Digital Collateral

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Motivation

About 590 million Africans live off the grid. Most of them rely on flame-based lamps powered by fossil fuels like kerosene. The light from these lamps is dim and comes with significant health and financial costs. A kerosene lamp may cost less than $5, but fuel averages about $57 per year. Sub-Saharan Africans burn up about $10 billion annually on kerosene, and worldwide, kerosene costs people without electricity $36 billion.

—Study by the International Finance Corporation (World Bank)

The Problem

Low quality light, burns fossil fuel ($$$), fire hazard

The Solution

A $30 solar lantern pays for itself in 8-10 weeks

The (Product Adoption) Puzzle

In LMICs, household investment in many basic technologies has extremely high returns

- Yet adoption has been slow and is not widespread

There are a number of explanations for why

- Both on the supply and demand side
- Today will focus on credit market frictions

Isn't microfinance the answer?

- Traditional microfinance
  - Expensive (and unsecured)
  - Inconvenient (high transaction costs)
  - Low uptake
  - Modest effects on the average borrower (Banerjee, 2015)

- Digital financial products are becoming increasingly popular. The growth has been facilitated by technology:
  - Access to mobile phones
  - Digital payments (mobile money)

What are the effects on households and firms? How best should they be utilized?

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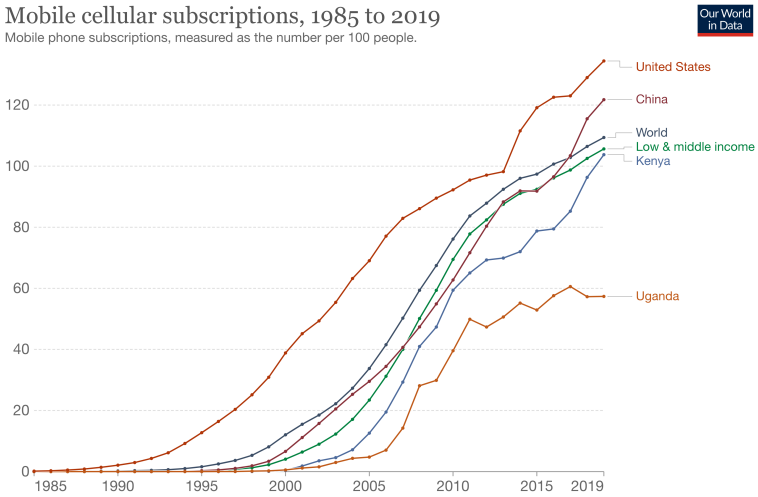
Adoption has been Rapid



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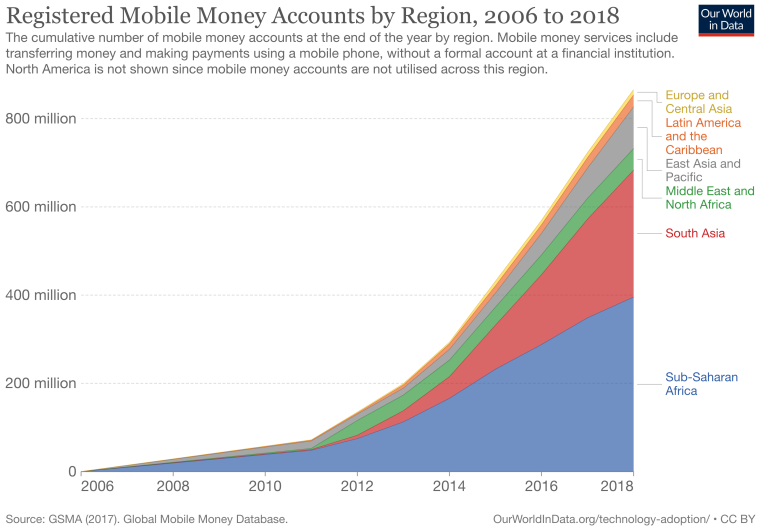

What about secured lending?

Collateralized lending is the predominant source of credit for households in rich countries

- More than 80% of US household debt is secured

Why? Collateral alleviates credit market frictions.

1. Moral hazard: incentives to repay
2. Adverse selection: screening device

Collateralized lending is much less common in poor countries.

- Supply side: Repossession costs
  - Contracts hard to enforce; property rights are difficult to establish
- Demand side: Income risk
  - Threat of repossession unattractive to households

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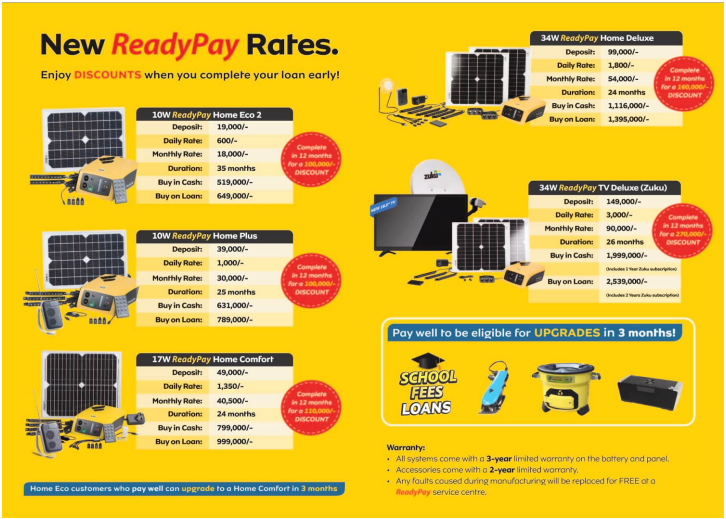
Enter PAYGO financing and “Digital Collateral"

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Research Questions

Experimental

- How valuable is securing loans with digital collateral to the lender?
  - Quantify the effect on repayment and profitability
- What is the channel?
  - Moral hazard vs adverse selection
- What are the impacts of the loans on households?

Theoretical

- What is the optimal way to utilize digital collateral?
  - Insurance vs incentives

Summary of Experimental Results

1. Securing loans with DC significantly increases repayment and profitability
   - Default rates decrease by 19pp
   - Loan profitability (IRR) increases by 38pp
2. Decomposition
   - $\approx 2/3$ due to moral hazard
   - $\approx 1/3$ due to selection
3. Household outcomes appear promising
   - Reasonably high take-up
   - No evidence of a “debt trap"
   - More work to be done here
4. Securing loans with DC is not without cost
   - Production and installation costs of the technology
   - Median household is locked 25% of first 200 days
   - Flexible repayment: feature or bug? but potential room for improvement...

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Theoretical Framework
Simple model of secured lending

Households

- Indexed by $i \in [0,1]$, no wealth
- Investment requires one unit of capital at date 0, delivers $R > 1$ at date 2
- Asset that delivers (random) utility $\tilde{v}_i \sim F$ at date 1
- Risky date 1 income $\tilde{y}_i \in \{0, \bar{y}\}$, $\Pr(\tilde{y}_i = 0) = q_i$

Lender

- Offers one unit of capital in exchange for p at date 1
- Repossession technology parameterized by
  - Recovery, κ: fraction of asset value recovered by lender
  - Lockout, λ: fraction of asset value household loses

Frictions: moral hazard (strategic default) and adverse selection (risk unobservable)

Household Payoffs

- Payoff (net of income) from **accepting** the loan is

$$\Pi_{i,a} = R + (1 - q_i)\mathrm{E}[\max\{\tilde{v}_i + \tilde{w}_i - p, (1 - \lambda)\tilde{v}_i\}] + q_i(1 - \lambda)\mathrm{E}[\tilde{v}_i],$$

  where $\tilde{w}_i$ is household continuation/intrinsic value from successful repayment

- Payoff from **rejecting** the loan is

$$\Pi_{i,r} = \mathrm{E}[\tilde{v}_i]$$

Lockout reduces strategic default

- Household repays if $\tilde{y}_i = \bar{y}$ and

$$\tilde{v}_i + \tilde{w}_i - p \geq (1 - \lambda)\tilde{v}_i$$

- Therefore, the probability i strategically defaults is

$$(1 - q_i)\Pr(\lambda\tilde{v}_i + \tilde{w}_i - p \geq 0)$$

  which is decreasing in λ

Lockout reduces adverse selection

- Household i accepts the loan if

$$\underbrace{R + (1-q_i)\mathrm{E}[\max\{\tilde{v}_i + \tilde{w}_i - p, (1-\lambda)\tilde{v}_i\}] + q_i(1-\lambda)\mathrm{E}[\tilde{v}_i]}_{\Pi_{i,a}} - \underbrace{\mathrm{E}[\tilde{v}_i]}_{\Pi_{i,r}} \geq 0$$

- $\Pi_{i,a} - \Pi_{i,r}$ is decreasing in both q_i and λ
- Hence, there exists a $\underline{q}$ such that only households $q_i \leq \underline{q}$ accept the loan.
- Moreover, $\underline{q}$ is decreasing in λ

Decomposition

Digitally secured loan ($\lambda = 1$) vs unsecured loan ($\lambda = 0$)

- Let $\underline{q}^s$ and $\underline{q}^u$ denote the respective threshold risk types that accept.
- Let $h(q) \equiv \mathrm{E}(q_i | q_i \leq q)$, denote the conditional expected income risk.
- The probability of repayment in the secured treatment group is

$$\Pr\left(\tilde{v}_i + \tilde{w}_i \geq p\right)\left(1 - h(\underline{q}^s)\right)$$

- The probability of repayment in the unsecured treatment group is

$$\Pr\left(\tilde{w}_i \geq p\right)\left(1 - h(\underline{q}^u)\right)$$

- Decompose the total difference in repayment as

$$\underbrace{\left(\Pr(\tilde{v}_i + \tilde{w}_i \geq p) - \Pr(\tilde{w}_i \geq p)\right)(1 - h(\underline{q}^s))}_{\text{moral hazard effect}} + \underbrace{\Pr(\tilde{w}_i \geq p)(h(\underline{q}^u) - h(\underline{q}^s))}_{\text{adverse selection effect}}$$

Comparative Statics

- Higher device values (FOSD) leads to
  - Decrease in loan take up
  - Increase in both MH and AS effect
- Greater fraction of households with high $\tilde{w}$ leads to
  - Decrease in the MH effect

Field Experiment

- Partnership with Fenix International (recently acquired by Engie)
  - Largest SHS supplier in Uganda
    - Operations in Kenya, Zambia, Mozambique, Cote D'Ivoire and Nigeria
  - Range of SHS products, 10-34W
    - LED bulb $\approx$ 4-7W,
    - Refrigerator $\approx$ 500W
  - Third largest user of mobile money in Uganda

Loan Product – School Fee Loans

In 2017, Fenix began offering "school fee" loans to existing SHS customers that were in good standing on their account

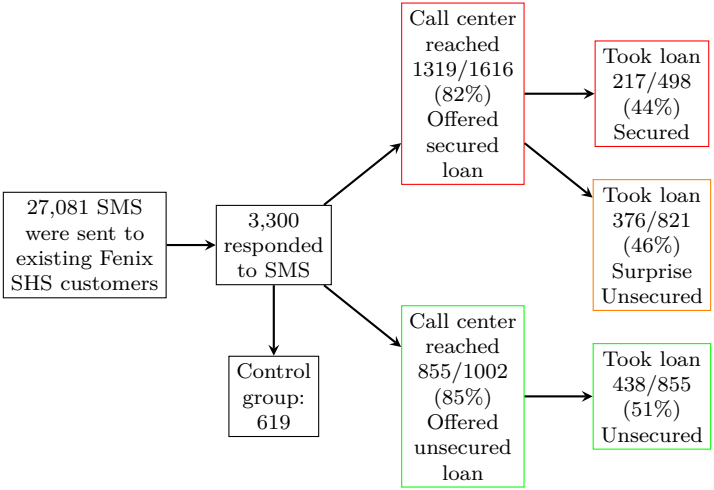
- Ranging from 100k-500k ($25-$125) loan size, 3x per year
- 100 day maturity, 15-20% deposit,
- PAYGO structure, e.g., on 300k loan
  - Make 50k deposit
  - Receive 300k a few days later
  - 3k per day, completed after 100 payments
  - If delinquent -> device locks
- Implied interest rate depends on repayment
  - 118% with 100% on time repayment
  - 64% with 50% repayment (1 out of every 2 days)

Experimental Design

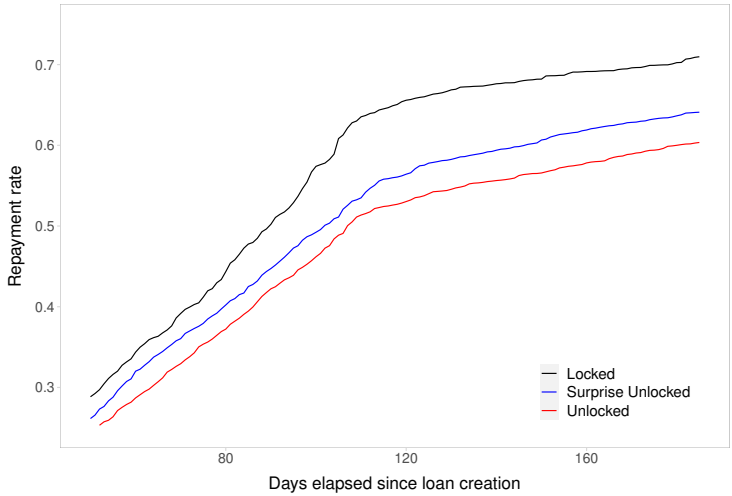
- Sample randomly divided into 4 groups
  1. Secured: Offered a loan secured by digital collateral (their SHS)
  2. Unsecured: Offered an unsecured loan
  3. Surprise Unsecured: Offered secured loan, if they accepted, we “surprised" them (ala Karlan and Zinman, 2009)
  4. Control: No offer

- Difference in repayment between Secured and Unsecured captures MH + AS
  - Secured - Surprise Unsecured: same offer $\implies$ only MH
  - Surprise Unsecured - Unsecured: different offer $\implies$ only AS

Sample Sizes and Take-up



Loan Repayment



Loan Repayment

Loan day	Mean Unsecured	Secured	Adverse Selection	Moral Hazard
100	0.46	0.13***	0.04	0.09**
		(0.04)	(0.03)	(0.04)
150	0.57	0.13***	0.05	0.09**
		(0.04)	(0.03)	(0.04)
200	0.62	0.11***	0.04	0.07*
		(0.04)	(0.03)	(0.04)
n		655	814	593

Loan Completion

Loan day	Mean Unsecured	Secured	Adverse Selection	Moral Hazard
110	0.31	0.10**	0.01	0.09*
		(0.05)	(0.04)	(0.05)
150	0.41	0.17***	0.05	0.12**
		(0.05)	(0.04)	(0.05)
200	0.47	0.19***	0.05	0.13**
		(0.05)	(0.04)	(0.05)
n		655	814	593

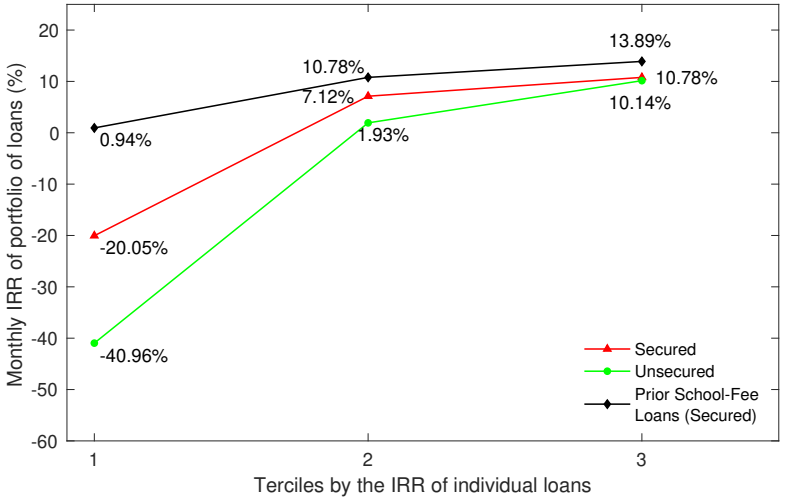
Heterogeneous treatment effects: primary loan repayment (PLR)

Repayment at Day 150	Lockout	Adverse Selection	Moral Hazard
Treatment	0.13**	0.10**	0.02
	(0.06)	(0.05)	(0.05)
Treatment × Below median PLR	0.01	-0.11*	0.13*
	(0.08)	(0.06)	(0.08)
Below median PLR	-0.15***	-0.15***	-0.27***
	(0.04)	(0.04)	(0.04)
Constant	0.63***	0.64***	0.73***
	(0.03)	(0.03)	(0.03)
n	655	814	593

Interpretation

- AS effect amplified by higher device values
- MH effect attenuated by higher continuation values

Profitability



Educational Outcomes

	Enrollment		Days absent		Log school expenditures	
Secured	0.11***		-2.39***		0.47***	
	(0.03)		(0.77)		(0.16)	
Surprise Unsecured	0.08***		-1.31*		0.32**	
	(0.03)		(0.74)		(0.15)	
Unsecured	0.10***		-2.00***		0.37**	
	(0.03)		(0.74)		(0.15)	
Pooled		0.09***		-1.83**		0.37**
		(0.03)		(0.72)		(0.15)
Pooled × Children	-0.02***	-0.02***	0.37**	0.38**	-0.05	-0.05
	(0.01)	(0.01)	(0.19)	(0.19)	(0.04)	(0.04)
Outcome control mean	0.88	0.88	2.77	2.77	81	81
n	1683	1683	1683	1683	1683	1683

Effect on Household Balance Sheet

	Asset purchases		Asset sales		Money borrowed		Net difference	
Secured (β_1)	15		-10		23		2	
	(44)		(20)		(47)		(62)	
Surprise Unsecured (β_2)	-23		-4		28		-47	
	(39)		(18)		(42)		(55)	
Unsecured (β_3)	33		14		17		2	
	(39)		(18)		(42)		(55)	
Pooled (β)		8		2		23		-17
		(34)		(16)		(37)		(48)
Outcome control mean	236	236	96	96	283	283	-143	-143
n	1877	1877	1877	1877	1877	1877	1877	1877

- No significant impact on household finances.

What is the real innovation?

Two possibilities:

1. Better technology for repossession
   - Provides repayment incentives without incurring repossession costs
   - Plausible (even likely)...but straightforward

2. Facilitates a richer space of contracts (e.g., “temporary" repossession) by lowering the cost of dynamically controlling household’s consumption of the good.
   - Question: is this actually valuable?
   - Answer: Yes! (Green and Sraer, 2022)

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Illustration: The Value of Temporary Repossession

Agent

- Private income process: $dY_t = \mu dt + \sigma dB_t$
  - Can "divert" income for consumption at rate $\gamma \leq 1$
- Derives utility from two goods: $dU_t = dC_t + q_t dt$
  - The consumption good, dC_t
  - The lockout good, $q_t dt$
- Risk-neutral, discount rate ρ.

Principal

- Technology to produce q-good
  - Fixed up-front cost of production
  - Zero marginal cost up to capacity $\bar{q}$
- Can also deliver consumption good to agent at mc=1
- Risk neutral, discount rate $r < \rho$

The Exercise

Compare two repossession technologies:

1. Traditional
   - Agent will consume $\bar{q}$ of q-good prior to repossession
2. Lockout
   - Principal can dynamically control agent's consumption of the q-good

Lockout is weakly superior

- We provide conditions under which it is strictly superior.

Contracts and Payoffs

Principal commits to a contract: a triple (I, q, τ), measurable wrt reported income:

- dI_t amount of consumption good to agent at t
- q_t flow of q-good to agent at t
- τ repossession date

Payoffs:

- To the agent

$$U_A = \int_0^\tau e^{-\rho s}(dI_s + q_s ds) + e^{-\rho\tau} R$$

where $R = \mu/\rho$ is the agent's autarky payoff.

- To the principal

$$U_P = \int_0^\tau e^{-rs}(d\hat{Y}_s - dI_s) + e^{-r\tau} L$$

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Truthful Reporting

- Let W_t denote the continuation value of the agent at time t
- By the MRT

$$dW_t = (\rho W_t - q_t)dt - dI_t + \beta_t(d\hat{Y}_t - \mu dt)$$

- As in DS06, reporting truthfully ($d\hat{Y}_t = dY_t$) is incentive compatible provided that

$$\beta_t \geq \gamma \tag{IC}$$

- Concavity of VF $\implies$ $\beta_t = \gamma$ is optimal.
- Plugging back into dW_t, we get

$$dW_t = (\rho W_t - q_t)dt - dI_t + \gamma(dY_t - \mu dt) \tag{PK}$$

Principal's Problem

- Let $b(W)$ denote principal VF. Principal's HJB

$$rb(W) = \max_{dI,q} \{\mu - dI + (\gamma W - q - dI)b'(W) + \frac{1}{2}(\rho\sigma)^2 b''(W)\}$$

- The marginal benefit of q and dI is the same: $-b'(W)$
- Only the marginal costs differ
  - Optimal to payout the consumption good when

$$-b'(W) \geq 1$$

  - Optimal to payout the q-good when

$$-b'(W) \geq 0$$

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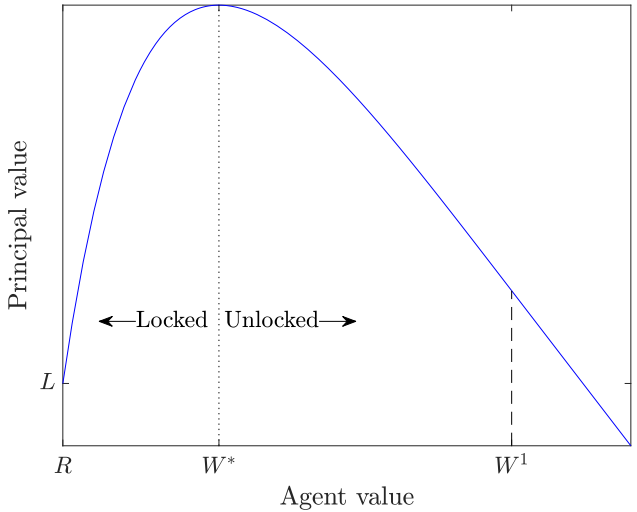

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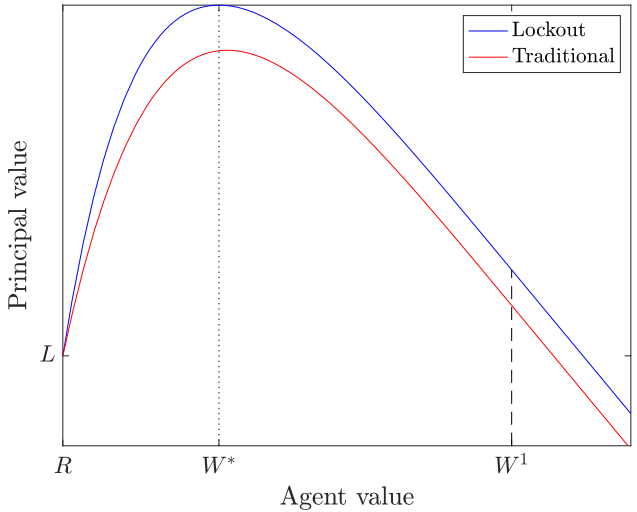

When is lockout valuable?

Result

Lockout is Pareto improving (i.e., $b > f$) if and only if $f'(R) > 0$.

- b is the principal's value function with lockout
- f is the principal's value function without lockout

Proof:

($\Rightarrow$) By weak dominance, $f'(R) > 0 \implies b'(R) > 0$, hence $q^*(W) = 0$ for $W \in N_s(R)$.
- Not feasible under traditional repossession

($\Leftarrow$) By concavity, $f'(R) < 0 \implies f'(W) < 0 \ \forall W$
- $b = f, q^*(W) = \bar{q}$ solve Principal's HJB
- No way to improve over traditional repossession

Note $f'(R) > 0$ does **not** imply that the principal can profitably lend without lockout
- f does not account for the fixed cost (or loan amount)

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Conclusion

- Firms: Securing loans with DC significantly increases repayment and profitability
- Households: Relatively high demand for credit secured by DC
  - Access to credit increases school enrollment and expenditures
- But not without cost: median HH locked 25% of first 200 days
  - Room for improvement? Overall welfare effect on households?
- Temporary repossession (as in PAYGO) can be optimal

Current and Future Directions

Contract Design

- Is it possible to reduce locking without sacrificing incentives for repayment?
  - Arrears vs Paygo
  - Implementation of optimal contract with loyalty program/virtual currency

Quantify the Welfare Effects

- Estimate a model of households and firms
  - Employs data from a randomized pricing experiment of smartphone contracts
- Counterfactual: no lockout, perfectly competitive pricing
- Current estimates
  - Current pricing: Household welfare ↑ 10-15% income for customers with 60% take up