”Strategic Complementarities in a Dynamic Model of Technology Adoption”

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Discussion by Nicolas Crouzet

Kellogg

Overview: the adoption of network technologies

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Step 1: Model of technology adoption with strategic complementarities

Decentralized equilibrium + optimal planning problem

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Step 1: Model of technology adoption with strategic complementarities

Decentralized equilibrium + optimal planning problem

Step 2: Data on digital payment app in Costa-Rica

Can observe adoption *within social networks* (neighborhood, coworkers, family)

Roadmap

1. The adoption of digital payments in India

2. The model

3. Mapping the model to the data

1. The adoption of digital payments in India

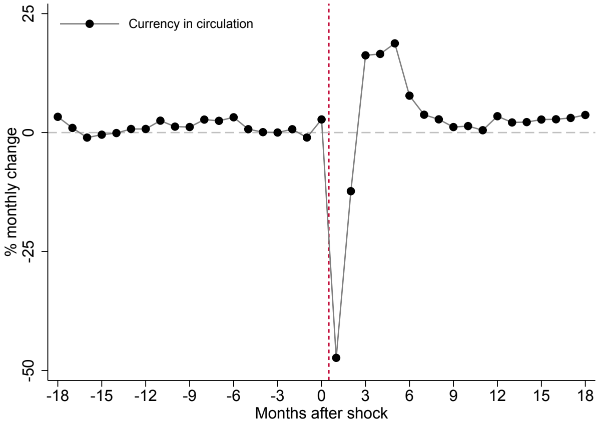
Context: the 2016 Indian Demonetization

Cash shortage

- unexpected
- large
- temporary

Adoption of an electronic wallet

- B2C transactions



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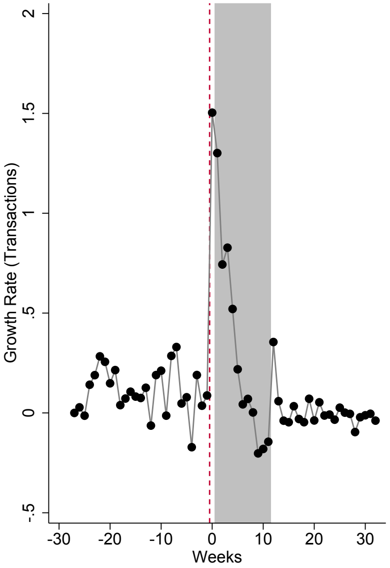


Model

Firm $i \in [0, 1]$:

$$\pi_{i,t} = \begin{cases} M_t & \text{if} \quad x_{i,t} = c & \text{(cash)} \\ \theta_0 + \theta_n N_t & \text{if} \quad x_{i,t} = e & \text{(e-wallet)} \end{cases}$$

M_t cash-based demand; exogenous, AR

$$N_t = \int \mathbf{1}\{x_{i,t} = e\}\, di = \text{number of adopters}$$

Firm i chooses a switching rate $c \leftrightarrow e$, $\tilde{k}_{i,t} \in [0, k]$, to maximize NPV of $\pi_{i,t}$

subject to law of motion for (M_t, N_t)

Adoption rules

<u>Equilibrium:</u> aggregate law of motion for N_t $\rightleftarrows$ optimal switching rate $\tilde{k}_{i,t}$

Result: *The equilibrium exists and is unique. Firms switch $c \rightarrow e$ at max rate k, if and only if:*

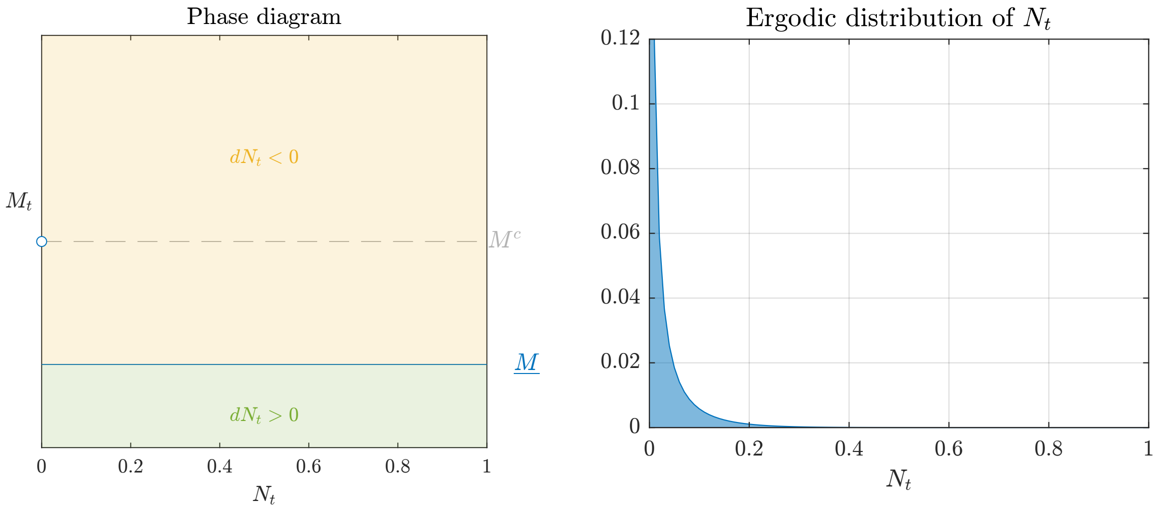
$$M_t \leq \underline{\mathbf{M}}(N_t; \theta_n),$$

where:

$$\theta_n = 0: \quad \underline{\mathbf{M}}(N_t; \theta_n) = \underline{M},$$

$$\theta_n > 0: \quad \underline{\mathbf{M}}(\underset{+}{N_t}; \theta_n).$$

Testing for complementarities: endogenous persistence



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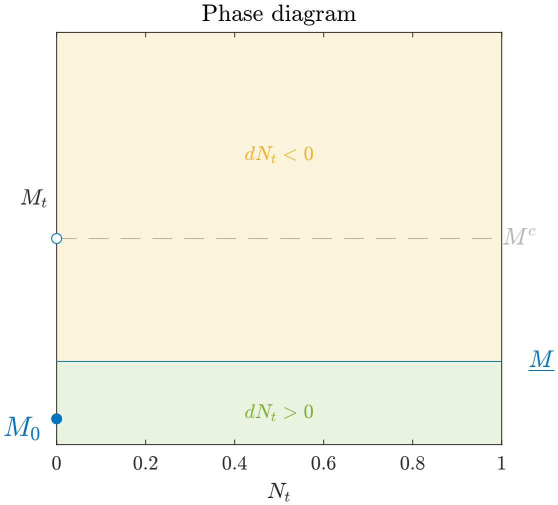

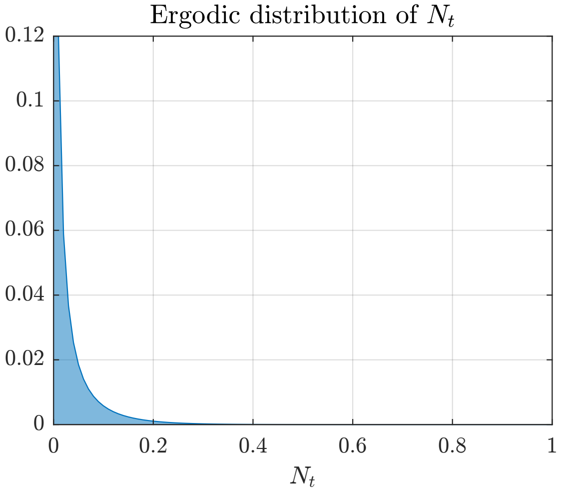

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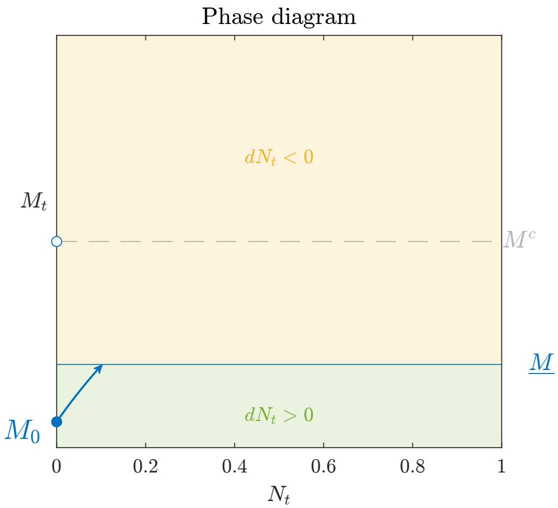

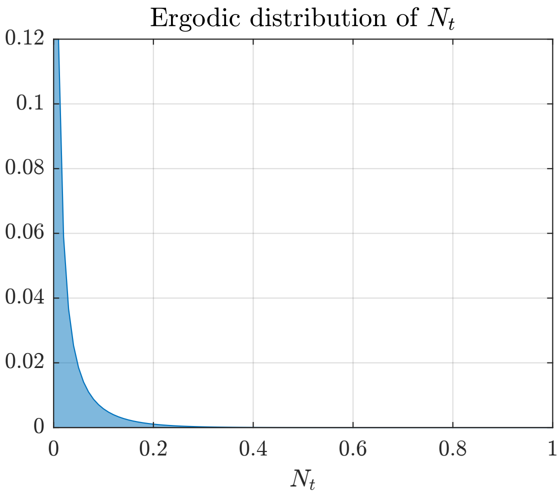

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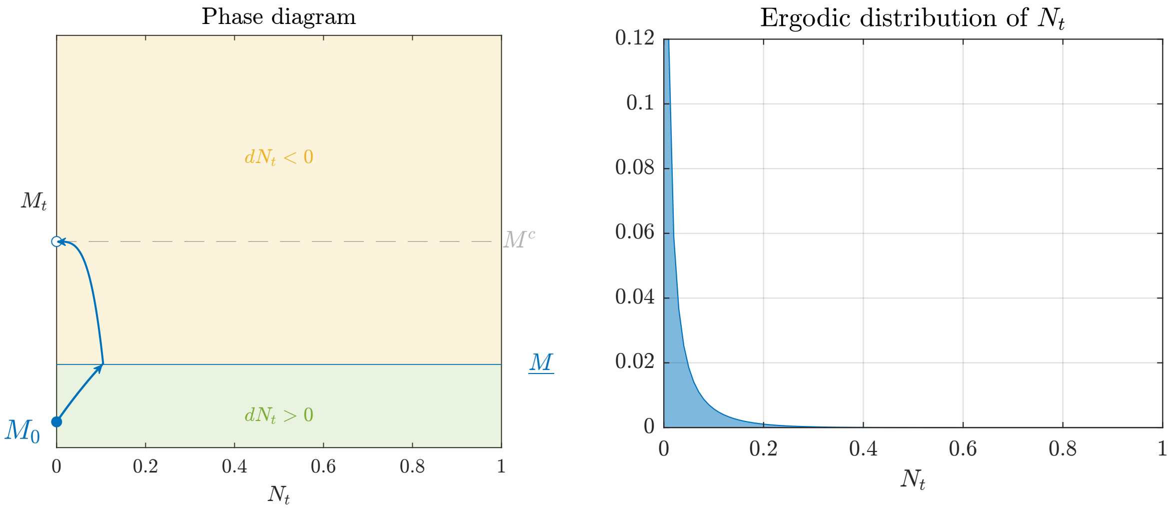

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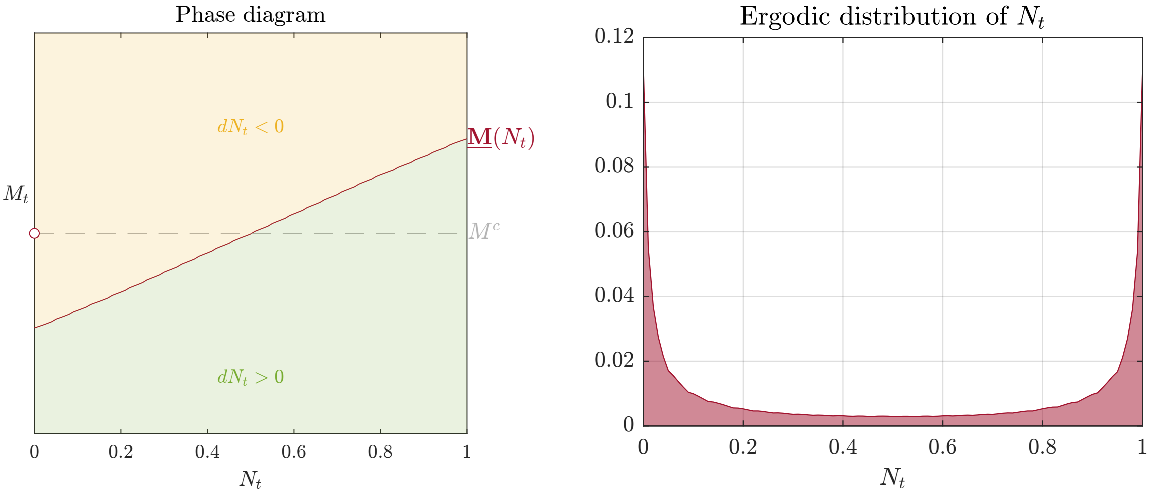

Complementarities ($\theta_n > 0$)

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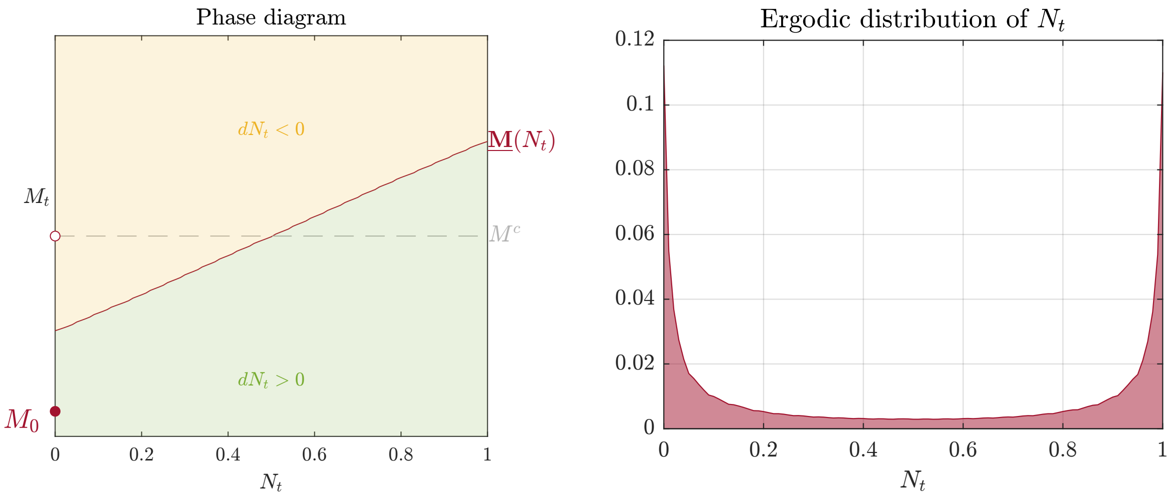

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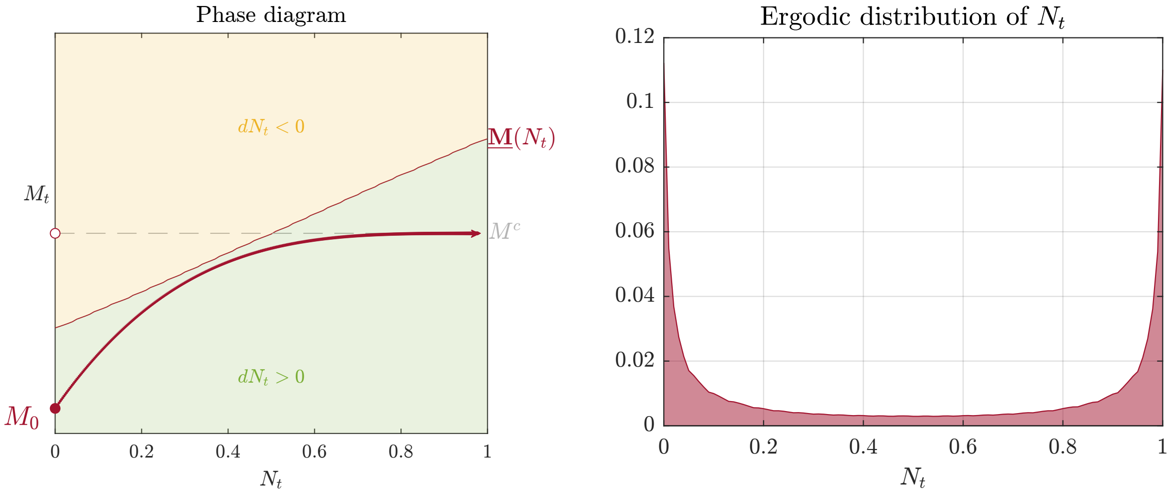

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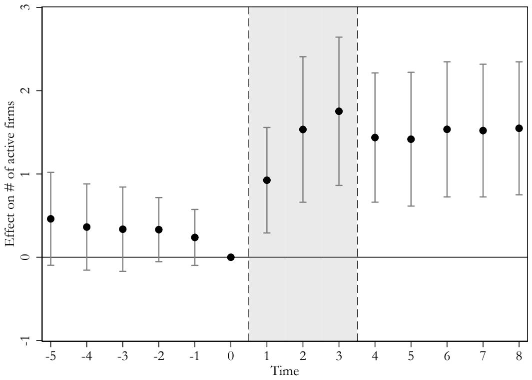
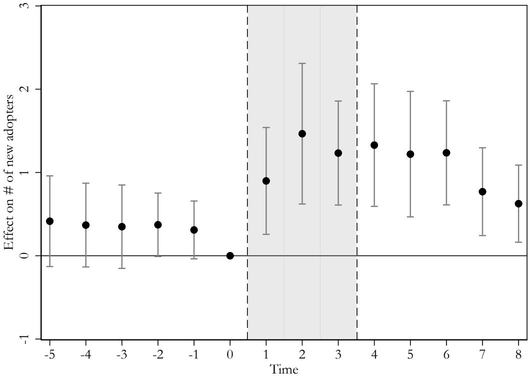


District d, quarter t

$$\log\left(y_{d,t}\right) = \alpha_t + \alpha_d + \delta_t (\text{Exposure})_d + \Gamma_t' Y_d + \epsilon_{d,t}$$

$y_{d,t}$: total # of active firms

Testing for complementarities: endogenous persistence



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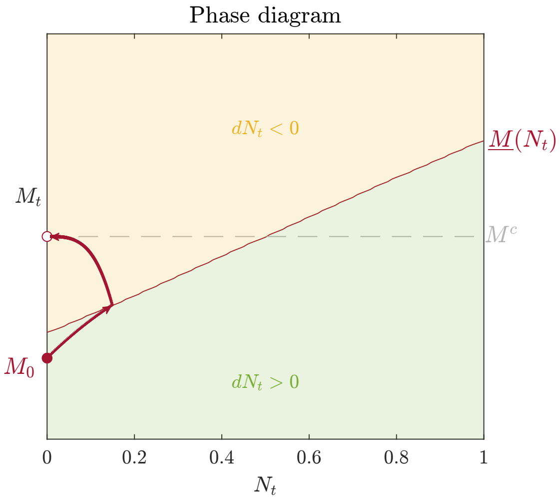
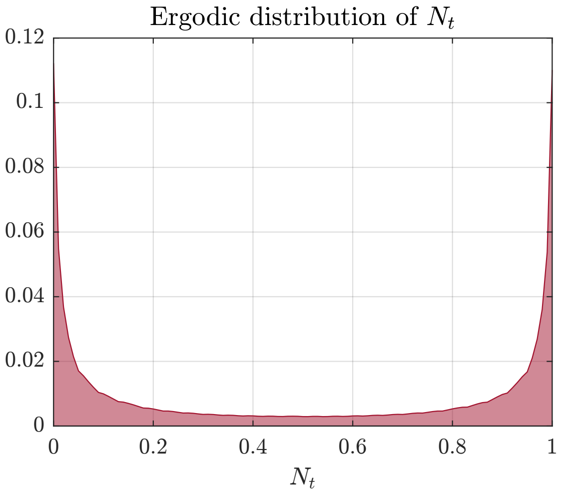
$y_{d,t}$: # of newly active firms

Testing for complementarities: state-dependence





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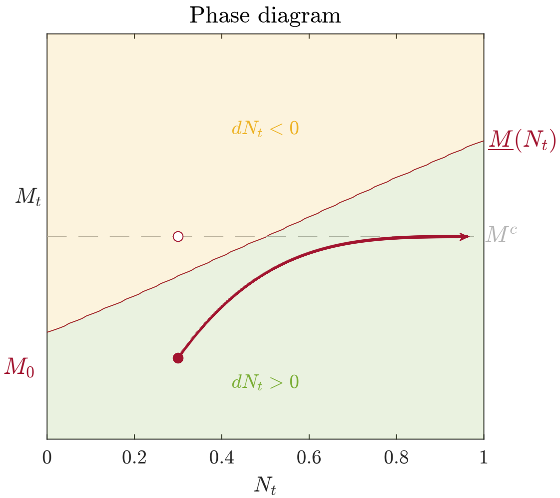

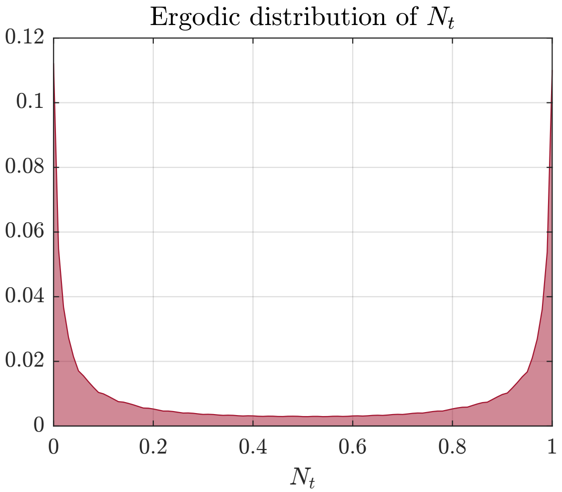

Complementarities ($\theta_n > 0$)

Key take-aways

In our setting

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Beyond our setting

Dynamic tests for strategic complementarities

- endogenous persistence
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$\theta_n > 0$; accounts for $\sim 1/2$ of adoption response

Beyond our setting

- Dynamic tests for strategic complementarities
  - endogenous persistence
  - positive state-dependence
- The limits of a "big push"
  - persistent increase in average adoption across networks
  - *at the cost of* more dispersion

2. The model

Comparing the models

		This paper	CGM
Flow benefits	No adoption	0	M_t
	Adoption	$x_{i,t}\,(\theta_0 + \theta_n N_t)$	$\theta_0 + \theta_n N_t$
Lock-in after adoption		Yes	No
Friction		Fixed cost c	Switching intensity $\tilde{k}_{i,t} \leq k$

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Which of these differences is economically important?

This paper : only idiosyncratic shocks

CGM : only aggregate shocks

Does aggregate risk matter for understanding technology adoption?

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"Phase shifts"

- Sudden adoption of "dormant" technology
- Sudden discarding of "dominant" technology

Aggregate risk *can* generate this

Idiosyncratic risk generates gradual and permanent diffusion

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- See global games
- But maybe not necessary: Alvarez, Lippi, Souganidis (2022) establish unicity in a closely related model

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Important for counterfactuals and policy analysis

Combining aggregate and idiosyncratic risk

CGM

As M_t crosses $\underline{\mathbf{M}}(N_t; \theta_n)$, mass kdt of firms change adoption decisions at once — "phase shift"

$\implies$ drift of N_t is a discontinuous function of M_t

This paper

Mass of firms revising their adoption decision remains small — no "phase shift"

Distribution of adopters follows a standard KFE

Combining the two

If sufficiently large idiosyncratic shocks, N_t might become a standard diffusive process

$$\underbrace{\text{Phase shifts } + \text{unicity}}_{\text{CGM}} + \underbrace{\text{tractability}}_{\text{this paper}}$$

3. Mapping the model to the data

Measuring strategic complementarities

Model

$$\log(\xi_{i,t}) = \tfrac{1}{1+p} \log\left(\theta_0 + \theta_n N_t\right) + \tfrac{1}{1+p} \log(x_{i,t}) \quad (1)$$

Data

$$\Delta \log(\xi_{i,t}) = \lambda_t + \psi \Delta S_{i,t} + \tilde{\theta} \Delta N_{i,t} + \varepsilon_{i,t} \quad (2)$$

$S_{i,t}$ = # of people in i's social network

$N_{i,t}$ = % of people in i's social network using the app

$\theta_n \overset{?}{\leftrightarrow} \tilde{\theta}$

The reflection problem [Manski, 1993]

Model

$$\log(\xi_i) = \theta_n N_i + \gamma \, \text{age}_i + \varepsilon_i$$

$$N_i = \mathbb{E}\left[\log(\xi_j) | i\text{'s network, age}_i\right]$$

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Do mass layoff regressions address this problem?

Choice of new firm might be driven by correlated characteristics among coworkers

Estimating the model

Model is calibrated

- $\theta_n \approx \tilde{\theta}$ + match median neighborhood adoption path
- Resulting model $\approx$ typical neighborhood

Could instead fit the distribution of adoption across neighborhoods: $\mathbb{E}_t(N_{n,t}), \sigma_t(N_{n,t}), \ldots$

- Need neighborhood fixed effects in the model; can use $N_{n,0}$, $\theta_0^{(n)}$, $U^{(n)}$
- Useful to tackle policy questions about *aggregate* adoption

Calibrated model $=$ complementarities + learning

- What identifies the learning component?
  - i.e. what features of the data does the complementarities-only model fail to match?

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What more is there to do?

Where is $\theta_n > 0$ coming from?

Two-sided markets [Jullien, Pavan, Rysman, 2021]

Social learning [Akbarpour, Malladi, Saberi, 2020]

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What are the broader implications of $\theta_n > 0$?

- Spillovers to consumption, investment [Higgins, 2022]
- Competition, concentration, regulation