Shocks and Technology Adoption:
Evidence from Electronic Payment Systems

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Motivation

Many Fintech products are network technologies, payment platforms, lending platforms. Adoption decisions are complements across users. ⇒ coordination problems (Katz and Shapiro, 1982).

Theoretical possibility, but...

1. are coordination problems a quantitatively large obstacle to Fintech adoption?
2. how can policy address them?

This paper: adoption of an electronic payments platform during the Demonetization...
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This paper: adoption of an electronic payments platform during the Demonetization
Findings

1. Theory: with adoption complementarities, after a temporary shock, (a) persistent increase in total users, (b) persistent increase in new users, (c) state-dependence in adoption.

2. Causal impact of Demonetization:
   - Instrument: local importance of chest banks
   - Responses qualitatively consistent with (a), (b), and (c).

3. Quantitative role of complementarities:
   - 60% of 8 month adoption response due to complementarities
   - Small but more persistent shocks → less variance in adoption
Findings

1 Theory:

- Persistent increase in total users
- Persistent increase in new users
- State-dependence in adoption

2 Causal impact of Demonetization

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Plan

1. Background
2. Theory
3. Reduced-form evidence
4. Structural estimation + counterfactuals
1. Background
The Indian demonetization of 2016
What was the effect on the use of electronic money?
What was the effect on the use of electronic money?

Study a large provider of electrony wallets
What was the effect on the use of electronic money?

Study a large provider of electronic wallets

registration only requires bank account + mobile phone
What was the effect on the use of electronic money?

Study a large provider of electronic wallets

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no set-up fees, no transaction fees
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Sample

≈ 1 million firms
amount and # of transactions; geo identifiers
weekly (May 2016 to June 2017)
2. Theory
Economic environment
Economic environment

- \( t = 0, \Delta, 2\Delta, 3\Delta, \ldots \) with \( \Delta \) small; firms \( i \in [0, 1] \)
Economic environment

- $t = 0, \Delta, 2\Delta, 3\Delta, \ldots$, with $\Delta$ small; firms $i \in [0, 1]$

- Flow profits

$$\Pi(x_{i,t}, M_t, X_t) = \begin{cases} 
M_t & \text{if } x_{i,t} = c \text{ (cash)} \\
M^e + CX_t & \text{if } x_{i,t} = e \text{ (electronic money)}
\end{cases}$$
Economic environment
- \( t = 0, \Delta, 2\Delta, 3\Delta, ..., \) with \( \Delta \) small; firms \( i \in [0, 1] \)
- Flow profits

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\( M_t \) exogenous, AR(1)
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X_t = \int_{i \in [0,1]} 1 \{ x_{i,t} = e \} \, di, \quad C \geq 0
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- Max PDV of \( \Pi_{i,t} \) over \( \{ x_{i,t} \}_{t \geq 0} \) — can adjust w.p. \( 1 - e^{-k\Delta} \) per period
The shock

\( S = \text{large shock to value of the cash technology, } M_t \)

\[
M_0 = (1 - e^{-\theta \Delta})M^c + e^{-\theta \Delta}M_{-\Delta} - S
\]
The shock

\[ S = \text{large shock to value of the cash technology, } M_t \]

\[ M_0 = (1 - e^{-\theta \Delta}) M^c + e^{-\theta \Delta} M_{-\Delta} - S \]

Compare dynamics under \( C = 0 \) and \( C > 0 \)
Abandon e-money
\[ \Delta X_t = - (1 - e^{-\Delta k}) X_{t-\Delta} < 0 \]

Adopt e-money
\[ \Delta X_t = (1 - e^{-\Delta k}) (1 - X_{t-\Delta}) > 0 \]

no complementarities \((C = 0)\)
Abandon e-money
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Adopt e-money
\[ \Delta X_t = (1 - e^{-\Delta k}) (1 - X_{t-\Delta}) > 0 \]

no complementarities \((C = 0)\)
no endogenous persistence
complementarities \((C > 0)\)

\[
\Delta X_t = - (1 - e^{-\Delta k}) X_{t-\Delta} < 0
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\[
\Delta X_t = (1 - e^{-\Delta k}) (1 - X_{t-\Delta}) > 0
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complementarities ($C > 0$) persistent increase in total users $X_t$

new users $\Delta X_t$
complementarities ($C > 0$)

state-dependence

Abandon e-money
$\Delta X_t = -(1 - e^{-\Delta k}) X_{t-\Delta} < 0$

Adopt e-money
$\Delta X_t = (1 - e^{-\Delta k})(1 - X_{t-\Delta}) > 0$
Testable predictions

With complementarities:

(a) persistent increase in total users

(b) persistent increase in new users

(c) state-dependence
Testable predictions

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With fixed costs: (a), but not (b) or (c)
Testable predictions

With complementarities:

(a) persistent increase in total users
(b) persistent increase in new users
(c) state-dependence

With fixed costs: (a), but not (b) or (c)

Next: test (a)-(c) using district- and firm-level data
3. Reduced-form evidence
Chest banks

- Want causal impact of cash contraction on SR and LR adoption
Chest banks

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- Use geographic variation in market share of *chest banks*
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  commercial banks handling cash distribution within districts
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  larger market share $\implies$ new cash circulated faster
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- Share of deposits at chest banks in district $d \equiv \text{Chest}_d$
Chest banks

- Want causal impact of cash contraction on SR and LR adoption

- Use geographic variation in market share of *chest banks*
  commercial banks handling cash distribution within districts
  larger market share $\Rightarrow$ new cash circulated faster

- Share of deposits at chest banks in district $d \equiv \text{Chest}_d$

- Exposure$_d = 1 - \text{Chest}_d$
Validation
Main specification

\[ \log (y_{d,t}) = \alpha_t + \alpha_d + \delta_t \text{(Exposure)}_d + \Gamma'_t Y_d + \epsilon_{d,t} \]

\( d \): district

\( t \): month (May 2016 to June 2017)

\( Y_d \): district covariates (conditionally balanced)

s.e. clustered by district
Total firms on the platform

Effect on # of active firms

Time
New firms on the platform
Robustness
Robustness

Demand story?
- higher exposure $\rightarrow$ lower consumption

Influential regions?
- one-state out

Placebo using consumption
State-dependence

Within district

Districts with larger pre-shock user base respond more.

Table

Between districts

Stronger effects for districts close to a large electronic payment hub?

\[ d = \min \text{distance to the 5 largest pre-shock hubs} \]

\[ X_d, s, t = \alpha_{st} + \alpha_d + \delta_t (D_d \times 1_{\{t \geq t_0\}}) + \gamma_t (\tilde{D}_d, s \times 1_{\{t \geq t_0\}}) + \Gamma' t Y_d + \epsilon_d, t \]
State-dependence

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Total firms on the platform

Effect on # of active firms

Time

-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8

-3 -2 -1 0 1 2 3 4 5 6 7 8
Summary

Reduced-form evidence shows:

(a) temporary shock $\rightarrow$ increase in total platform users

(b) temporary shock $\rightarrow$ increase in new platform users

(c) state-dependence
Summary

Reduced-form evidence shows:

(a) temporary shock $\rightarrow$ increase in total platform users

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Qualitatively consistent with complementarities, but quantitative role?
4. Estimation and counterfactuals
Estimation and results

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- Estimate $C$ and other structural parameters using SMM

$C$ identified using average cumulative change in $X_t$ after Feb 17

$S = \frac{24.6\%}{6 \text{ s.d.}} \times \text{G.E. estimates of Chodorow-Reich et al. (2018)}$
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  3.0% lower profits if $X = 0$, 3.3% higher if $X = 1$
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- Short-run decline in cash-based revenue: $S = 24.6\%$ or 6 s.d.

  3× of G.E. estimates of Chodorow-Reich et al. (2018)
Average change in adoption relative to October 2016 ($E_{t_0} [\Delta_{t_0} X_{d,t}]$)

- **Data**
- **Baseline**
- **Counterfactual: no complementarities**


(%)

0 1 2 3 4 5 6 7 8
Counterfactuals

Short-lived shocks $\Rightarrow$ state-dependence $\Rightarrow$ more dispersion

$$\text{arg max}_{S, \theta} E_{t=0} \left[ \Delta_{t=0} X_d, t_0 + T \right] - g_2 \text{var}_{t=0} \left[ \Delta_{t=0} X_d, t_0 + T \right] \text{s.t.} B(S, \theta) \leq B(\hat{S}, \theta_0)$$

Baseline Alternative policy interventions $g = 0$ $g = 0.1$ $g = 0.25$ $g = 0.5$

Shock size (p.p.) 24.56, 21.00, 18.31, 16.81, 14.22

Shock HL (months) 0.82, 1.05, 1.29, 1.37, 1.55

$E[\Delta X_d]$ (p.p.) 7.22, 8.34, 8.32, 8.23, 7.82

$sd[\Delta X_d]$ (p.p.) 26.42, 36.66, 34.64, 28.67, 24.81
Counterfactuals

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$$\arg \max_{S, \theta} \quad \mathbb{E}_{t_0} [\Delta_{t_0} X_{d, t_0+T}] - \frac{g}{2} \text{var}_{t_0} [\Delta_{t_0} X_{d, t_0+T}] \quad \text{s.t.} \quad B(S, \theta) \leq B(\hat{S}, \theta_0)$$
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$$B(S, \theta) = \text{NPV of } M^c - M_t$$
Counterfactuals

Short-lived shocks \( \implies \) state-dependence \( \implies \) more dispersion

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### Baseline vs. Alternative policy interventions

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Take-aways

1. About 60% of the LR response of adoption due to complementarities

2. Smaller, more persistent shock would have led to:
   - higher average adoption increase
   - less dispersion in LR adoption rates across districts
5. Conclusion
Conclusion

1. Are coordination problems an obstacle to Fintech adoption?

2. Can policy interventions help?
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   In the case of the Demonetization: they account for 60% of adoption response

2. Can policy interventions help?
Conclusion

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   yes; large, temporary shocks → persistent increase in adoption
Conclusion

1. Are coordination problems an obstacle to Fintech adoption?

   In the case of the Demonetization: they account for 60% of adoption response

2. Can policy interventions help?

   yes; large, temporary shocks → persistent increase in adoption
   but temporary shocks also exacerbate initial adoption differences
Appendix
Dynamics of the number of users

\[ X_t = \int_{i \in [0,1]} 1 \{ x_{i,t} = e \} \, di \]  
(number of firms using \( e \))
Dynamics of the number of users

\[ X_t = \int_{i \in [0,1]} 1 \{x_{i,t} = e\} \, di \quad \text{(number of firms using } e) \]

\[ \Delta X_t = \]
Dynamics of the number of users

\[ X_t = \int_{i \in [0,1]} 1 \{ x_{i,t} = e \} \, di \quad \text{(number of firms using e)} \]

\[ \Delta X_t = (1 - e^{-k\Delta}) (1 - X_{t-\Delta}) 1 \{ x(c, B_{t-\Delta}) = e \} \]

\[ \text{switchers (c \rightarrow e)} \]
Dynamics of the number of users

\[ X_t = \int_{i \in [0,1]} 1 \{x_{i,t} = e\} \, di \quad \text{(number of firms using } e) \]

\[ \Delta X_t = \left(1 - e^{-k\Delta}\right) (1 - X_{t-\Delta}) 1 \{x(c, B_{t-\Delta}) = e\} - \left(1 - e^{-k\Delta}\right) X_{t-\Delta} 1 \{x(e, B_{t-\Delta}) = c\} \]

- **Switchers (c \rightarrow e)**
- **Switchers (e \rightarrow c)**
Solution

Fixed costs

Must pay $\kappa > 0$ to switch from $c$ to $e$

Technology choice

$$x(x_i,t-\Delta, B_{t-\Delta}) = \begin{cases} 
    c & \text{if } B_{t-\Delta} \leq 0 \\
    x_{i,t-\Delta} & \text{if } B_{t-\Delta} \in [0, \kappa] \\
    e & \text{if } B_{t-\Delta} > \kappa
\end{cases}$$

where $B_t$ = relative value of operating under $e$ vs. $c$.

Equilibrium

switch to $e$ $\iff$ $B_{t-\Delta} > \kappa$ $\iff$ $M_{t-\Delta} < \Phi(X_{t-\Delta})$

switch to $c$ $\iff$ $B_{t-\Delta} < 0$ $\iff$ $M_{t-\Delta} > \Phi(X_{t-\Delta})$ $($>$\Phi(X_{t-\Delta}))$
Fixed costs

\[ \Delta X_t = -(1 - e^{-\Delta t})X_{t-\Delta} < 0 \]

Adoption of paper money

\[ \Delta X_t = (1 - e^{-\Delta t}) (1 - X_{t-\Delta}) > 0 \]

Adoption of electronic money

\[ M_t = M \]

Inaction

\[ \Delta X_t = 0 \]

\[ M^c \]

Fraction of users (\(X_{t-\Delta}\))

Shock (\(M_{t-\Delta}\))

Back to testable predictions
Fixed costs

Number of e-money users $\mathbb{E}_t[X_{d,t}]$

Adoption decision

Back to testable predictions
Fixed costs
Mean quarterly growth in bank deposits

<table>
<thead>
<tr>
<th>Time</th>
<th>Annual % change in deposits</th>
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<tbody>
<tr>
<td>-15</td>
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</tr>
<tr>
<td>-10</td>
<td>-10</td>
</tr>
<tr>
<td>-5</td>
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</tr>
<tr>
<td>0</td>
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Therefore, the shock led to a significant but temporary cash-crunch;
- Cash in circulation re-started to grow already in January;
- The Government removed all the cash withdrawal conditions already on January 31st.
### Exposure validation

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<th>( \Delta \log(\text{deposits}) )</th>
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<td></td>
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<td>(3)</td>
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<td>Chest Exposure</td>
<td>0.094***</td>
<td>0.083***</td>
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</tr>
<tr>
<td></td>
<td>[0.013]</td>
<td>[0.012]</td>
<td>[0.013]</td>
</tr>
<tr>
<td>log(Pre Deposits)</td>
<td>-0.035***</td>
<td>-0.035***</td>
<td>-0.677**</td>
</tr>
<tr>
<td></td>
<td>[0.003]</td>
<td>[0.003]</td>
<td></td>
</tr>
<tr>
<td>% villages with ATM</td>
<td>0.023</td>
<td>0.020</td>
<td></td>
</tr>
<tr>
<td></td>
<td>[0.040]</td>
<td>[0.042]</td>
<td></td>
</tr>
<tr>
<td>% villages with banks</td>
<td>-0.051**</td>
<td>-0.051**</td>
<td>-1.000**</td>
</tr>
<tr>
<td></td>
<td>[0.023]</td>
<td>[0.024]</td>
<td></td>
</tr>
<tr>
<td>Rural Pop./Total Pop.</td>
<td>-0.063***</td>
<td>-0.070***</td>
<td>-1.224**</td>
</tr>
<tr>
<td></td>
<td>[0.016]</td>
<td>[0.017]</td>
<td></td>
</tr>
<tr>
<td>log(population)</td>
<td>0.036***</td>
<td>0.035***</td>
<td>0.707**</td>
</tr>
<tr>
<td></td>
<td>[0.003]</td>
<td>[0.003]</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>512</td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.118</td>
<td>0.313</td>
<td>0.099</td>
</tr>
<tr>
<td>District Controls</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes: Standard errors clustered at district level in brackets. *** p < 0.01, ** p < 0.05, * p < 0.1.
### Exposure validation

<table>
<thead>
<tr>
<th></th>
<th>(1) 201604</th>
<th>(2) 201603</th>
<th>(3) 201602</th>
<th>(4) 201601</th>
<th>(5) 201504</th>
<th>(6) 201503</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Exposure)$_d$</td>
<td>1.621***</td>
<td>-0.404</td>
<td>0.476**</td>
<td>0.137</td>
<td>0.163</td>
<td>0.342</td>
</tr>
<tr>
<td></td>
<td>[0.238]</td>
<td>[0.260]</td>
<td>[0.236]</td>
<td>[0.234]</td>
<td>[0.268]</td>
<td>[0.255]</td>
</tr>
<tr>
<td>Observations</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.313</td>
<td>0.027</td>
<td>0.026</td>
<td>0.162</td>
<td>0.020</td>
<td>0.054</td>
</tr>
<tr>
<td>District Controls</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>(7) 201502</th>
<th>(8) 201501</th>
<th>(9) 201404</th>
<th>(10) 201403</th>
<th>(11) 201402</th>
<th>(12) 201401</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Exposure)$_d$</td>
<td>-0.040</td>
<td>0.315</td>
<td>0.345</td>
<td>-0.734***</td>
<td>0.165</td>
<td>0.012</td>
</tr>
<tr>
<td></td>
<td>[0.231]</td>
<td>[0.240]</td>
<td>[0.291]</td>
<td>[0.280]</td>
<td>[0.257]</td>
<td>[0.269]</td>
</tr>
<tr>
<td>Observations</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.044</td>
<td>0.061</td>
<td>0.017</td>
<td>0.037</td>
<td>0.100</td>
<td>0.124</td>
</tr>
</tbody>
</table>

Notes: Standard errors clustered at district level in brackets. *** p < 0.01, ** p < 0.05, * p < 0.1.
<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>mean</th>
<th>univariate OLS</th>
<th>baseline controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>coeff.</td>
<td>R²</td>
</tr>
<tr>
<td>Log(Pre Deposits)</td>
<td>11.083</td>
<td>-1.290***</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.273)</td>
<td></td>
</tr>
<tr>
<td>% villages with ATM</td>
<td>0.036</td>
<td>0.090***</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.023)</td>
<td></td>
</tr>
<tr>
<td># Bank Branches per 1000’s</td>
<td>0.047</td>
<td>0.002</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.012)</td>
<td></td>
</tr>
<tr>
<td># Agri Credit Societies per 1000’s</td>
<td>0.045</td>
<td>-0.016</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.027)</td>
<td></td>
</tr>
<tr>
<td>% villages with banks</td>
<td>0.085</td>
<td>0.131***</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.036)</td>
<td></td>
</tr>
<tr>
<td>Log(Population)</td>
<td>14.376</td>
<td>-0.501**</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.208)</td>
<td></td>
</tr>
<tr>
<td>Literacy rate</td>
<td>0.622</td>
<td>-0.029</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.025)</td>
<td></td>
</tr>
<tr>
<td>Sex Ratio</td>
<td>0.946</td>
<td>0.008</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.015)</td>
<td></td>
</tr>
<tr>
<td>Growth Rate</td>
<td>0.208</td>
<td>-0.219</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.139)</td>
<td></td>
</tr>
<tr>
<td>Working Pop./Total Pop.</td>
<td>0.410</td>
<td>0.026</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.016)</td>
<td></td>
</tr>
</tbody>
</table>
Traditional electronic payments: intensive margin

**Figure 1:** Monthly growth in transaction on debit and credit cards
Traditional electronic payments: extensive margin

**Figure 2:** Monthly growth in application for electronic payments
## Propagation: between-districts

<table>
<thead>
<tr>
<th></th>
<th>log(amount)</th>
<th>log(# transactions)</th>
<th>log(# firms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td></td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
</tr>
<tr>
<td>(Distance to hub) (d \times 1{t \geq t_0} )}</td>
<td>-5.473***</td>
<td>-3.663***</td>
<td>-3.567***</td>
</tr>
<tr>
<td></td>
<td>[0.946]</td>
<td>[1.175]</td>
<td>[0.597]</td>
</tr>
<tr>
<td>Observations</td>
<td>6,846</td>
<td>6,846</td>
<td>6,846</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.848</td>
<td>0.885</td>
<td>0.860</td>
</tr>
<tr>
<td>District Controls × Month f.e.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>State × Month f.e.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes: Standard errors clustered at district level are reported in brackets. Significance level: *** p < 0.01, ** p < 0.05, * p < 0.1.
The model with $\theta < k$

Adoption of paper money
$\Delta X_t = -\left(1 - e^{-\Delta t}\right) X_{t-\Delta} < 0$

Adoption of electronic money
$\Delta X_t = \left(1 - e^{-\Delta t}\right) (1 - X_{t-\Delta}) > 0$
The model with $\theta < k$

- Weaker state-dependence: districts tend to converge to full adoption regardless of initial conditions
Difference-in-differences: Monte-Carlo validation

<table>
<thead>
<tr>
<th></th>
<th>No complementarities ((C = 0))</th>
<th>Complementarities ((C &gt; 0))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1_{{d \in \mathcal{T}}} \times 1_{{t \geq t_0}})</td>
<td>0.116 (0.025,0.208)</td>
<td>0.118 (0.109,0.126)</td>
</tr>
<tr>
<td>Observations per simulation</td>
<td>22,000</td>
<td>22,000</td>
</tr>
<tr>
<td>Average R-sq.</td>
<td>0.389</td>
<td>0.688</td>
</tr>
</tbody>
</table>

\(X_{d,t} = \alpha_d + \beta 1_{\{t \geq t_0\}} + \gamma 1_{\{d \in \mathcal{T}\}} + \delta (1_{\{d \in \mathcal{T}\}} \times 1_{\{t \geq t_0\}}) + \epsilon_{d,t}\)
Difference-in-differences: Monte-Carlo validation

High minus low exposure to the shock - dynamic effects

\[ X_{d,t} = \alpha_d + \beta_t + \delta_t 1_{d \in T} + \epsilon_{d,t} \]
State dependence: Monte-Carlo validation

<table>
<thead>
<tr>
<th>No complementarities ((C = 0))</th>
<th>Complementarities ((C &gt; 0))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1{x_{0,d} \in \hat{x}_0} \times 1{t \geq t_0})</td>
<td>(-0.009) ((-0.017, -0.002))</td>
</tr>
<tr>
<td>Observations per simulation</td>
<td>22,000</td>
</tr>
<tr>
<td>Average R-sq.</td>
<td>0.211</td>
</tr>
</tbody>
</table>

\[
X_{d,t} = \alpha_d + \beta 1\{t \geq t_0\} + \gamma 1\{x_{0,d} \geq \hat{x}_0\} + \delta \left(1\{x_{0,d} \geq \hat{x}_0\} \times 1\{t \geq t_0\}\right) + \epsilon_{d,t}
\]
State dependence: Monte-Carlo validation

\[ X_{d,t} = \alpha_t + \beta_d + \delta_t \mathbf{1}_{\{X_{0,d} \geq \bar{X}_0\}} + \epsilon_{d,t} \]
### State dependence: within district

<table>
<thead>
<tr>
<th>Model</th>
<th>Log(# transactions)</th>
<th>Log(amount)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>$1(t \geq t_0) \times 1(\text{Any adopter}_d)$</td>
<td>2.803***</td>
<td>4.864***</td>
</tr>
<tr>
<td></td>
<td>(0.246)</td>
<td>(0.346)</td>
</tr>
<tr>
<td>$1(t \geq t_0) \times \log(\text{Amount of transactions}_d)$</td>
<td>0.281***</td>
<td>0.230***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.052)</td>
</tr>
<tr>
<td>Month f.e.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>District f.e.</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>District Controls</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Observations</td>
<td>5,780</td>
<td>5,780</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.609</td>
<td>0.603</td>
</tr>
<tr>
<td>Number of districts</td>
<td>578</td>
<td>578</td>
</tr>
</tbody>
</table>

**Notes:** Standard errors clustered at district level are reported in brackets. Significance level: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 

$X_d, t = \alpha t + \alpha d + \delta X_d, t - 1 + \Gamma t Y_d + \epsilon_d, t$. 

Back
State dependence at the firm level: Monte-Carlo validation

<table>
<thead>
<tr>
<th>No complementarities ($C = 0$)</th>
<th>Complementarities ($C &gt; 0$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>0.862</td>
</tr>
<tr>
<td></td>
<td>(0.861, 0.864)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>$-0.175$</td>
</tr>
<tr>
<td></td>
<td>(-0.180, -0.170)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>$-0.016$</td>
</tr>
<tr>
<td></td>
<td>(-0.020, -0.011)</td>
</tr>
<tr>
<td>Observations per simulation</td>
<td>2,100,000</td>
</tr>
<tr>
<td>Average R-sq.</td>
<td>0.754</td>
</tr>
</tbody>
</table>

$x_{i,d,t} = \alpha_i + \rho x_{i,d,t-\Delta} + \beta M_{d,t-\Delta} + \gamma X_{d,t-\Delta} + \epsilon_{i,d,t}$
Map Exposure
Consumption response

Survey-time vs. Effect on total consumption

Rob.
Drop One State

Effect on amount transacted

State excluded from sample
**FIGURE 3:** Evidence from Google Search Trends
State-dependence: firm level

![Graphs showing state-dependence at the firm level](image-url)
Placebo

Effect on Total Consumption

Placebo Survey-time

Chest Bank Exposure

Ideally, we would want to measure for each district:

\[
\text{Chest}_d = \frac{\text{Deposits in the banks with a currency chest in the district}}{\text{Total deposits in all banks in the district}}
\]

Drawback:
- deposit data available at district-bank group level, not district-bank level

Assume:
- deposits uniformly distr. across branches within bank group \(g\) in district \(d\)

\[
\text{Chest}_d = \frac{1}{D_d} \left( \sum_{g \in G_d} \left( D_{gd} \times \frac{N^{\text{chest}}_{gd}}{N^{\text{all}}_{gd}} \right) \right)
\]
### State-dependence: firm level

\[ x_{i,k,p,t} = \log(\# \text{ transactions})_{i,k,p,t} \]

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_{i,k,p,t} - 1 )</td>
<td>0.707***</td>
<td>0.617***</td>
<td>0.593***</td>
<td>0.577***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>( X_{k,p,t} - 1 )</td>
<td>0.032***</td>
<td>0.062***</td>
<td>0.041***</td>
<td>0.017***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>R²</td>
<td>0.549</td>
<td>0.574</td>
<td>0.601</td>
<td>0.606</td>
</tr>
<tr>
<td>Firm f.e.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Industry × Week f.e.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Pincode × Week f.e.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Observations</td>
<td>11,750,558</td>
<td>11,750,558</td>
<td>11,541,757</td>
<td>11,541,757</td>
</tr>
</tbody>
</table>

**Notes:** Standard errors clustered at district level are reported in brackets. Significance level: *** p < 0.01, ** p < 0.05, * p < 0.1.
\( C = 0, \kappa > 0 \) (pure fixed costs): no increase in switchers

- Permanent increase in the number of users
- Transitory increase in the number of switchers
$C = 0, \kappa > 0$ (pure fixed costs): adoption policies

Adoption policy is independent of $X_t - X_{t-\Delta} < 0$.

$\Delta X_t = -\left(1 - e^{-\kappa}\right) X_{t-\Delta} < 0$
Expression for $B$

$$B(M_{t-\Delta}, X_{t-\Delta}) = \text{value of using } e - \text{value of using } c$$

$$= \mathbb{E}_{t-\Delta} \left[ (\Pi_t^e - \Pi_t^c) \Delta + e^{-(r+k)\Delta} B(M_t, X_t) \right]$$
Expression for $B$

\[
B(M_t-\Delta, X_t-\Delta) = \text{value of using } e - \text{value of using } c = E_t-\Delta \left[ (\Pi_t^e - \Pi_t^c) \Delta + e^{-(r+k)\Delta} B(M_t, X_t) \right] + e^{-r\Delta} \left( 1 - e^{-k\Delta} \right) E_t-\Delta \left[ g(B(M_t, X_t)) \right]
\]

\[
g(B) = \max(0, \min(B, \kappa))
\]
Estimation methodology

Objective function:

\[
\hat{\Theta} = \arg\min \left( \hat{\Xi} - \frac{1}{S} \sum_{s=1}^{S} \Xi_{\text{sim}} (\Theta; \gamma_s) \right) \prime W \left( \hat{\Xi} - \frac{1}{S} \sum_{s=1}^{S} \Xi_{\text{sim}} (\Theta; \gamma_s) \right),
\]

where \( \hat{\Xi} = (\hat{\beta}, \hat{\gamma}, \hat{\delta}, \hat{\zeta}, \hat{\xi}, \hat{\eta}, \hat{\kappa}, \hat{\nu}) \).

Use the optimal weighting matrix:

\[
W = \frac{1}{N_m} \text{var} \left( \hat{\Xi} \right)^{-1},
\]

with \( \text{var} \left( \hat{\Xi} \right) \) estimated using the bootstrap, clustering by district:

\[
\text{var} \left( \hat{\Xi} \right) = \frac{1}{B-1} \sum_{b=1}^{B} \left( \hat{\Xi}_b - \hat{\Xi} \right) \prime \left( \hat{\Xi}_b - \hat{\Xi} \right).
\]
## Model fit

<table>
<thead>
<tr>
<th>Moment</th>
<th>Emp. val.</th>
<th>Sim. val.</th>
<th>Std. error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\hat{\beta}$</td>
<td>0.030</td>
<td>0.032</td>
<td>0.004</td>
<td>0.32</td>
</tr>
<tr>
<td>$\hat{\gamma}$</td>
<td>0.038</td>
<td>0.035</td>
<td>0.003</td>
<td>0.06</td>
</tr>
<tr>
<td>$\hat{\delta}$</td>
<td>0.081</td>
<td>0.080</td>
<td>0.005</td>
<td>0.40</td>
</tr>
<tr>
<td>$\hat{\zeta}$</td>
<td>0.027</td>
<td>0.007</td>
<td>0.004</td>
<td>0.00</td>
</tr>
<tr>
<td>$\hat{\xi}$</td>
<td>0.083</td>
<td>0.093</td>
<td>0.004</td>
<td>0.02</td>
</tr>
<tr>
<td>$\hat{\eta}$</td>
<td>0.098</td>
<td>0.096</td>
<td>0.004</td>
<td>0.26</td>
</tr>
<tr>
<td>$\hat{\kappa}$</td>
<td>0.102</td>
<td>0.092</td>
<td>0.007</td>
<td>0.08</td>
</tr>
<tr>
<td>$\hat{\zeta}$</td>
<td>0.045</td>
<td>0.050</td>
<td>0.003</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OID stat</th>
<th>Degrees of freedom</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7076</td>
<td>3</td>
<td>0.1945</td>
</tr>
</tbody>
</table>
Estimation

5 structural parameters

C  Strength of complementarities
k  Speed of technology adjustment
S  Size of aggregate shock
Me Returns to electronic payments with no adoption
σ  Volatility of idiosyncratic innovations
Estimation

5 structural parameters

- $C$  Strength of complementarities
- $k$  Speed of technology adjustment
- $S$  Size of aggregate shock
- $M^e$ Returns to electronic payments with no adoption
- $\sigma$ Volatility of idiosyncratic innovations

8 data moments

\[ \Delta_{t_0} X_{d,t} = \beta + \gamma 1 \{ t \geq t_0 + 3 \} + \delta X_{d,t_0} + \zeta (1 \{ t \geq t_0 + 3 \} \times X_{d,t_0}) + \epsilon_{d,t}, \]

\[ \hat{\text{var}}_t (\Delta_{t_0} X_{d,t}) = \eta + \kappa 1 \{ t \geq t_0 + 3 \} + \mu_t, \]

\[ \hat{\text{var}}_d (\Delta_{t_0} X_{d,t}) = \nu + \omega_d, \quad \hat{\epsilon}_{d,t}^2 = \xi + \omega_{d,t}. \]
Estimation

5 structural parameters

\[ C \quad \text{Strength of complementarities} \quad \rightarrow \gamma \]
\[ k \quad \text{Speed of technology adjustment} \]
\[ S \quad \text{Size of aggregate shock} \]
\[ M_e \quad \text{Returns to electronic payments with no adoption} \]
\[ \sigma \quad \text{Volatility of idiosyncratic innovations} \]

8 data moments

\[ \Delta_{t_0}X_{d,t} = \beta + \gamma 1 \{ t \geq t_0 + 3 \} + \delta X_{d,t_0} + \zeta (1 \{ t \geq t_0 + 3 \} \times X_{d,t_0}) + \epsilon_{d,t}, \]
\[ \hat{\text{var}}_i(\Delta_{t_0}X_{d,t}) = \eta + \kappa 1 \{ t \geq t_0 + 3 \} + \mu_t, \]
\[ \hat{\text{var}}_d(\Delta_{t_0}X_{d,t}) = \nu + \omega_d, \quad \hat{\epsilon}_{d,t}^2 = \xi + \omega_{d,t}. \]
Estimation

5 structural parameters

\begin{align*}
C & \quad \text{Strength of complementarities} \\
k & \quad \text{Speed of technology adjustment} \\
S & \quad \text{Size of aggregate shock} \\
M^e & \quad \text{Returns to electronic payments with no adoption} \\
\sigma & \quad \text{Volatility of idiosyncratic innovations}
\end{align*}

8 data moments

\begin{align*}
\Delta_{t_0}X_{d,t} &= \beta + \gamma 1 \{t \geq t_0 + 3\} + \delta X_{d,t_0} + \zeta (1 \{t \geq t_0 + 3\} \times X_{d,t_0}) + \epsilon_{d,t}, \\
\hat{\text{var}}_t(\Delta_{t_0}X_{d,t}) &= \eta + \kappa 1 \{t \geq t_0 + 3\} + \mu_t, \\
\hat{\text{var}}_d(\Delta_{t_0}X_{d,t}) &= \nu + \omega_d, \quad \hat{\epsilon}^2_{d,t} = \xi + \omega_{d,t}.
\end{align*}
Estimation

5 structural parameters

- \( C \): Strength of complementarities \( \rightarrow \gamma \)
- \( k \): Speed of technology adjustment \( \rightarrow \kappa \)
- \( S \): Size of aggregate shock \( \rightarrow \beta \)
- \( M^e \): Returns to electronic payments with no adoption \( \rightarrow \nu \)
- \( \sigma \): Volatility of idiosyncratic innovations \( \rightarrow \xi \)

8 data moments

\[
\Delta_{t_0}X_{d,t} = \beta + \gamma 1 \{ t \geq t_0 + 3 \} + \delta X_{d,t_0} + \zeta (1 \{ t \geq t_0 + 3 \} \times X_{d,t_0}) + \epsilon_{d,t},
\]

\[
\hat{\text{var}}_i(\Delta_{t_0}X_{d,t}) = \eta + \kappa 1 \{ t \geq t_0 + 3 \} + \mu_t,
\]

\[
\hat{\text{var}}_d(\Delta_{t_0}X_{d,t}) = \nu + \omega_d, \quad \hat{\epsilon}_{d,t}^2 = \xi + \omega_{d,t}.
\]