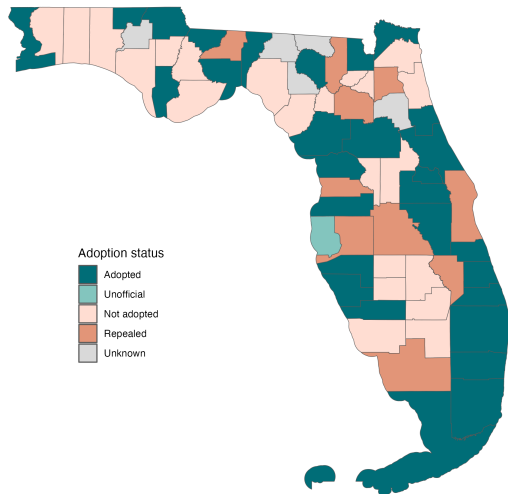
DATASETS: PACE LOANS LINKED TO PERMITS AND PROPERTIES

- **Individual PACE loan data** FOIA requested from all participating PACE counties
 - ▶ 77,564 loans (80% of FL market) matched using the assessor's parcel number (APN)
 - ▶ Combine with data from two PACE companies and assessor rolls
- **Cotality (CoreLogic) Owner Transfers, Mortgage, Tax, and Involuntary Liens data**
 - ▶ House prices, buyers and sellers, information about the use (e.g. single vs. multi-family), tax assessment, combined loan-to-value (CLTV) ratios, property location, and tax delinquency
- **Cotality (CoreLogic) Building Permits**
 - ▶ Tracks building permit applications tied to APNs
 - ▶ New approach to classify green home investments using keyword parsing [▶▶ Method](#)
- **Credit bureau data (Equifax)**
 - ▶ Borrower credit scores, account balances, derogatory events, delinquencies, and bankruptcies
- **Regulatory county-insurer-level insurance premium data (Florida QUASR)**

ENTRY OF R-PACE LENDING IN FLORIDA: 2011 – 2023

ENTRY OF R-PACE LENDING IN FLORIDA: 2011 – 2023

PACE adoption and lender activity 2023



- Variation comes from take-up of PACE driven by programs becoming newly available in the area
 - ▶ First stage: adoption dates from news sources, LexisNexis, and loan records
- Local govt. PACE adoption in a year is uncorrelated with...
 - ▶ Population size, race, income, education, unemployment, Democratic vote share, muni balance sheet
- Only thing that predicts PACE adoption is **turnover in the tax assessor (retirements)** [▶ Results](#)

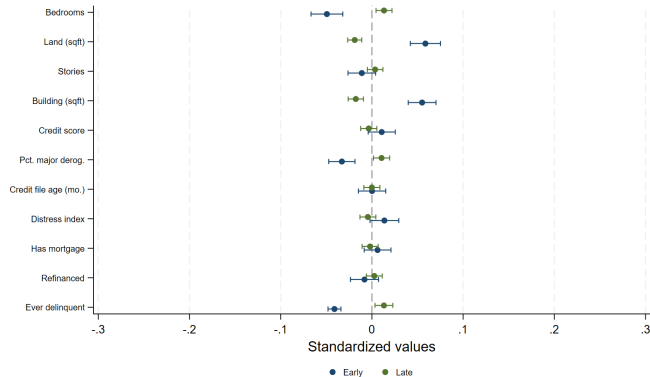
BATTERY OF STAGGERED DiD DESIGNS TO OVERCOME SELECTION

- ① Study borrower delinquency and property sales price by **comparing early to late PACE borrowers** using Cengiz et al. (2019) stacked DiD estimator
 - ▶ Holds fixed the subprimeness of PACE borrowers relative to alternate loan products
- ② Use **instrumental variables (IV) design** which exploits the staggered adoption of PACE programs across Florida counties as an instrument for individual loan take-up
 - ▶ Idea: take-up is driven by county-level policy decisions rather than purely by household financial conditions
 - ▶ IV first-stage take-up rate will be close to weighted average across counties in our sample
- ③ **DiD using staggered enrollment into the program by counties**
 - ▶ Exploits fact that timing of adoption appears quasi-random w.r.t. observables
 - ▶ We lack linkable insurance contract-level data
 - ▶ Use IV to scale up intent-to-treat estimates

EFFECTS ON PROPERTY TAX DELINQUENCY

EARLY VS. LATE DESIGN HOLDS FIXED BORROWER SUBPRIMENESS

- **Identification:** focus on PACE borrowers in owner-occupied, single-family homes.
 - ▶ Each cohort is compared to not-yet-treated borrowers: those whose loan originates more than three years later
- PACE borrower cohorts more balanced on *ex ante* characteristics than HELOC vs. PACE
 - ▶ Differences in z-scores < 0.25 for all covariates (Imbens and Wooldridge 2009; Rubin 2001)



▶▶ Raw differences

▶▶ No FEs

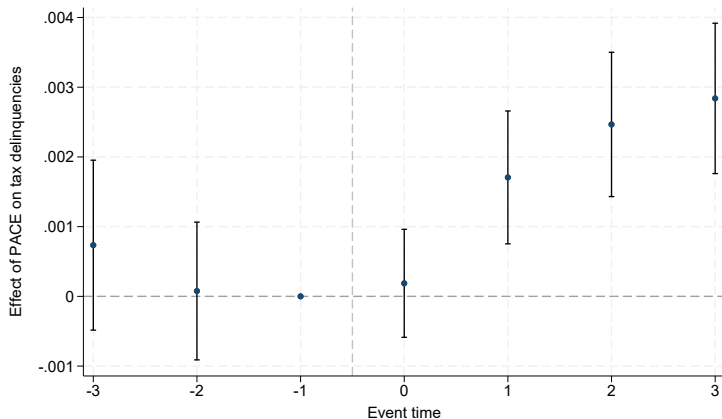
DELINQUENCY $\uparrow$ BY 0.2 P.P. (11% $\uparrow$ RELATIVE TO BASELINE)

$$\text{Delinquent}_{i,c,t} = \beta \cdot \text{PACE}_{i,c,t} + \gamma'_c \cdot \mathbf{X}_{i,t-1} + \eta_{i,c} + \theta_{c,t} + \varepsilon_{i,c,t}$$

Dep. variable:	Ever Delinquent		
Post PACE loan	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)
Observations	1,286,222	1,286,222	1,286,222
Adjusted R ²	0.365	0.365	0.365
Cohort $\times$ Year FE	x	x	x
Cohort $\times$ Property FE	x	x	x
Cohort $\times$ Building sq. ft. FE		x	x
Cohort $\times$ Bedrooms FE		x	x
Cohort $\times$ Effective year built FE		x	x
Cohort $\times$ Borrower credit controls			x

- Robust to **► IV** that exploits the staggered adoption of PACE to isolate loan take-ups driven by county-level policy decisions from household financial conditions
 - First-stage take-up rate of 7.5% among owner-occupied, single-family homes

DYNAMIC EFFECT ON TAX DELINQUENCIES



- Effect grows over time due to ever-delinquency flag
- Consistent with PACE raising HH debt service burden and exposure to liquidity shocks

HOUSE PRICE CAPITALIZATION EFFECTS OF PACE

PACE PROJECTS CAPITALIZED INTO HOME VALUES: PRICE $\uparrow$ 5.8%

$$\log(\text{Price}_{i,c,z,t}) = \beta \cdot \text{PACE}_{i,c,t} + \gamma'_c \cdot \mathbf{X}_{i,t-1} + \theta_{z,c} + \delta_{m,c} + \varepsilon_{i,c,t}$$

Dep. variable:	log(Price)		
Post PACE loan	0.052*** (0.010)	0.057*** (0.009)	0.056*** (0.009)
Observations	88,033	88,033	88,033
Adj. R ²	0.478	0.599	0.600
Cohort $\times$ sale month FE	x	x	x
Cohort $\times$ ZIP FE	x	x	x
Cohort $\times$ sale number FE		x	x
Cohort $\times$ building sq. ft. FE		x	x
Cohort $\times$ bedrooms FE		x	x
Cohort $\times$ effective year FE		x	x
Cohort $\times$ credit controls			x

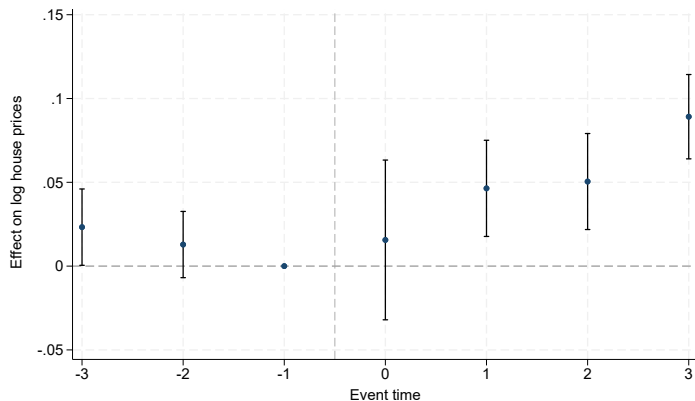
►► Summary stats

►► Subsamples

►► Assessed values

►► Oster test

DYNAMIC PRICING EFFECTS OF PACE PROJECTS



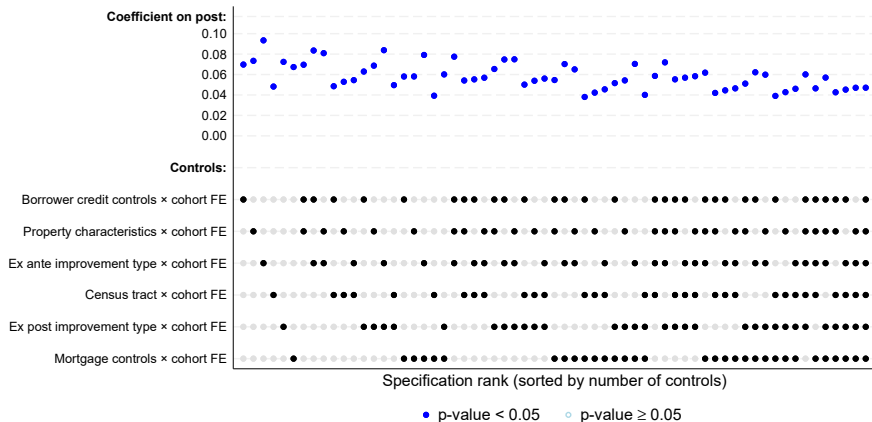
- ATT effect corresponds to $\approx 60\%$ of the average PACE loan $\rightarrow \Delta P = \$16k$
- **Timing:** improvement occurs within year of origination
 - ▶ Typically required by the program + permits expire within 12 months

STRONGER EFFECTS FOR WIND-PROOFING + COASTAL AREAS

	Log House Price					
	Climate proofing		Coastal location		Ex post solar	
	No	Yes	Inland	Coastal	No	Yes
Post PACE loan	0.048*** (0.011)	0.072*** (0.014)	0.040*** (0.011)	0.069*** (0.014)	0.059*** (0.009)	-0.054 (0.123)
Observations	63,346	24,143	44,301	43,645	83,331	2,987
Adj. R-squared	0.589	0.658	0.625	0.582	0.610	0.427
Cohort × sale number FE	x	x	x	x	x	x
Cohort × sale month FE	x	x	x	x	x	x
Cohort × ZIP FE	x	x	x	x	x	x
Cohort × prop. char.	x	x	x	x	x	x
Cohort × credit controls	x	x	x	x	x	x

- No house price gains for purely clean energy projects → consistent with recent work on solar market (e.g., Gillingham & Watten 2024)
- **Prediction #4:** stronger capitalization for projects which generate greater flow utility

SPECIFICATION CURVE: $\% \Delta P \in [4.0\%, 9.9\%]$



- Strong test: control for complete property-level history of home improvement permitting
 - ▶ $\implies$ Value creation beyond the financed project itself

NO DISCERNIBLE EFFECT ON REFINANCING PROBABILITY

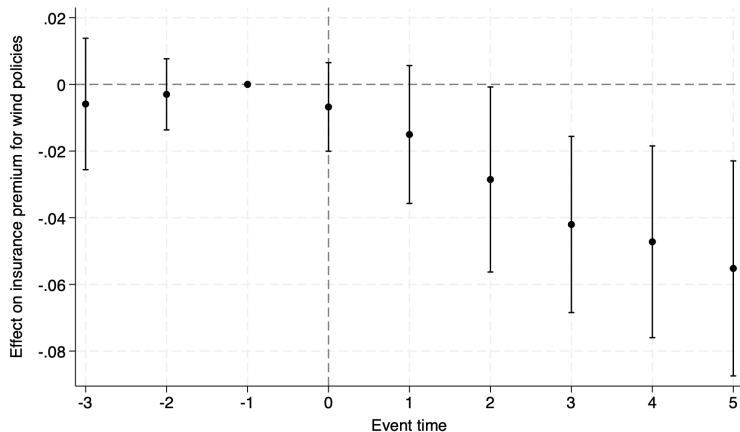
	$\mathbb{1}\{\text{Refinance Mortgage}\}$		
	(1)	(2)	(3)
Post PACE loan	-0.0004 (0.0016)	-0.0004 (0.0016)	-0.0005 (0.0016)
Observations	1,286,222	1,286,222	1,286,222
Adj. R-squared	0.914	0.914	0.914
Cohort FE $\times$ Year FE	x	x	x
Cohort FE $\times$ Property FE	x	x	x
Cohort FE $\times$ Building sq. ft. FE		x	x
Cohort FE $\times$ Bedrooms FE		x	x
Cohort FE $\times$ Effective year FE		x	x
Cohort FE $\times$ Credit bureau controls			x

- Similar null result if restrict to conforming mortgages for which **GSE restriction** applies
- Suggests capitalization not attenuated by deterioration in liquidity of property

▶▶ HMDA results

▶▶ GSEs

PASS THROUGH OF PACE TO LOWER HO INSURANCE PREMIA



- HO insurance premia in PACE counties fall by 3–5% after program adoption

PASS THROUGH SLIGHTLY STRONGER FOR WIND CONTRACTS

$$\log(\text{Premium}_{c,t}) = \alpha + \beta^{ITT} \cdot \text{PACE}_{c,t} + \theta_c + \delta_t + \gamma' \cdot \mathbf{X}_{c,t-1} + \varepsilon_{c,t}$$

	Log Insurance Premium					
	All policies		Wind policies		Private wind policies	
	(1)	(2)	(3)	(4)	(5)	(6)
PACE	-0.028*** (0.010)	-0.040*** (0.011)	-0.032*** (0.010)	-0.045*** (0.011)	-0.031*** (0.010)	-0.046*** (0.012)
Observations	4,060	1,184	4,060	1,184	4,060	1,184
Adj. R-squared	0.981	0.988	0.982	0.989	0.977	0.989
Cohort $\times$ Year FE	x	x	x	x	x	x
Cohort $\times$ County FE	x	x	x	x	x	x
County controls		x		x		x

- Homeowner's Insurance Wind Mitigation Discount Law requires insurers to lower premia for home-hardening upgrades: wind policies show a larger premium decrease [▶ Shift-share](#)
- Real effects of PACE in terms of lower damages from hurricanes [▶ FEMA damages](#)

DO THESE ESTIMATES OF HOUSE PRICE GAINS MAKE SENSE?

- PACE reduces county avg. wind insurance premia by 3.1% (\$56 per insured home-year)
 - ▶ Scaling this ITT estimate by the 7.5% first-stage take-up rate implies annual premium savings of $\Delta Premium = \$750$ per PACE borrower [▶ Map](#) [▶ IV](#)
- Insurance savings rationalize the capital gains at discount rates of $r = 2.7\text{--}3.6\%$
 - ▶ Gordon growth model for an infinitely-lived asset: $r = \Delta Premium / \Delta P$
 - ▶ $\Delta P = \$20,840$ for climate-proofing projects $\implies r = 3.6\%$
 - ▶ Upper-bound capitalization estimate of $\Delta P = \$27,513 \implies r = 2.7\%$
- **Robustness:** secular insurance premium inflation raises implied discount rate
 - ▶ Allowing premium savings to grow raises the implied discount rate range to 6.8–8.4%
- **Standard infinite Gordon growth discount rates in line with literature**
 - ▶ 2.6% rate reported by Giglio et al. (2015) for leaseholds and 2.7% rate computed by Ge et al. (2022) for flood insurance

LOCAL COST-BENEFIT IMPLICATIONS OF PACE

COMBINING OUR ESTIMATES $\implies$ PACE EXPANDS TAX BASE

- Simple back-of-envelope calculation combining our DiD estimates

$$\Delta R_{t,t+1} = \underbrace{\tau_{t+1}}_{\text{effective tax rate}} \times \left(\underbrace{\Delta P_{t,t+1}}_{\text{capitalization effect}} - \underbrace{\Delta D_{t,t+1} \cdot P_t}_{\text{short-run tax revenue loss}} \right)$$

- Even after netting out delinquencies, **revenues grow by \$185 to \$250 per PACE loan-year** in Florida counties participating in program [» Break-even](#)

- ▶ Lower ΔP if instead use market assessed values (tax base revalued each year in FL)

★ But statutory tax rates higher than effective rates in FL (1.6% vs. 1.2%) [» Details](#)

- ▶ ATT effects: evidence from HMDA consistent with positive pecuniary externalities

- **Lower-bound** estimate of the increase in revenue because...

- ▶ This is without accounting for spillovers to local employment or non-PACE investments
- ▶ Some delinquency costs are partially borne by municipal bond investors
- ▶ Measure ΔD using an “ever-delinquent” flag, but some loans are performing

PACE REMAINS CONTROVERSIAL, BUT EQUITY-EFFICIENCY TRADEOFFS IN PROGRAM DESIGN



Ray and Kelly Coulter display the paperwork from when they financed a new roof and impact windows on their West Palm Beach home through Green Solutions and Ygrene Energy Florida. MATIAS J. OCNER mocner@miamiherald.com

As more complaints surfaced, other counties soon followed Pasco's lead by introducing stronger consumer protections and disclosure forms for new PACE customers.

- No evidence of crowdout of traditional mortgage credit
- CFPB complaints against PACE districts allege contractors mislead borrowers
 - ▶ Dec. 2024 CFPB final rule adding property tax liens to **Regulation Z**
 - ▶ PACE lien can make it difficult for consumers to refinance
 - ▶ We find no impact on refinancing prob.
- Delinquency leads to mild revenue losses relative to expansion of tax base
- **Optimal screening**, LTV caps, income requirements?

SCOPE TO PAIR HI LOANS WITH HO INSURANCE CONTRACTS TO PREVENT UNRAVELING



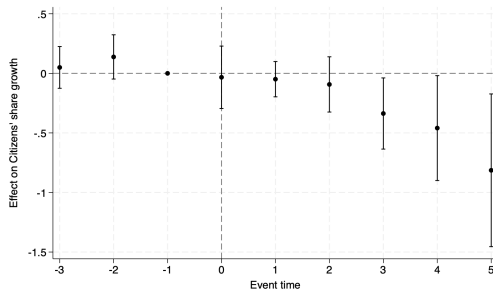
Press Release

Citizens' Policy Count Drops Below 1 Million

12.04.24

Citizens Property Insurance Corporation's policy count has dipped below 1 million for the first time in more than two years as the Florida property insurance market continues to improve.

The reduced policy count, which was 987,650 as of November 29, 2024, is due in large part to the success of the Citizens Depopulation Program. Since January 2024, the program has transferred more than 428,000 Citizens policies to private insurance companies approved by the Office of Insurance Regulation.



Notes: Data from Quarterly and Supplemental Reporting System (QUASR) collapsed to the county level for Citizens share of HO insurance policies. Coefficients obtained from the stacked estimator.

- County PACE adoption slows growth in local Citizens share of contracts
- Proposed FL state bill in 2025 to formally bundle PACE-financed improvements with insurance contracts

CONCLUSION: GOVT. BACKING IMPROVES RESILIENCE OF HOUSING

- We show that local government-backed loans can help close the **investment gap** in green residential projects while growing the tax base → “infinite” MVPF
- **Mechanism:** lowering screening standards without subsidizing credit helps relax households’ **financing constraints** to do profitable home improvements
 - ▶ PACE borrowers are negatively selected compared to HELOC borrowers and pay rate premium of > 200 bps. due to lack of outside options
- Wind-proofing projects strongly capitalized into home values → rationalized by **homeowners insurance premia** ↓↓
- Super seniority generates value rather than simply redistributing among claimholders
 - ▶ Unlike traditional lending, tax lien creates virtually non-existent strategic default motives
 - ▶ **Incentive compatibility** is a major strength relative to other green lending programs
- **Future work:** implications for other PACE programs, optimal policy design

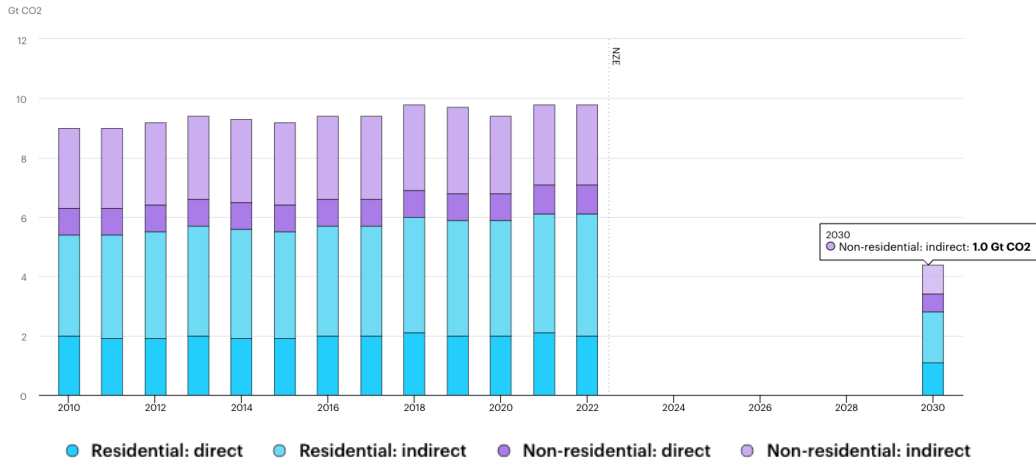
THANK YOU!

SSRN paper downloadable here



APPENDIX

BUILDING OPERATIONS ACCOUNTED FOR 26% OF 2022 GLOBAL ENERGY EMISSIONS

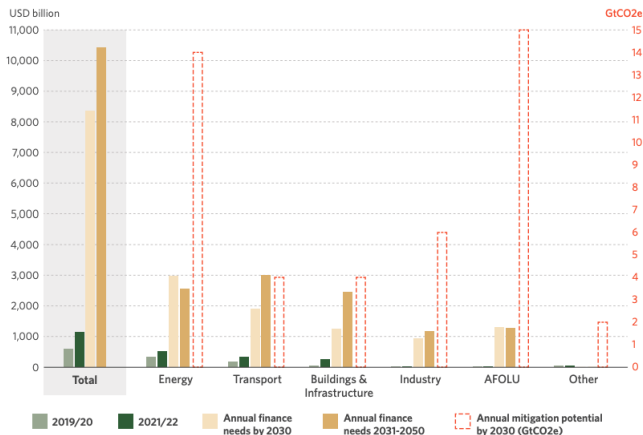
[▶ BACK](#)

Source: International Energy Agency (IEA): <https://www.iea.org/energy-system/buildings> (June 15, 2023)

CPI 2023 REPORT: MITIGATION INVESTMENT WOULD NEED TO INCREASE 30-FOLD TO REACH NZE TARGET BY 2050

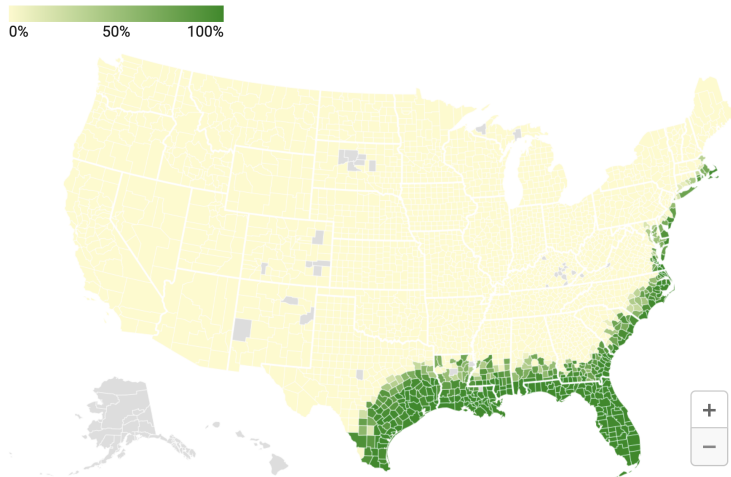
» BACK

Figure 9: Climate finance flows in key mitigation sectors, finance needs and mitigation potential



Note: Historical finance flows (2019-2022) are expressed in nominal USD. Climate finance needs for 2023-2050 are expressed in 2022 USD. Average mitigation potential is sourced from the IPCC AR6 (2022a). This applies to similar analyses hereafter.

Percentage of housing properties identified as at risk for "insurance correction" due to wind risk



Map: Lance Lambert • Source: First Street Foundation • Created with [Datawrapper](#)

CURRENT PROJECTIONS SHOW STORMS MIGRATING NORTH

» BACK

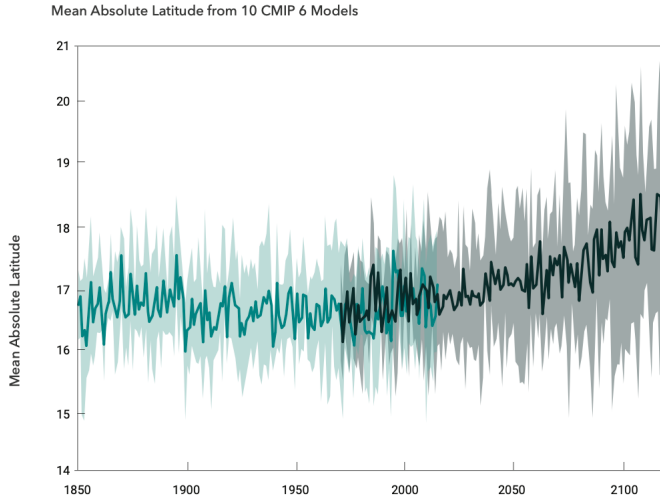


Figure 3. Mean absolute storm latitude from global modeled storms under historical conditions (green line) and future conditions (black line) from Dr. K. Emanuel (pers. comm, 2023)

FL'S STORM RISK EXPECTED TO DECLINE OVER NEXT 30 YEARS

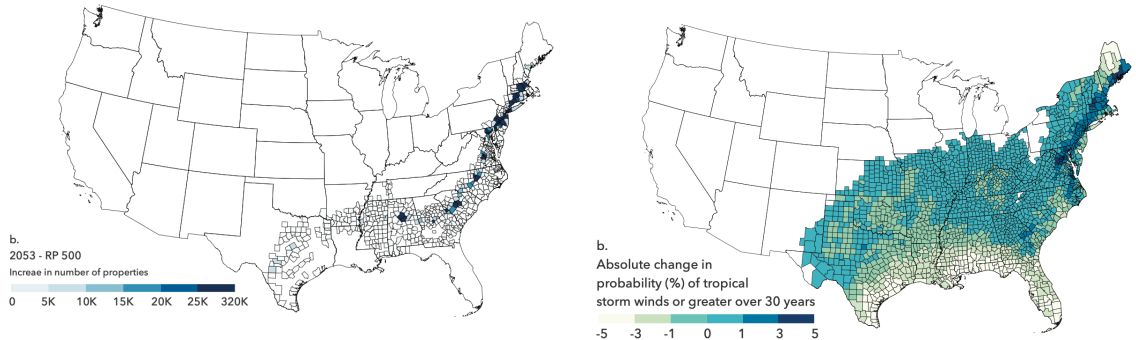


Figure 19. Number of properties with damages for RP 500 in 2023 (a) and the increase in the number of properties with damages for RP500 in 2053 (b)

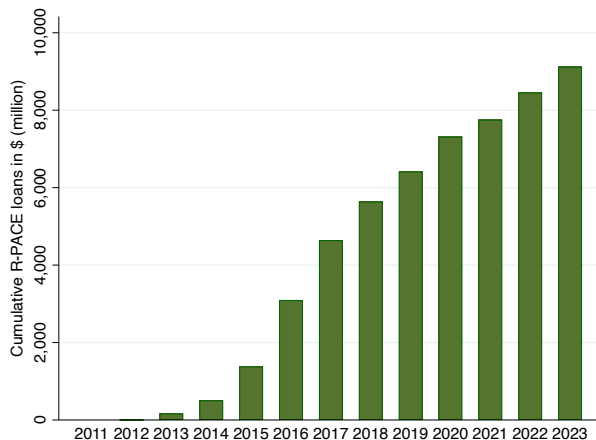
Source: First Street Foundation. "The 7th National Risk Assessment: Worsening Winds."

- Similar to problems in the place-based policy literature → very hard for government to pick "winning" areas to subsidize for climate migration [▶ Back](#)

WHAT MARKET FAILURE(S) CAN GOVERNMENT SOLVE? [▶ BACK](#)

- Under-investment in climate-resilient retrofitting could be due to...
 - ▶ High discount rates due to (false) perception that risks are at long horizons
 - ▶ Uncertainty about returns or hedonic value of such investments
 - ▶ **Liquidity constraints** preventing $NPV > 0$ projects
- On top of this, there may be **externalities** associated with PACE projects
 - ▶ Increasing resiliency of structures may put downward pressure on insurance premia
 - ▶ Peer effects: uncertainty about future returns to green home improvements may be resolved by observed success of neighbors
- PACE program could create **new frictions** in the form of predatory lending (exempt from Truth in Lending Act) and **crowdout effects on mortgage supply**
- **Evidence:** PACE relaxes borrowing constraints by **lowering credit screening standards** rather than through direct subsidies

R-PACE PROGRAM REACHED \$9.1 BILLION IN TOTAL ORIGINATIONS BY END OF 2023



Source: <https://www.pacenation.org/pace-market-data/>.

► Back

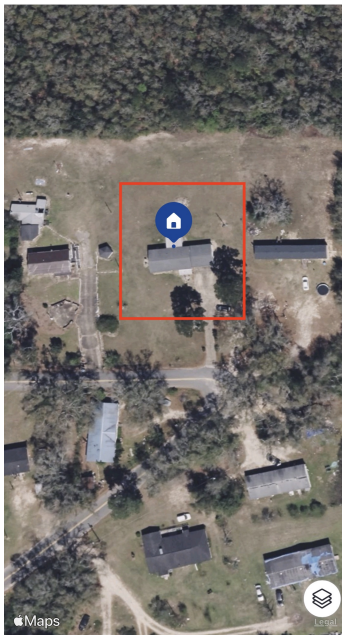


Map

Lot Lines



Street View



... More

3 bd | 1 ba | 984 sqft

388 Charlie Harris Loop, Quincy, FL 32352

● Off market

Zestimate®: **\$136,700** | Rent Zestimate®: **\$1,090**

Est. refi payment: \$770/mo

[Refinance your loan](#)[Home value](#)[Owner tools](#)[Home details](#)[Neighborhood details](#)

Public tax history

Year	Property taxes	Tax assessment
2023	\$417 +1.9%	\$60,071 +3%
2022	\$409 -0.5%	\$58,322 +3%
2021	\$412 +1.4%	\$56,624 -0.8%
2020	\$406 -3.5%	\$57,063 -1.3%
2019	\$421	\$57,825

WHAT PREDICTS COUNTIES' PACE ADOPTION DECISIONS?

► BACK

Dep. variable: PACE Adopted	(1)	(2)	(3)	(4)	(5)	(6)
Population	-0.011 (0.070)	0.005 (0.071)	-0.470 (1.012)	-0.070 (0.982)	0.457 (1.362)	0.111 (0.983)
Household median income	0.735** (0.348)	0.500 (0.397)	-0.244 (0.341)	-0.236 (0.334)	-0.001 (0.427)	-0.148 (0.334)
% Bachelor's degree or higher	-1.890** (0.782)	-1.808** (0.778)	1.592 (1.300)	1.227 (1.206)	1.553 (1.380)	1.316 (1.164)
% Black	0.746 (2.505)	1.763 (2.374)	1.090 (2.590)	0.841 (2.505)	-0.826 (4.040)	0.093 (2.490)
% Latino	1.126 (2.180)	1.820 (2.067)	-1.566 (7.204)	-0.721 (6.824)	-5.305 (8.790)	-2.846 (6.657)
% White	0.734 (2.171)	1.915 (2.033)	-4.792 (4.791)	-1.394 (5.033)	-5.562 (6.930)	-3.184 (4.962)
Unemployment rate	-4.364*** (1.435)	-4.046*** (1.248)	-0.931 (1.212)	-1.259 (1.209)	-0.894 (1.294)	-0.926 (1.127)
Municipal debt/Revenue	0.017 (0.038)	-0.005 (0.039)	-0.014 (0.027)	-0.021 (0.026)	0.005 (0.024)	-0.018 (0.024)
Democratic leaning	1.322** (0.635)	0.535 (0.584)	-0.607 (1.076)	-0.928 (0.959)	-1.338 (1.241)	-1.235 (1.002)
Neighbor PACE	0.051 (0.104)	-0.048 (0.099)	0.065 (0.085)	0.045 (0.086)	0.006 (0.077)	0.065 (0.083)
#Declared natural disasters	0.132*** (0.025)	0.097*** (0.027)	-0.009 (0.027)	-0.015 (0.028)	-0.018 (0.036)	-0.024 (0.027)
Abnormal property damage	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.000)	-0.000 (0.000)	-0.001 (0.001)	-0.000 (0.000)
Climate concerns		0.036*** (0.012)		0.021 (0.019)	0.029 (0.021)	0.020 (0.018)
Assessor turnover		0.001 (0.724)		-1.250** (0.515)	-1.367* (0.697)	
Assessor turnover × Climate concerns		-0.000 (0.013)		0.023** (0.009)	0.025* (0.013)	
Retirement turnover						-1.719** (0.681)
Retirement turnover × Climate concerns						0.031*** (0.011)
Sample	All	All	All	All	Pre-2020	All
Observations	466	466	466	466	344	466
R-squared	0.343	0.384	0.710	0.726	0.692	0.730
County FE			x	x	x	x
Year FE			x	x	x	x

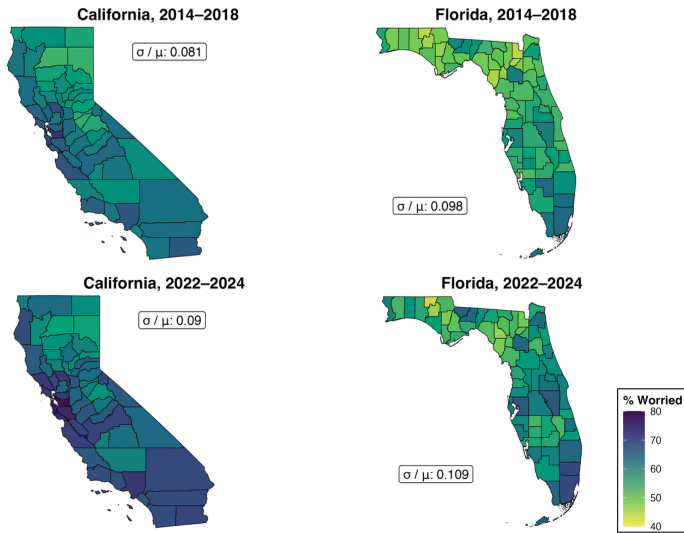
- Run linear probability models with dummy for county adoption of PACE in a given year as the outcome
- Economic, political, demographic conditions not predictive within county and within year
- But, counties more **concerned about climate change** with a new assessor are more likely to adopt PACE
 - FL tax assessor's are elected officials
 - Robust to (exogenous) “retirement turnovers”

FOR CA, TIMING OF PACE ADOPTION MORE RANDOM

[▶ BACK](#)

Dep. variable: PACE Adopted	(1)	(2)	(3)	(4)	(5)	(6)
Population	-0.014 (0.020)	-0.004 (0.017)	-0.006 (0.017)	0.341 (0.512)	0.337 (0.525)	1.180* (0.693)
Household median income	0.002 (0.004)	0.0005 (0.003)	0.002 (0.004)	-0.0008 (0.005)	-0.0003 (0.005)	-0.004 (0.008)
% with Bachelor's degree or higher	0.011 (0.010)	0.008 (0.010)	0.009 (0.010)	-0.006 (0.020)	-0.005 (0.020)	0.032 (0.024)
% White	0.0001 (0.005)	0.006 (0.005)	0.007 (0.005)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.008)
% Black	0.023* (0.014)	0.033** (0.013)	0.031** (0.013)	0.054 (0.063)	0.055 (0.063)	0.092 (0.073)
% Hispanic	0.003 (0.003)	0.001 (0.003)	0.001 (0.003)	-0.029 (0.024)	-0.028 (0.024)	-0.004 (0.029)
% Worked in Past Year	0.007 (0.006)	0.007 (0.006)	0.003 (0.006)	0.015 (0.010)	0.014 (0.009)	0.017 (0.010)
County Debt/Revenue	0.003 (0.003)	0.005 (0.003)	0.002 (0.005)	0.003* (0.002)	0.003* (0.002)	0.003 (0.003)
Democratic leaning	-0.242 (0.612)	-1.050* (0.559)	-1.170** (0.564)	2.150* (1.110)	2.250* (1.130)	1.400 (1.360)
Neighbor PACE	0.349*** (0.058)	0.250*** (0.053)	0.222*** (0.049)	-0.130* (0.076)	-0.132* (0.077)	-0.124* (0.070)
# Declared wildfires	0.049*** (0.011)	0.017 (0.011)	0.025* (0.014)	-0.002 (0.011)	-0.001 (0.011)	0.002 (0.016)
Abnormal property damage from wildfires	0.004 (0.006)	0.005 (0.006)	0.003 (0.005)	-0.000 (0.002)	-0.0001 (0.002)	-0.0008 (0.003)
Climate concerns		0.042*** (0.009)	0.045*** (0.010)		-0.005 (0.014)	0.005 (0.014)
Assessor Turnover		-0.608 (0.470)	-0.487 (0.523)		-0.162 (0.294)	-0.083 (0.423)
Auditor-Controller Turnover		0.156 (0.326)	-0.420 (0.417)		0.144 (0.308)	0.160 (0.372)
Assessor Turnover		0.011 (0.007)	0.009 (0.008)		0.003 (0.004)	0.002 (0.007)
× Climate concerns						
Auditor-Controller Turnover		-0.002 (0.005)	0.007 (0.007)		-0.002 (0.005)	-0.003 (0.006)
× Climate concerns						
County FE	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes

FAR MORE SPATIAL VARIATION IN CLIMATE CONCERNS IN FL

[▶ BACK](#)

Note: Tabulated based on county-level responses to the Yale Program on Climate Change Communication surveys.

PACE vs. HELOC INTEREST RATE PREMIUM [▶ BACK](#)

$$\text{Rate}_{\ell,c,t} = \beta \cdot \text{PACE}_{\ell} + \gamma' \mathbf{X}_{\ell} + \theta_c + \delta_t + \varepsilon_{\ell,c,t}$$

	Interest Rate			
	(1)	(2)	(3)	(4)
PACE loan	2.623*** (0.125)	2.621*** (0.127)	2.731*** (0.128)	2.890*** (0.130)
Observations	6,355	6,355	6,354	6,354
Adj. R-squared	0.228	0.229	0.235	0.253
Year FE	x	x	x	x
County FE	x	x	x	x
Credit bureau controls		x	x	x
Mortgage controls			x	x
House characteristics				x
Permit controls				x

- PACE vs. HELOC rate premium widens to 289 bps. conditional on full set of observables

PACE vs. HELOC INTEREST RATE PREMIUM [▶ BACK](#)

$$\text{Rate}_{\ell,c,t} = \beta_1 \cdot \text{PACE}_{\ell} + \beta_2 \cdot \text{PACE}_{\ell} \times \text{Subprime}_{\ell} + \gamma' \mathbf{X}_{\ell} + \theta_c + \delta_t + \varepsilon_{\ell,c,t}$$

	Interest Rate			
	(1)	(2)	(3)	(4)
PACE loan	2.407*** (0.138)	2.446*** (0.138)	2.555*** (0.139)	2.722*** (0.139)
PACE loan × Subprime borrowers	0.411*** (0.144)	0.269* (0.153)	0.294* (0.152)	0.281* (0.151)
Observations	6,355	6,355	6,354	6,354
Adj. R-squared	0.230	0.231	0.237	0.255
Year FE	x	x	x	x
County FE	x	x	x	x
Credit bureau controls		x	x	x
Mortgage controls			x	x
House characteristics				x
Permit controls				x

- Additional rate premium of 27–41 bps. for subprime borrowers

SUMMARY STATS FOR HOUSE PRICE SAMPLE

[▶ BACK](#)

	<i>N</i>	Mean	Std. Dev.	p5	p95
Sale amount	88,482	266,305.5	206277.7	72,000	535,000
Assessed value	88,307	241,925.3	153,728.2	86,540	454,430
Building sq.ft ²	88,334	1,734.155	635.439	986	2,896
Bedrooms	82,054	3.128	0.806	2	4
Land sq.ft ²	88,468	11,173.29	28,949.41	2,240	21,202
Stories	87,276	1.187	0.396	1	2
Year built	88,297	1978	19.369	1950	2010
Effective year built	85,450	1986	17.891	1956	2014
FICO score	88,482	554.913	236.066	0	782
Derogatory events	88,482	0.035	0.094	0	0.214
Credit file age	88,482	125.541	95.004	0	296
Severe distress index	88,482	0.989	0.448	0	2
Hardening projects	88,482	0.278	0.448	0	1
Coastal location	88,482	0.496	0.500	0	1
Solar panel	88,482	.071	0.335	0	1

SUMMARY STATS FOR OTHER SAMPLES [▶ BACK](#)

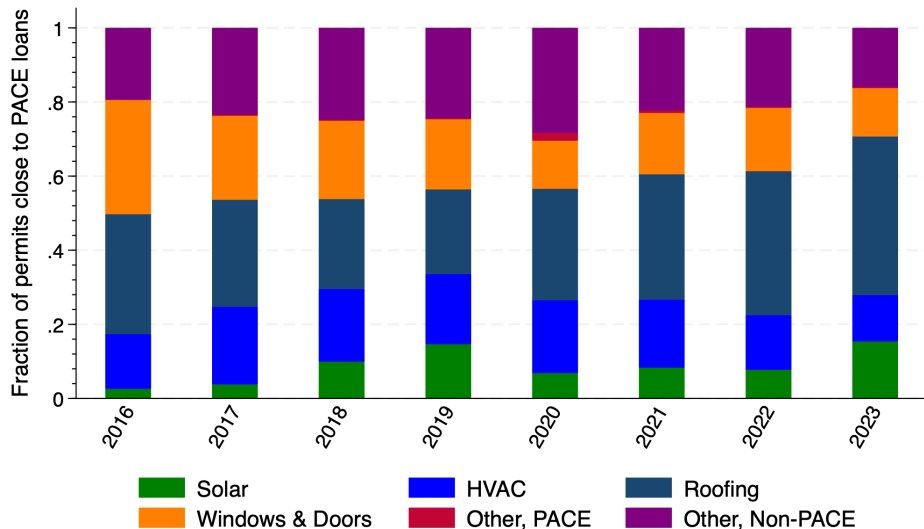
<i>Panel A: Individual data</i>				
	Mean	SD	P25	P75
FICO score	590.50	248.58	567.00	747.00
Derogatory events	0.04	0.10	0.00	0.00
Credit file age (months)	182.74	127.59	96.00	257.00
Severe distress index	1.03	0.49	1.00	1.00
Building area (sq. ft.)	1,727.26	634.87	1,308.00	1,994.00
Bedrooms	3.09	0.80	3.00	3.00
Lot size (sq. ft.)	11,180.38	30,192.22	6,000.00	10,000.00
Stories	1.14	0.36	1.00	1.00
Year built	1,976.08	18.21	1,960.00	1,990.00
Observations		1,792,188		
<i>Panel B: County-level Insurance Analysis</i>				
$\log(\text{Premium})_{c,t}$ (all)	7.469	0.282	7.265	7.634
$\log(\text{Premium})_{c,t}$ (wind)	7.485	0.300	7.268	7.660
Observations		680		

LARGER, MORE AFFLUENT COUNTIES HAVE PACE [» BACK](#)

	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

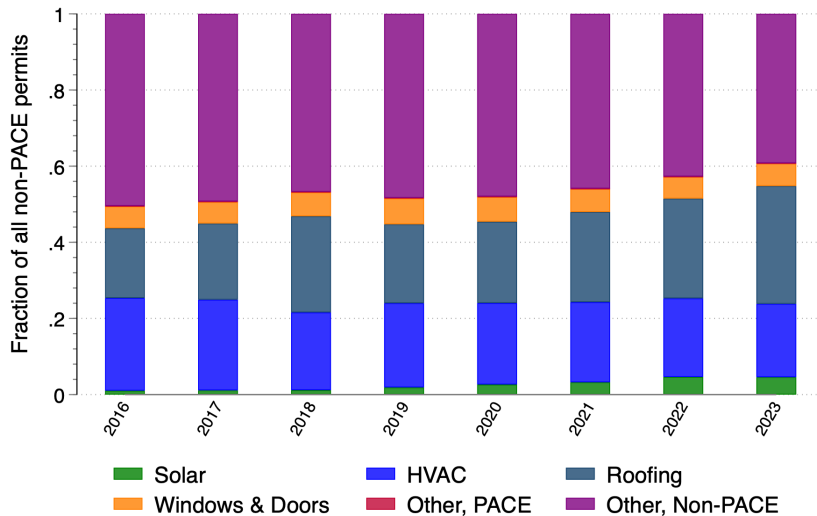
Sources: FEMA, the decennial Census, and the American Community Survey (ACS).

PACE PERMITTING OVER TIME: SHIFT TOWARDS ROOFING

[▶ BACK](#)

NO CHANGE IN PERMIT FRACTIONS FOR NON-PACE PROPERTIES

» BACK



KEYWORD CLASSIFICATION FOR HOME IMPROVEMENT PERMITS

- Use CoreLogic Building Permits to identify types of projects
 - ▶ Focus on permit applications, but dates, but subset to completed permits
 - ▶ Each permit can have multiple projects listed (up to 3)
 - ▶ Focus on SFHs, no teardowns, no new construction
- Parse strings from town clerk's memo to sort permits into 5 mutually exclusive types:
 - ▶ **Windows and doors:** windows, doors, impact, etc.
 - ▶ **Roofing:** roof, shingle, asphalt, etc.
 - ▶ **HVAC:** cool, heat, air conditioning, AC, HVAC, duct, etc.
 - ▶ **Solar:** photovoltaic, cell, solar, generator, etc.
 - ▶ **Other PACE:** niche categories ($< 1\%$), including septic-to-sewer conversions, wind anchors, insulation, water efficiency, energy storage, natural lighting
 - ▶ **Other, non-PACE:** any other permits with no explicitly mentioned PACE-qualified project

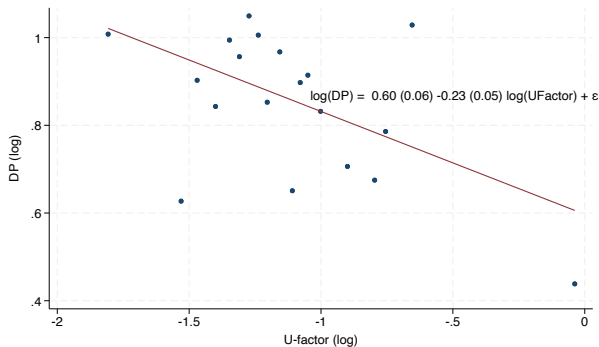
SAME RESULT USING EARLY VS. LATE ADOPTER BLOCKS

» BACK

Dependent Variable	Extensive Margin	Intensive Margin	Mean
Applications	-0.0205 (0.0135)	0.0180 (0.2737)	0.4994
Inspections	-0.0204*** (0.0072)	-0.1760 (0.1622)	0.1812
Rental assistance (\$)	-10.42* (5.846)	-19.33 (143.4)	94.6803
Repair assistance (\$)	-14.70** (6.304)	-121.9 (84.11)	32.2758
Real property damage (\$)	-13.67* (7.394)	-83.55 (108.2)	68.1506
Personal property damage (\$)	-3.038 (2.089)	-67.38** (33.65)	12.8358

- Within a block group, blocks with pre-hurricane PACE upgrades to those with 3-years post-hurricane PACE upgrades (avoid reverse causality)
- Note: FEMA data for later hurricanes (e.g., Ian in 2022 and Milton/Helene in 2024) not available below zip code level

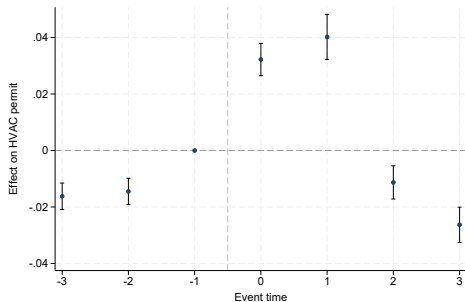
ENERGY EFFICIENCY AND RESILIENCE OFTEN GO TOGETHER

[▶ BACK](#)

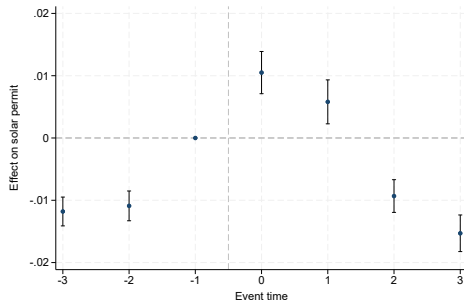
- Scrape information on 500 window products from the National Fenestration Rating Council
- **Design pressure (DP)** rating ranks products on 0 to 100 on how well they can withstand storms
- **U-Factor** on scale from 0.2 to 1.2, with lower values indicating better **insulation**
- 1% U-Factor $\uparrow$ associated with a 0.23% $\downarrow$ in window's DP rating
- $\implies$ can be energy efficiency gains even if motivation is hurricane-proofing

ENERGY EFFICIENCY PERMITS SPIKE AROUND PACE ORIGINATION

HVAC Permits



Solar Panel Permits

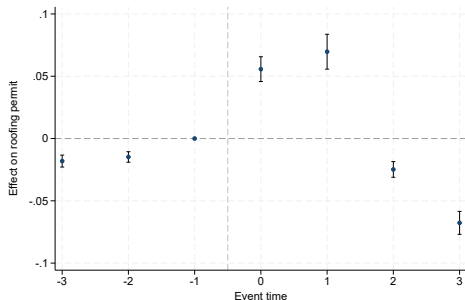


- Clear jump in permitting probability of 2-3 p.p. for **energy efficiency** projects

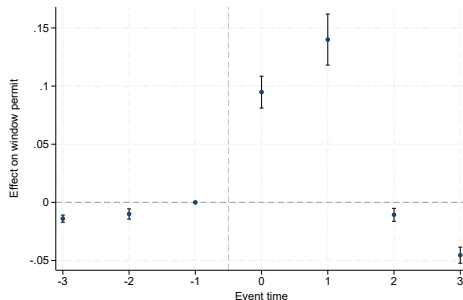
▶▶ Back

HOME-HARDENING PERMITS SPIKE AROUND PACE ORIGINATION

Roofing Permits



Window & Door Permits



- Larger jump in permitting probability for **disaster-proofing** projects [» Back](#)
- Jump is largest for window & door permits at ≈ 13 p.p.

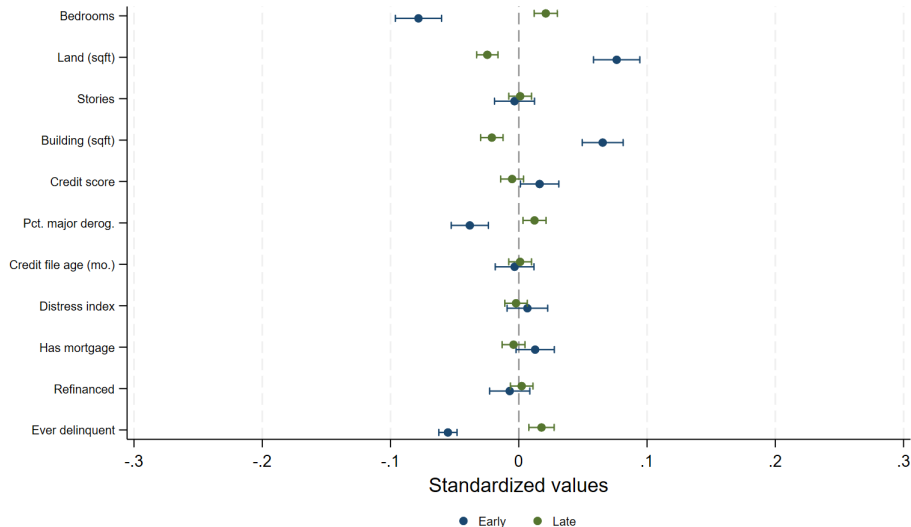
RAW WITHIN-TRACT DIFFERENCES BETWEEN COHORTS ARE SMALL

» BACK

	Group means		Difference	
	Early	Late	Unadjusted	Adjusted
FICO score	609.36	604.64	4.72**	2.63
Derogatory events	0.030	0.035	−0.004***	−0.002
Credit file age (months)	188.18	188.86	−0.68	−0.92
Severe distress index	1.000	0.995	0.005	0.006
Building area (sq. ft.)	1,757.75	1,706.72	51.02***	27.28***
Bedrooms	3.050	3.112	−0.065***	0.026**
Lot size (sq. ft.)	12,045.83	10,716.42	1,329.41***	302.21
Stories	1.150	1.149	−0.001	−0.005
Year built	1977.94	1975.77	2.16***	0.03
Observations	65,478			

- To the extent some small differences in property characteristics remain, we control directly for them

EARLY VS. LATE PACE: UNCONDITIONAL BALANCE TEST

[» BACK](#)

IMPACT ON TAX DELINQUENCIES – IV ANALYSIS [▶▶ BACK](#)

	(1)	(2)	(3)
<i>Panel A: First stage</i>		Has a PACE loan	
County adopted PACE	0.075*** (0.013)	0.075*** (0.013)	0.075*** (0.013)
Observations	1,792,188	1,792,188	1,792,188
<i>Panel B: Second stage</i>		Ever Delinquent	
Has a PACE loan	0.049*** (0.012)	0.049*** (0.012)	0.049*** (0.012)
Kleibergen-Paap F-statistic	31.41	31.41	31.19
Observations	1,792,188	1,792,188	1,792,188
Counties	59	59	59
Year FE	x	x	x
Property FE	x	x	x
Property characteristic bin FE		x	x
Credit controls			x

ROBUSTNESS OF CAPITALIZATION EFFECTS: TAX ASSESSED VALUES

	Tax Assessed Value		
	(1)	(2)	(3)
Post PACE loan	0.014*** (0.006)	0.014*** (0.006)	0.016*** (0.006)
Observations	152,383	152,383	152,383
Adj. R-squared	0.936	0.936	0.936
Cohort $\times$ Year FE	x	x	x
Cohort $\times$ Property FE	x	x	x
Cohort $\times$ Building sq. ft. FE		x	x
Cohort $\times$ Bedrooms FE		x	x
Cohort $\times$ Effective year built FE		x	x
Cohort $\times$ Borrower credit controls			x

- Baseline results on house price capitalization condition on PACE borrowers subsequently selling in an arms-length transaction
 - ▶ This half of the sample tends to be more positively selected
- Due to Florida Save Our Homes Act, tax assessed value changes are capped at the minimum of CPI inflation ($\approx 1-2\%$) or 3% [▶ Back](#)

OSTER TEST FOR BIAS FROM UNOBSERVABLES

[▶▶ BACK](#)

$$\beta^* - \hat{\beta} \approx \delta \left(\hat{\beta} - \beta^\circ \right) \frac{R_{\max} - \hat{R}}{\hat{R} - R^\circ}$$

δ	Bias	Adjusted β	% of baseline
0.50	-0.0060	0.0620	119.1
0.75	-0.0090	0.0650	124.8
1.00	-0.0119	0.0680	130.5
1.25	-0.0149	0.0710	136.3
1.50	-0.0179	0.0739	142.0

- For β^* unbiased estimator, δ captures value for which unobservables-induced bias drives pricing effect $\rightarrow 0$
- Unobserved heterogeneity would need to be substantially stronger than selection on observables and operate in the opposite direction to explain away capitalization
 - ▶ Compare to baseline estimate: $\hat{\beta} = 0.056$

NO EFFECT ON REFINANCING FOR CONFORMING LOANS

» BACK

	$\mathbb{1}\{\text{Refinance Mortgage}\}$		
	(1)	(2)	(3)
Post PACE loan	-0.0023 (0.0015)	-0.0023 (0.0016)	-0.0024 (0.0016)
Observations	994,147	994,147	994,147
Adj. R-squared	0.944	0.944	0.944
Cohort FE $\times$ Year FE	x	x	x
Cohort FE $\times$ Property FE	x	x	x
Cohort FE $\times$ Building sq. ft. FE		x	x
Cohort FE $\times$ Bedrooms FE		x	x
Cohort FE $\times$ Effective year FE		x	x
Cohort FE $\times$ Credit bureau controls			x

- Since 2010, Fannie Mae and Freddie Mac will not purchase mortgages in a junior position to a PACE lien

- We follow Horton et al. (2024), who map effective tax rates (ETRs) and statutory tax rates (STRs) across the U.S.
- Sample restrictions: 2015-19 to avoid COVID period, single-family homes and condos, winsorize sale prices at the 1st and 99th percentiles
- We compute ETRs as the average of the buyer's tax bill in $t + 1$ and seller's tax bill in $t - 1$ relative to the sale price in t :

$$ETR_{i,t} = \frac{TaxBill_{i,t+1} + TaxBill_{i,t-1}}{2 \cdot SalePrice_{i,t}}$$

- STRs follow the same convention but using winsorized assessed values rather than sale prices as the denominator

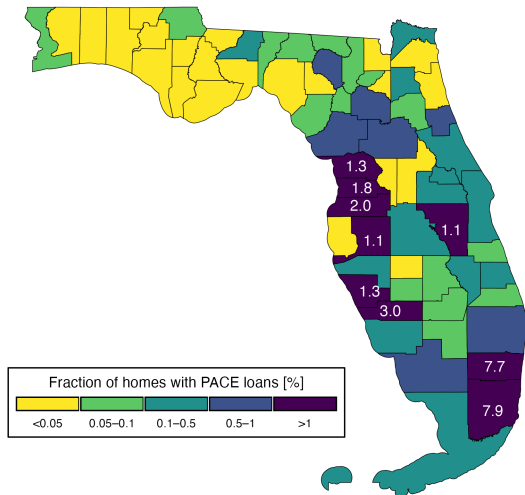
WHAT IS THE BREAK-EVEN $\% \Delta P$ FOR REVENUE? [▶ BACK](#)

- Simple back-of-envelope calculation combining our DiD estimates

$$\Delta R_{t,t+1} = \underbrace{\tau_{t+1}}_{\text{effective tax rate}} \times \left(\underbrace{\Delta P_{t,t+1}}_{\text{capitalization effect}} - \underbrace{\Delta D_{t,t+1} \cdot P_t}_{\text{short-run tax revenue loss}} \right)$$

- ▶ Upper bound $\% \Delta P \approx 7.5\%$ restricting to climate-proofing projects
 - ▶ Lower bound $\% \Delta P \approx 5.8\%$ from baseline effect including all projects
 - ▶ $\implies$ range of revenue gains per loan-year of \$185 to \$250
- Break even capitalization effect to cancel out delinquencies of $\% \Delta P = 1\%$
 - Florida has an assessment growth cap of $\% \Delta \bar{V} = \min\{\% \Delta CPI, 3\%\}$
 - ▶ Even if cap were binding for all households at inflation rate, still at break even
 - ▶ We find average $\% \Delta V \approx 2\%$ after a PACE loan with an eligible project

BORROWER TAKEUP RATES CLUSTERED IN MIAMI/TAMPA

[▶ BACK](#)

- Takeup = ratio of owner-occupied SFH properties with a PACE upgrade as of 2023 to total # in property tax roll
- Note: counties can have PACE loans even without a formal law
 - ▶ Leon County Circuit Court case and similar legal challenges
- Avg. take-up rate across counties is 2%
 - ▶ Take-up rate closer to 5% if reweight in proportion to county composition in our pricing sample
- First-stage effect from IV: 6.3% for pricing, 7.5% for delinquency sample

SHIFT-SHARE: DECLINE IN PREMIA DRIVEN BY INSURERS MORE EXPOSED TO PACE

» BACK

Dep. variable: $\log(\text{Premium}_{i,c,t})$	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\text{PACE}_{c,t} \times \text{ExposureShare}_{i,c,t}$	-0.075*** (0.021)	-0.094*** (0.024)	-0.076*** (0.025)	-0.082*** (0.024)	-0.088*** (0.017)	-0.046* (0.025)	-0.058*** (0.017)
$\text{ExposureShare}_{i,c,t}$	0.179*** (0.045)	0.208*** (0.047)	0.181*** (0.047)		0.055*** (0.017)	0.128*** (0.047)	0.032* (0.017)
$\text{PACE}_{c,t}$	0.020 (0.012)	0.027** (0.013)					
Population		0.041 (0.196)					
% Black		0.541 (0.799)					
% Hispanic		0.778 (0.761)					
Unemployment rate		-0.131 (0.224)					
% Bachelor's degree or higher		0.139 (0.211)					
Abnormal property damage		-0.000 (0.000)					
Sample Estimator	All OLS	All OLS	All OLS	All OLS	All Stacked	Wind OLS	Wind Stacked
Observations	40,614	23,087	40,614	40,593	214,823	39,959	212,278
Adj. R-squared	0.764	0.771	0.762	0.794	0.782	0.801	0.814
Insurer FE	Yes	Yes	Yes	—	Yes	Yes	Yes
Year FE	Yes	Yes	—	—	—	—	—
County FE	Yes	Yes	—	—	—	—	—
County $\times$ Year FE	No	No	Yes	Yes	Yes	Yes	Yes
Insurer $\times$ Year FE	No	No	No	Yes	No	No	No

FEMA DISASTER APPLICATIONS FALL AROUND IRMA FOR AREAS WITH PACE ACCESS

» BACK

$$Y_b = \beta \cdot PACE_b + \alpha_g + \epsilon_b$$

Dependent Variable	Extensive Margin	Intensive Margin	Mean
Applications	-0.0270** (0.0125)	-0.0740 (0.2296)	0.4001
Inspections	-0.0203*** (0.0057)	-0.1892 (0.1188)	0.1419
Rental assistance (\$)	-9.394* (5.448)	-24.50 (122.1)	75.3748
Repair assistance (\$)	-8.882** (3.437)	-107.3* (59.02)	22.0627
Real property damage (\$)	-6.475 (5.164)	-39.94 (89.96)	46.5853
Personal property damage (\$)	-2.645 (1.699)	-56.83** (26.34)	11.6732

- Within a block group, compare blocks where at least one house has a PACE upgrade ($PACE_b = 1$)

THEORY APPENDIX

MODEL DETAILS: ENVIRONMENT

- Borrower type is $\theta \in \{P, S\}$, with different probabilities of low cash flow

$$0 < p_P < p_S < 1, \quad Y \in \{Y_L, Y_H\}$$

- A household owns a house worth V , owes mortgage repayment M , and considers a project costing I
- With promised HELOC and PACE repayments Z^{HELOC} and Z^{PACE} , total housing debt service is

$$B = M + Z^{\text{HELOC}} + Z^{\text{PACE}}$$

$$d_{\theta}(B) = \Pr(Y < B \mid \theta) = \begin{cases} 0, & B \leq Y_L, \\ p_{\theta}, & Y_L < B \leq Y_H, \\ 1, & B > Y_H \end{cases}$$

- Project j creates value $\Delta V_j = \gamma_j I$, with $\gamma^{\text{PACE}} > \gamma^{\text{HELOC}} > 0$

MODEL DETAILS: CREDIT ACCESS

- A competitive junior HELOC lender breaks even at

$$R^{\text{HELOC}}(p_\theta) = \frac{1}{1 - p_\theta}$$

- Repayment must remain feasible in the high cash-flow state, so maximum HELOC capacity is

$$\bar{L}^{\text{HELOC}}(p_\theta) = (1 - p_\theta)(Y_H - M),$$

which decreases with borrower risk p_θ

- In the model's parameter region,

$$I \leq \bar{L}^{\text{HELOC}}(p_P), \quad I > \bar{L}^{\text{HELOC}}(p_S)$$

Prime HHs can finance the project with a HELOC, while subprime HHs cannot

- A super senior PACE loan can finance the entire project for a constrained household when

$$R_S^{\text{PACE}} \leq \gamma^{\text{PACE}}$$

MODEL DETAILS: PRICING, DELINQUENCY, AND CAPITALIZATION

PACE pricing with provider market power

$$R_P^{\text{PACE}} = 1 + \left(\gamma^{\text{PACE}} - \gamma^{\text{HELOC}} \right), \quad R_S^{\text{PACE}} = \gamma^{\text{PACE}},$$

$$R_S^{\text{PACE}} - R_P^{\text{PACE}} = \gamma^{\text{HELOC}} - 1 > 0$$

Delinquency

$$\Delta D(\theta) = p_\theta > 0, \quad \Delta D(S) > \Delta D(P)$$

Capitalization

$$\Delta V^{\text{PACE}} - \Delta V^{\text{HELOC}} = \left(\gamma^{\text{PACE}} - \gamma^{\text{HELOC}} \right) I > 0$$

- For constrained households, PACE also creates an extensive margin gain because they could not otherwise undertake the project

EX ANTE MORTGAGE LENDING RESULTS

HOW MIGHT MORTGAGE LENDERS RESPOND TO PACE?

- Simple conceptual framework where lenders make underwriting decisions with vs. w/o PACE availability to mortgage borrowers
 - ▶ Two-period model: HH makes downpayment and buys house in $t = 1$ and then decides on PACE in $t = 2$
- **Crowdout:** reduce mortgage supply due to loss given default $\uparrow$ and default probability $\uparrow$
 - ▶ PACE super seniority makes other loans less liquid on secondary market
 - ▶ CDTI higher w/PACE, leading to strategic defaults on mortgage (Ganong & Noel 2023)
- **Crowdin:** collateral recovery value grows if PACE loans are used to finance projects which result in $\Delta P \gg 0$
 - ▶ Default prob. might decline if projects generate new cash flows (e.g. energy savings or lower HO insurance premia) put towards making mortgage payment
- Ultimately an empirical question which force dominates!

SUMMARY OF OUR FINDINGS – MORTGAGE CROWDIN AFTER PACE

$$Lending_{i,c,t} = \beta \cdot PACE\ adoption_{c,t} + \gamma' \cdot \mathbf{X}_{i,c,t} + \alpha_c + \delta_t + \varepsilon_{i,c,t}$$

- Using DiD estimators with county-level staggered adoption (Cengiz et al. 2019; Sun & Abraham 2021; Baker et al. 2022), we find...

① **Loan approvals ↑ for both purchase and refinance mortgages**

►► Robustness

►► Rates

- ★ 1.3 p.p. ↑ in approval rate, or 2% increase relative to $t = -1$

② Credit supply response concentrated among higher risk (i.e. high LTI) borrowers

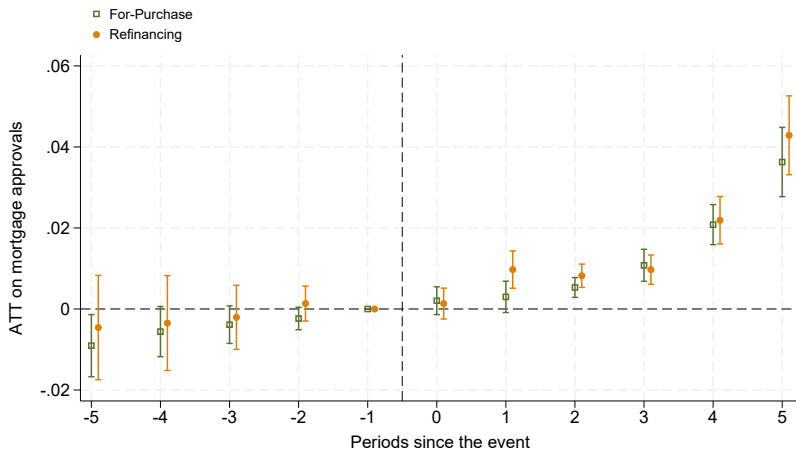
③ **Driven by loans which are subsequently private-label securitized**

④ 8% ↓ in home improvement loan demand (applications)

►► HI loans

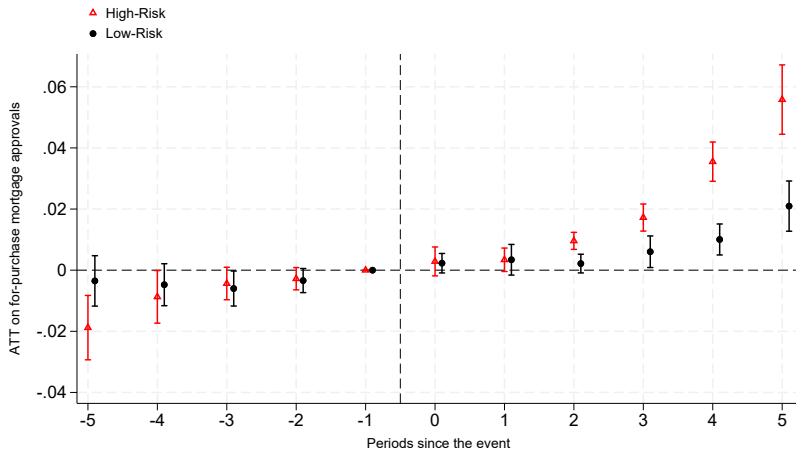
- ★ Two opposing effects: PACE is substitutable for HELOC for qualified borrowers, but HELOC allows for “top-up” funding to do multiple HI projects

CREDIT SUPPLY EXPANDS DUE TO IMPROVED COLLATERAL VALUES



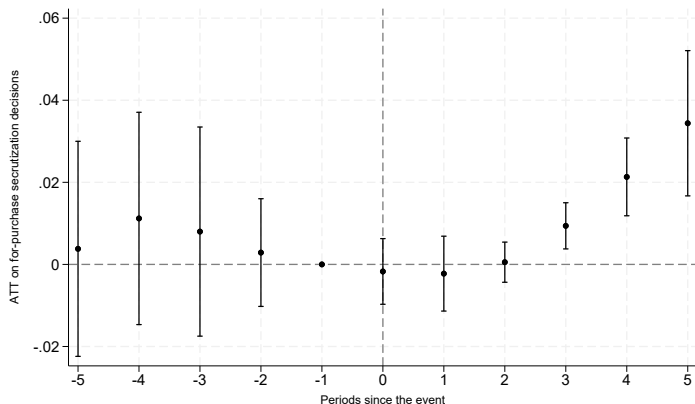
- **Effect grows over time with PACE takeup** $\implies$ not an anticipatory effect ► Stacked DiD
- **Placebo: no effect on approvals if randomly assign adoption dates** ► Dates ► Conventional

CREDIT SUPPLY $\uparrow$ DRIVEN BY HIGH-RISK BORROWER APPROVALS



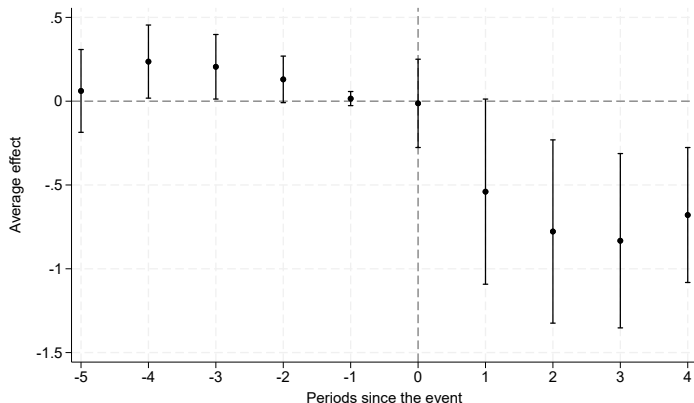
- High/low risk proxied by above/below median loan-to-income (LTI) ratio
- $\implies$ democratization of access to credit in primary mortgage market

NEW MORTGAGE LOANS ARE PRIVATE-LABEL SECURITIZED



- In response to PACE passage in California, GSEs announced in July 2010 that they would not purchase mortgages with a PACE lien attached due to super seniority

DECLINE IN HOME IMPROVEMENT LOAN APPLICATIONS

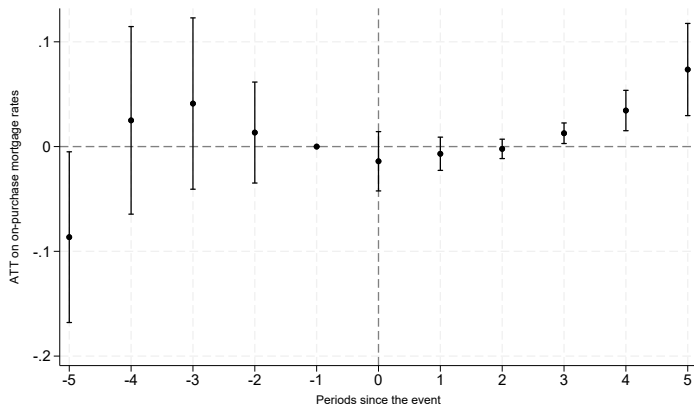
[▶ BACK](#)

- Avg. number of HI loan applications in a tract-year $\Rightarrow 0.5/6 \approx -8\%$ decline
- **PACE substitutes for HELOC** despite rate spread due to concerns about credit score

POOLED SA DiD MORTGAGE MARKET RESULTS [▶ BACK](#)

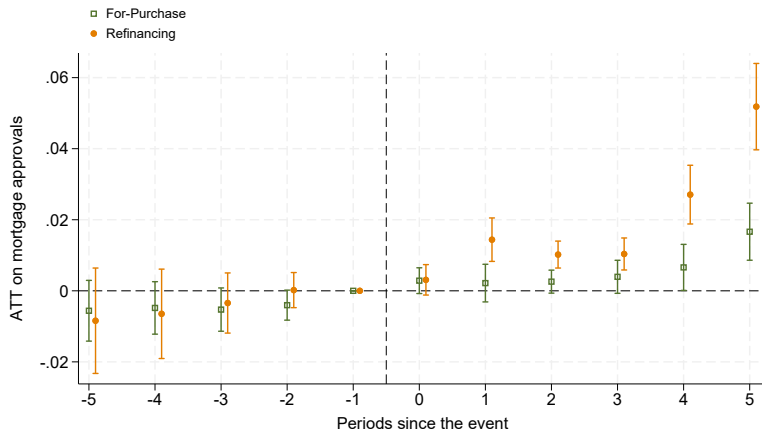
Dep. variable:	Approval				PriSec	RateSpread
	(1)	(2)	(3)	(4)	(5)	(6)
PACE adoption _{c,t}	0.013*** (0.002)	0.016*** (0.002)	0.021*** (0.002)	0.008*** (0.002)	0.010*** (0.004)	0.016* (0.009)
Loan type	Purchase	Refinancing	Purchase	Purchase	Purchase	Purchase
Borrower Sample:	All	All	High LTI	Low LTI	All	All
Observations	2,136,429	1,705,797	1,037,778	1,098,026	1,817,657	624,855
R-squared	0.086	0.178	0.090	0.089	0.523	0.153
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Lender FE	Yes	Yes	Yes	Yes	Yes	Yes
Borrower Controls	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dep. Var.	0.843	0.843	0.836	0.874	0.328	0.945

RATES ON FOR-PURCHASE LOANS ↑ AFTER PACE ADOPTION

[▶▶ BACK](#)

- Rate ↑ even conditional on applicant characteristics
- Consistent with model framework, since expected CLTI will be higher with PACE

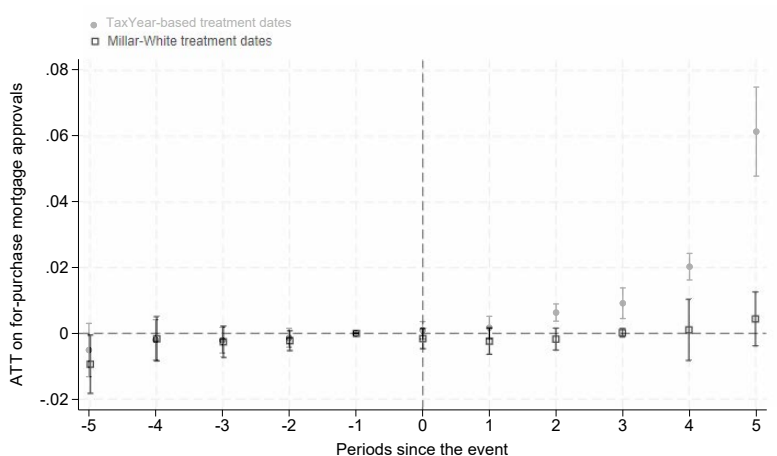
STRONGER RESPONSE OF APPROVALS FOR CONVENTIONAL LOANS



- Unsurprising given that conventional loans are not government-backed, and therefore super seniority of PACE is less of an issue [▶▶ Back](#)

USING PRECISE TREATMENT TIMING BASED ON TAX ROLL MATTERS FOR MORTGAGE MARKET RESULTS

» BACK



- Still, no evidence of crowdout even if we use purely news-based PACE adoption dates

MORTGAGE LENDERS' RESPONSES À LA HOLMSTROM/TIROLE (1)

- Households' expected utility function with mortgage repayment D , PACE repayment ℓ , and random income $\tilde{R}_2$:

$$U(A, D) = \underbrace{-A}_{\text{down payment}} + \underbrace{\beta \int_{\underline{R}}^{D+\ell} \tilde{R}_2 dF(\tilde{R}_2)}_{\text{Expected utility if default}} + \underbrace{\beta \int_{D+\ell}^{\bar{R}} \tilde{R}_2 - D - \ell dF(\tilde{R}_2)}_{\text{Expected utility if no default}}$$

- HH defaults whenever $\tilde{R}_2 < D + \ell$, and **PACE increases probability of default (CDTI $\uparrow$)**
- Lender's have profit function with discount factor $\delta > \beta$ (gains from trade):

$$\Pi(A, D) = \underbrace{-(H_0 - A)}_{\text{Loan amount}} + \underbrace{\delta \int_{\underline{R}}^{D+\ell} H + \Delta H - \ell dF(\tilde{R}_2)}_{\text{Expected profit if borrower defaults}} + \underbrace{\delta \int_{D+\ell}^{\bar{R}} D dF(\tilde{R}_2)}_{\text{Expected profit if borrower does not default}}$$

- PACE loans have a theoretically ambiguous effect on lenders' profits! [▶ Back](#)

MORTGAGE LENDERS' RESPONSES À LA HOLMSTROM/TIROLE (2)

- Assume $\tilde{R}_2$ uniformly distributed and optimal repayment $D^* \in [\underline{R}, \bar{R}]$
- First-order condition for households: [► Back](#)

$$\underbrace{\beta \int_{D+\ell}^{\bar{R}} dF(\tilde{R}_2) - \beta(D + \ell)f(D + \ell)}_{\text{Marginal NPV cost of more debt repayment}} =$$

$$\underbrace{\delta(H + \Delta U - \ell)f(D + \ell) + \delta \int_{D+\ell}^{\bar{R}} dF(\tilde{R}_2) - \delta Df(D + \ell)}_{\text{Marginal NPV benefit of lower downpayment}}$$

- **Key observation** $\partial D / \partial \Delta H > 0$: lenders more willing to supply credit when collateral recovery value is greater (i.e. loss given default is lower)
 - Since, ΔH is independent of $\tilde{R}_2$, can think of this as lenders follow local HPI
 - Empirical results: ΔH from PACE-financed projects is large enough to avoid crowdout