Picking Up the PACE:
Loans for Residential Climate-Proofing

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Motivation

- **Liquidity constraints** are major barriers to invest in Energy Efficiency (EE) projects
  - Higher discount rates stemming from long payback periods, uncertainty about savings and measurement (Giglio et al., 2021, Hovekamp et al., 2023)
  - Especially for low-income households and cash-constrained industries (Hirst and Brown 1990, Golove and Eto, 1996, Schleich and Gruber, 2008)
  - Transition to EE & low-carbon requires Government intervention, but trade-off between reducing emissions and economic costs (e.g., carbon pricing, Känzig 2024)

- We study a new class of financial contracts which aims to reduce the EE gap;
  - Residential **Property Assessed Clean Energy (PACE)** loans
  - Specialized lenders ("administrators") partner with local jurisdictions (counties)
  - Borrowers pay off debt through their local property tax bill → publicly-backed;
  - PACE relaxes borrowing constraints by lowering credit screening standards

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RQ: Can PACE loans solve EE gap?

- **Disagreement**: can PACE loan reach its objectives in a cost-efficient way?

- Yes: they increase the debt capacity of households
  - Super-seniority of property tax payment reduces financial constraints
  - The liabilities are attached to the house and follow the next owner

- No: they increase default risks and could crowd out traditional mortgages
  - PACE liabilities cannot be discharged through personal bankruptcy
  - PACE super seniority makes other loans less liquid on secondary market
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Preview of results

1. Economic, demographic, or political factors do not predict county-level adoption of PACE
   - We find an **assessor** $\times$ **climate concerns** effect on PACE introduction;
2. Households that **appear financially constrained** use more PACE loans
   - Houses are, on average, smaller, older, and with a lower assessed value
3. PACE Loans take-up react to changes in **investment opportunities**
   - PACE loan take-up $\nearrow$ significantly due to local damages caused by Hurricane Irma
4. PACE loan finances projects that **increase significantly the value of the house**
   - PACE home experiences an average appreciation in home sale prices of 34%
5. PACE loans significantly **increase delinquency rates**
   - $\nearrow$ delinquent on their property tax bills by 12% (30%) within 1y (3y) of origination.
6. We find **no evidence of a crowding out** of traditional mortgages
   - Exploit cross-county PACE: 1.5% $\nearrow$ approval for 1st-lien home purchase and refinance loans

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Contribution and related literature

1. **Effects of climate adaptation on property/mortgage markets**

   Eichholtz et al. (2010); Goodman & Zhu (2016); Issler et al. (2019); Jaffee et al. (2019); Keys & Mulder (2020); Rose & Wei (2020); Giglio et al. (2021); CFPB (2023); Sastry et al. (2024); Millar & White (2024)

   → First cost-benefit analysis of PACE using comprehensive microdata

2. **Green investment gap**

   Fowlie et al. (2015,18); Levinson (2016); Houde & Aldy (2017); Gerarden et al. (2017); Hahn & Metcalfe (2021); Berkouwer & Dean (2022); Myers et al. (2022); Clara et al. (2022); Lu & Spaenjers (2023)

   → Highlight the role of households' financial constraints in developed countries

3. **Green financial contracts**

   Zerbib (2019); Tang & Zhang (2020); Flammer (2021); Baker et al. (2022); Kim et al. (2022)

   → We study a new type of local govt.-backed lending product

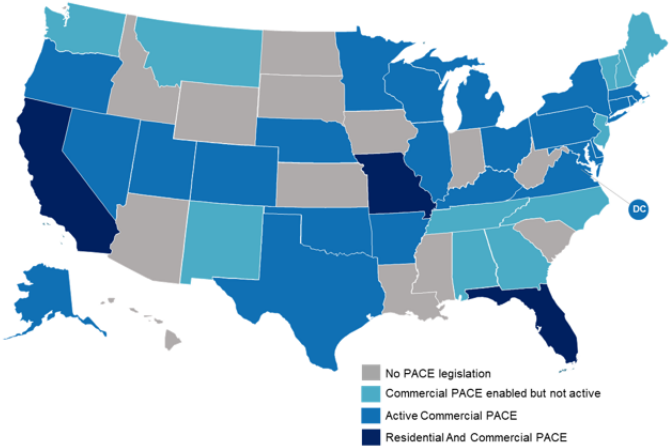
4. **Corporate environmental liens**

   Bellon (2021); Akey & Appel (2021); Ohlrogge (2022); Chen (2022)

   → We study environmental liens linked to households

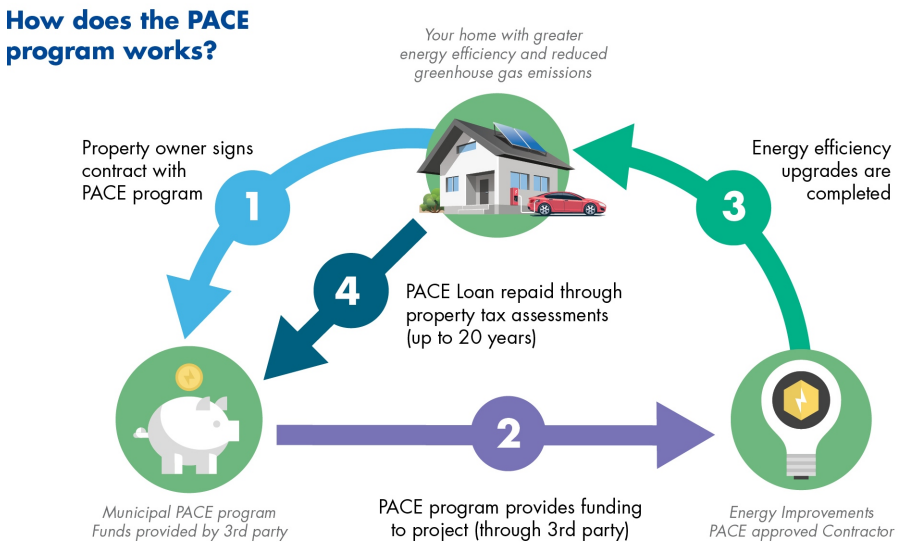
A. Institutional Background

Status of PACE Financing by State



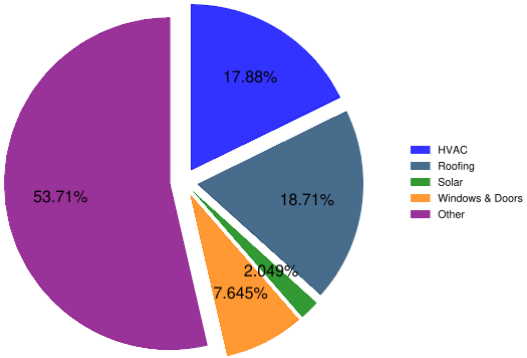
- PACE loans offered in 30 states + D.C. and growing
- R-PACE only available in California, Florida, and Missouri → but $8.5 bil. market (2022)

PACE DEFINITION

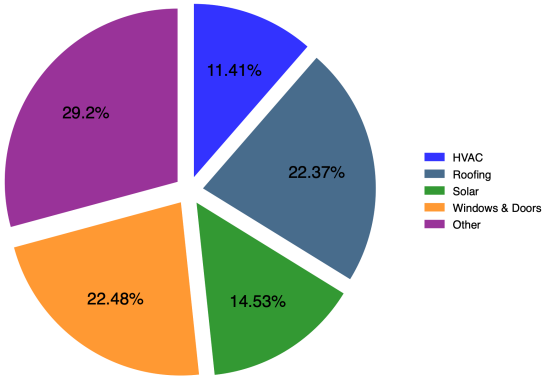


PACE loans mainly used for hurricane proofing in FL

All FL Residential Permits



Permits Tied to FL R-PACE Properties



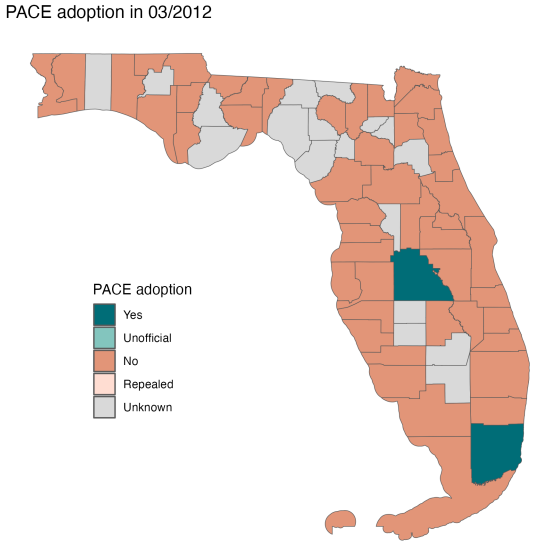
Source: Bellon, LaPoint, Mazzola, Xu (2024): "Picking Up the PACE: Loans for Residential Climate-Proofing"

B. Data & empirical strategies

Datasets: overview

- **PACE loan data**
  - $>$ 16,000 property-level loans matched using the assessor's parcel number (APN)
- **CoreLogic Owner Transfers, Mortgage, and Tax data**
  - House prices, buyers and sellers, information about the use (e.g. single vs. multi-family), tax assessment, combined loan-to-value (CLTV) ratios, and location of the property
- **CoreLogic Involuntary Liens data**
  - Isolate liens placed on property due to local tax delinquency (i.e. PACE default)
- **CoreLogic Building Permits**
  - Tracks the universe of any building permit applications tied to APNs appearing in the other CoreLogic datasets
- **HMDA mortgage lending data**
  - Applicant's demographic information, lender's approval/rejection, pricing, and securitization decisions
- **SHELDUS natural hazards data**
  - Spatial Hazard Events and Losses Database for the United States (SHELDUS)

Entry of R-PACE lending in Florida: 2012 – 2023



- County-level staggered DiD design for mortgage/insurance market outcomes
  - Adoption dates from news sources, LexisNexis, and official loan records
- Local govt. PACE adoption in a year is uncorrelated with...
  - Population size, racial demographics
  - Household income, unemployment, college education
  - Democratic voting share
- Only thing that predicts PACE adoption is **turnover in the tax assessor** $\times$ local climate concerns Table

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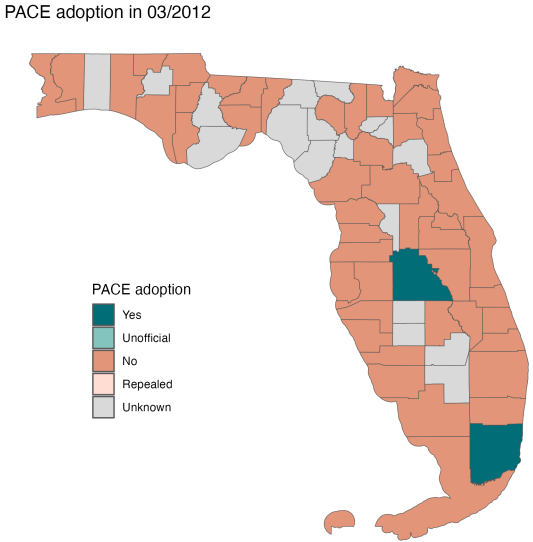

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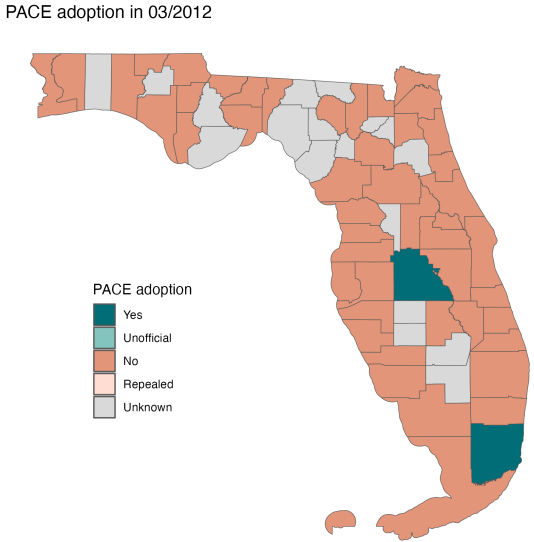

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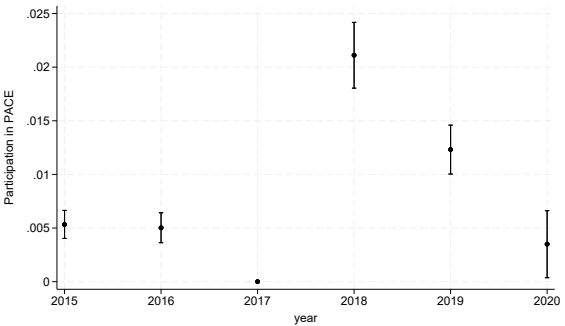
PACE loan takeup spikes after Hurricane Irma (2017)

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



- Irma was a Category 4 hurricane causing $50 bil. in total damages across Florida
- But even before Irma, **property damages predictive of PACE adoption** ▸▸ Table
- Per capita property damages (DMG_c) based on county-level insurance payouts
- Stronger results if focus on PACE projects w/permit for windows + doors as outcome

Battery of staggered DiD designs to overcome selection

1. In matched loan-property sample, **compare early to late PACE borrowers** using Callaway & Sant'Anna (2021) estimator
   - Holds fixed the subprimeness of PACE borrowers relative to alternate loan products
   - Estimate in long differences to render pre-period coefficients interpretable (Roth 2024)

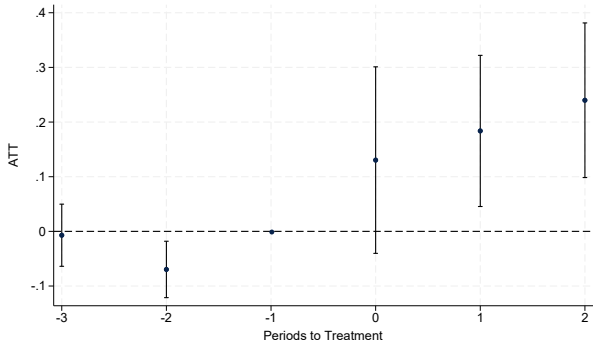
2. **Compare delinquency rates of PACE to HELOC borrowers**, controlling for observables showing negative selection of PACE
   - Use stacked DiD (Cengiz et al. 2019; Baker et al. 2022) given that there is no untreated group in this setting
   - Idea: HELOCs are similar loans to PACE except not paid through tax system

3. **DiD using staggered enrollment into the program by counties**
   - Exploits fact that timing of adoption appears quasi-random w.r.t. observables
   - Apply to HMDA data on loan approvals (supply) and applications (demand)

C. Evaluating the effects of PACE on housing markets

Strong capitalization effect of PACE into house prices

$$\log(Price_{i,t}) = \beta \cdot PACE_{i,t} + \gamma' \cdot \mathbf{X}_{i,t-1} + \theta_{z,t} + \varepsilon_{i,t}$$



- $\Delta P = 27\% \uparrow \implies$ ROI of $\approx$ 1.5x
  - Annualized capital gain of 31%, similar to Giacoletti & Westrupp (2018)

⏩ Robustness ⏩ Summary stats

- Add in origination costs, permit fees, and discounted change in tax bill
  - Permit fees typically very small, vary by town ($100 – $200)
  - Origination fees for FL PACE capped at 2% of loan amount, or $\approx$ $600
- **Complementarity of PACE and other financing** (e.g. HELOCs) to do multiple projects simultaneously

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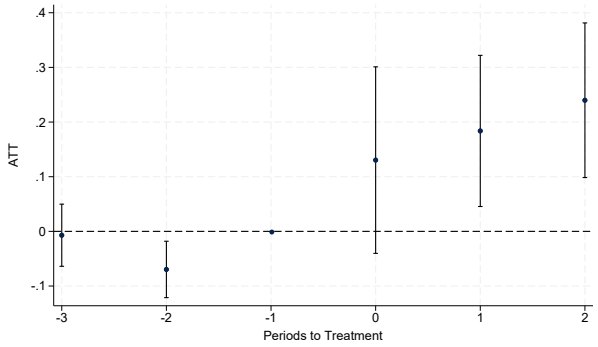

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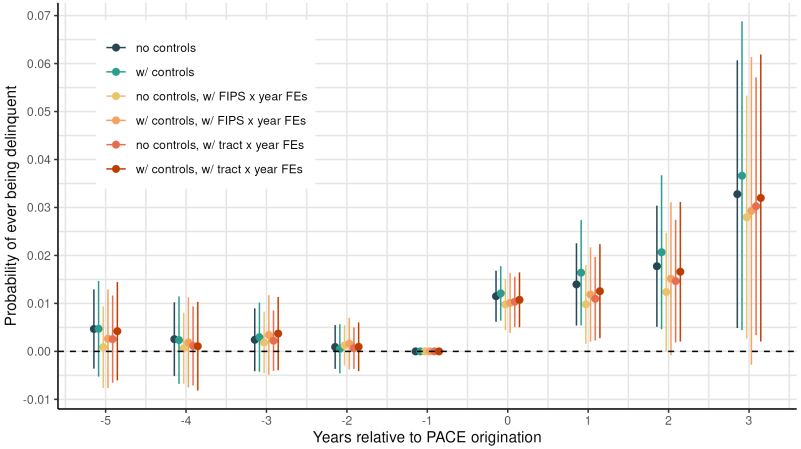
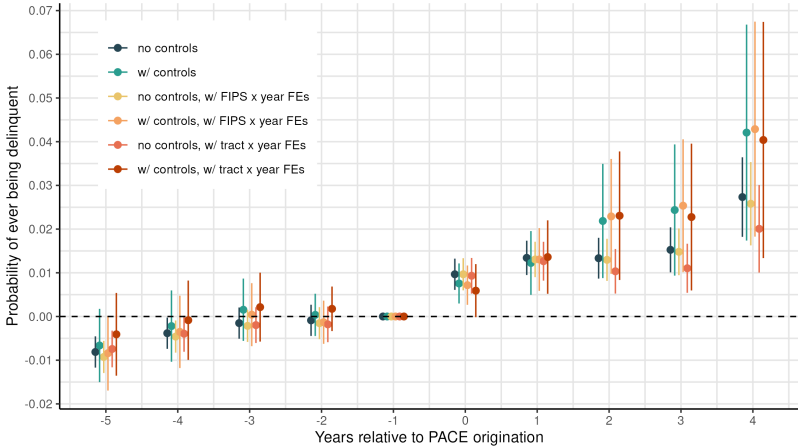
Property Tax Delinquency Rates for PACE Borrowers

Delinquency ↑ by 1 p.p. (12%) within year of origination



- Effect grows over time due to ever-delinquency flag (2.5 p.p., or 30% ↑ within 3 years)
  - Similar trajectory if use property or property × owner combo as the panel unit

Delinquency ↑ if compare PACE to HELOC borrowers



- Spike of similar magnitude to within-PACE loan early vs. late comparison
- Some pre-trend indicates negative selection of PACE borrowers

Does PACE Loan Adoption Crowdout Other Forms of Mortgage Credit?

How might mortgage lenders respond to PACE?

- Simple conceptual framework where lenders make underwriting decisions with vs. w/o PACE availability to mortgage borrowers Full model
  - 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 ↑ and default probability ↑
  - 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 becomes higher, not lower if PACE loans are used to finance projects with $\Delta P >> 0$
  - 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!

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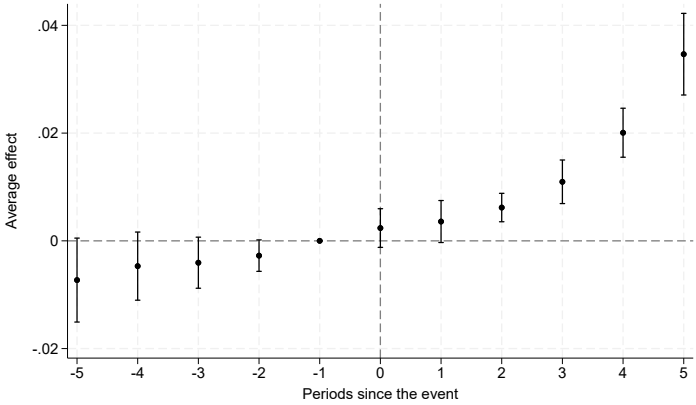
Summary of our findings – mortgage crowdin after PACE

$$Lending_{i,c,t} = \beta \cdot \textit{PACE adoption}_{c,t} + \gamma \cdot \mathbf{X}_{i,c,t} + \alpha_c + \delta_t + \varepsilon_{i,c,t}$$

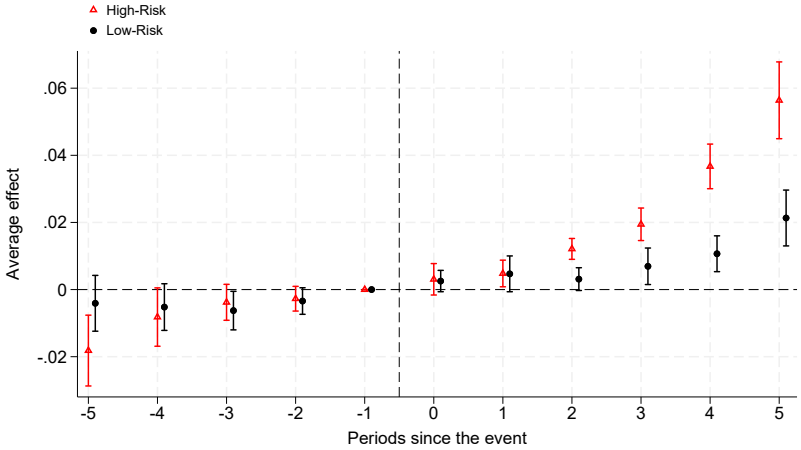
- Using DiD estimators with county-level staggered adoption (Cengiz et al. 2019; Sun & Abraham 2021; Baker et al. 2022), we find...
  1. **Loan approvals ↑ for both purchase and refinance mortgages** ⏩ Robustness ⏩ Refis
     - ★ 1.5 p.p. ↑ in approval rate, or 2% increase relative to $t = -1$
  2. Credit supply response concentrated among higher risk (i.e. high LTI) borrowers
  3. **Driven by loans which are subsequently private-label securitized**
  4. Zero average effect on home improvement loan demand (applications) ⏩ HI loans
     - ★ Two opposing effects wash out: 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



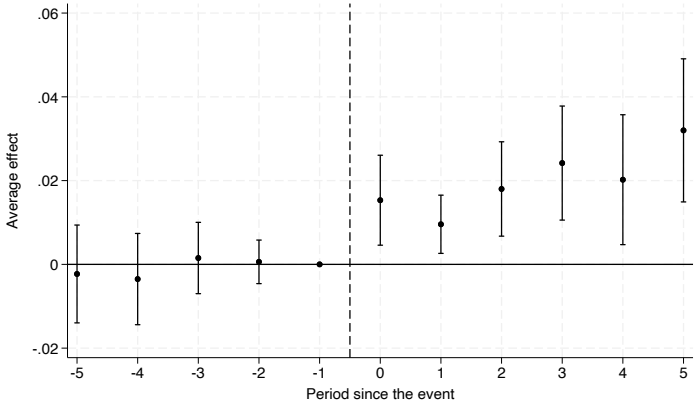
- **Effect grows over time** with household takeup $\Longrightarrow$ not an anticipatory effect
- Placebo test: no effect on loan approvals if randomly assign PACE county adoption dates

Credit supply ↑ driven by high-risk borrower approvals



- High/low risk proxied by above/below median loan-to-income (LTI) ratio
- Coefficients directly on top of each other in pre-period

New loans are private-label securitized



- GSEs will not purchase mortgages with a PACE lien attached due to super seniority

Local Cost-Benefit Implications of PACE

Combining our estimates $\Longrightarrow$ PACE expands tax base

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

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

- Even after netting out delinquencies, **revenues grow by $664 per PACE loan-year** in counties participating in program
  - Similar ΔP if instead use market assessed values (tax base revalued each year in FL)
  - ATT effects: evidence from HMDA consistent with positive pecuniary externalities
- Again, **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

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D. Conclusion

Conclusion: locally, PACE does more good than harm

- **We show that local government-backed loans can help close the investment gap in green residential projects $\longrightarrow$ revenues $\uparrow$ by $664 per loan-year**
- **Mechanism:** lowering screening standards without subsidizing credit helps relax households' **financing constraints**
  - PACE borrowers are negatively selected compared to HELOC borrowers for home improvement projects
  - Uptick in delinquency rates quantitatively small relative to capitalization into home values
- Super seniority of the tax lien does not lead to crowdout of traditional mortgage credit, since recovery value of collateral $\uparrow$
  - incentives for the private sector to invest in mitigation and adaptation.
- **Future agenda:** expand analysis to CRE and to California where loans typically used for energy efficiency projects (i.e. solar)
  - Spillovers/GE effects: local employment impact of PACE through contractor operations

THANK YOU!

A. Background

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 through annual local property tax bill.

- Public-private partnership: local govt. issues bonds backed by tax payments and outsources underwriting to private lenders ("administrators")
- Qualified uses are fairly expansive: solar panels, HVAC upgrade, **re-roofing, impact-resistant windows/doors,** generator, water conservation, etc.
- 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)

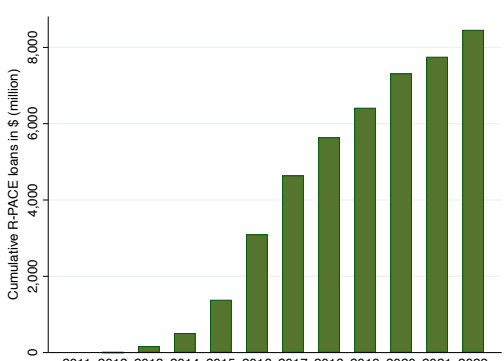
Appendix: How do borrowers obtain PACE financing?

- Two applications methods:
  1. Apply directly through districts or lender's website
  2. Work with 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 cannot exceed 100% of income, 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

Appendix: PACE loans are growing



- Most states have proposed C-PACE legislation (pacenation.org)
- R-PACE only available in California, Florida, and Missouri
- Substantial growth of the asset class since 2011

What predicts counties' PACE adoption decisions?

Back

	(1)	(2)	(3)	(4)	(5)	(6)
Population	-0.018	-0.030	-0.021	0.001	-0.219	-0.387
	(0.071)	(0.074)	(0.078)	(0.910)	(0.960)	(0.944)
Household median income	0.365	0.535	0.412	-0.255	-0.172	-0.205
	(0.365)	(0.381)	(0.418)	(0.323)	(0.342)	(0.356)
% Bachelor degree or higher	-1.546**	-1.784**	-1.681**	0.808	1.416	1.369
	(0.714)	(0.750)	(0.800)	(1.216)	(1.183)	(1.175)
% Black	1.421	1.437	1.627	-0.557	0.527	1.294
	(2.196)	(2.354)	(2.407)	(2.425)	(2.520)	(2.542)
% Latino	1.363	1.443	1.614	-1.509	-4.040	-4.690
	(1.950)	(2.045)	(2.080)	(5.655)	(6.690)	(6.818)
% White	1.417	1.430	1.702	-1.102	-3.249	-3.816
	(2.000)	(2.109)	(2.157)	(4.208)	(5.028)	(4.974)
Unemployment rate	-3.723***	-3.840***	-4.260***	-1.141	-0.578	-0.470
	(1.115)	(1.223)	(1.318)	(1.119)	(1.238)	(1.327)
Debt/Revenue	-0.010	-0.005	-0.008	-0.011	-0.016	-0.018
	(0.038)	(0.037)	(0.038)	(0.025)	(0.026)	(0.025)
Democratic leaning	0.369	0.687	0.670	-1.149	-1.328	-1.190
	(0.601)	(0.653)	(0.687)	(1.015)	(1.042)	(1.117)
Neighbor PACE	-0.044	-0.065	-0.075	-0.015	0.014	0.043
	(0.097)	(0.097)	(0.098)	(0.089)	(0.088)	(0.092)
Climate concerns	0.038***	0.034**	0.036***	0.033*	0.030	0.027
	(0.011)	(0.013)	(0.013)	(0.019)	(0.020)	(0.019)
Assessor turnover	0.027	0.040	0.134	-1.055*	-1.087**	-1.205**
	(0.686)	(0.696)	(0.714)	(0.528)	(0.527)	(0.527)
Climate concerns×Assessor turnover	-0.001	-0.001	-0.003	0.019*	0.020**	0.022**
	(0.012)	(0.012)	(0.013)	(0.010)	(0.010)	(0.009)
#Declared natural disasters	0.062***			-0.016		
	(0.020)			(0.028)		
#Declared natural disasters L1		0.101***			-0.026	
		(0.029)			(0.029)	
#Declared natural disasters L2			0.088**			-0.007
			(0.033)			(0.030)
Observations	504	466	430	504	466	430
R-squared	0.375	0.362	0.325	0.712	0.723	0.731
County FE	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	Yes	Yes	Yes

- Run linear probability models with dummy for county adoption of PACE in a given year as the outcome
- Labor market conditions are no longer predictive within county and within year
- On average, counties with new assessors are far less likely to adopt PACE
- But, counties more **concerned about climate change** with a new assessor are more likely to adopt PACE
  - FL tax assessor's are elected officials
  - Data source: Yale Climate Change Surveys

Pooled CSDID pricing results

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Dep. Variable: log(Price)	(1)	(2)	(3)	(4)	(5)
$PACE_{i,t}$	0.185***	0.142***	0.192***	0.185***	0.240**
	(0.030)	(0.028)	(0.028)	(0.068)	(0.099)
Observations	5,155	5,155	4,496	4,496	2,669
County × Year FE	Yes	No	No	No	No
Zip code × Year FE	No	Yes	No	No	No
Census Tract × Year FE	No	No	Yes	Yes	Yes
Permit Controls	No	No	No	Yes	Yes
Property Controls	No	No	No	No	Yes
Mean Dep. Var.	12.439	12.439	12.492	12.492	12.483

Pooled SA DiD mortgage market results

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Dep. Variable:	Accept					PriSec	RateSpread
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PACEadoption_{c,t}$	0.017***	0.013***	0.016***	0.022***	0.005***	0.006***	0.018**
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.011)
Loan type	Purchase	Purchase	Refinancing	Purchase	Purchase	Purchase	Purchase
Borrower Sample:	All	All	All	High-risk	Low-risk	All	All
Observations	2,137,169	2,136,429	1,705,797	1,037,778	1,098,026	1,776,835	624,855
R-squared	0.033	0.086	0.178	0.090	0.089	0.346	0.153
Borrower Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lender FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Mean Dep. Var.	0.853	0.853	0.853	0.836	0.874	0.290	0.694

Null effect on home improvement loan applications

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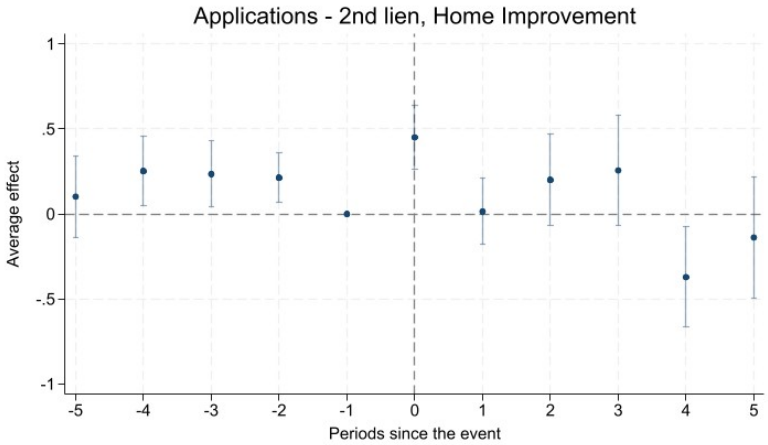

- Borrowers use HELOCs to "top-up" PACE funding but also demand is lower to extent HELOCs are substitutable contracts

Credit supply also expands for refinancing loans

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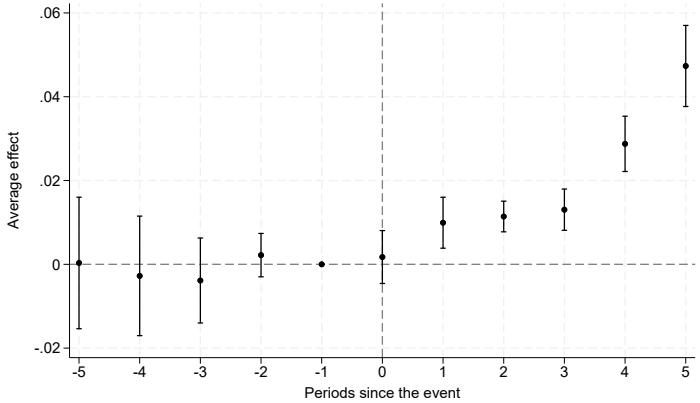

- $\Longrightarrow$ PACE expands credit supply to both new and existing mortgage borrowers

Mortgage lenders' responses à la Holmstrom/Tirole (1)

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

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

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

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

- PACE loans have a theoretically ambiguous effect on lenders' profits!

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Mortgage lenders' responses à la Holmstrom/Tirole (2)

- Assume $\widetilde{R}_2$ uniformly distributed and optimal repayment $D^* \in [\underline{R}, \overline{R}]$
- First-order condition for households: Back

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

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

- **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 $\widetilde{R}_2$, can think of this as lenders follow local HPI
  - Empirical results: ΔH from PACE-financed projects is large enough to avoid crowdout