Technology Adoption and Leapfrogging: Racing for Mobile Payments

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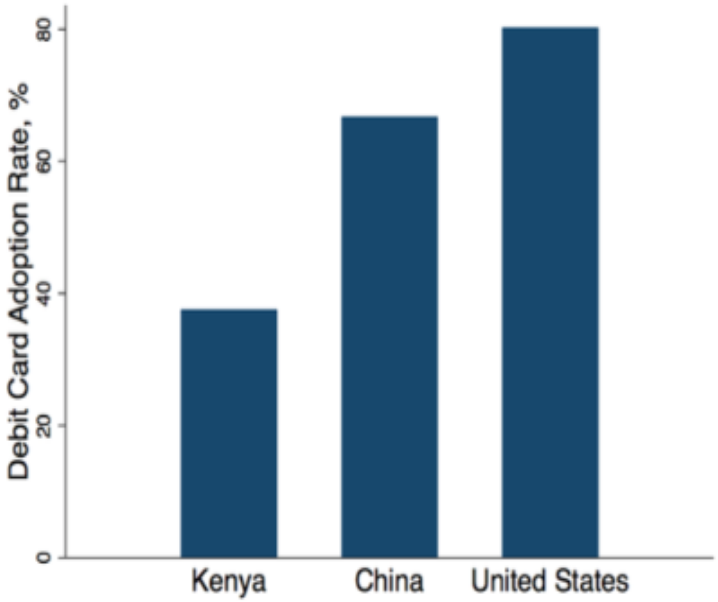
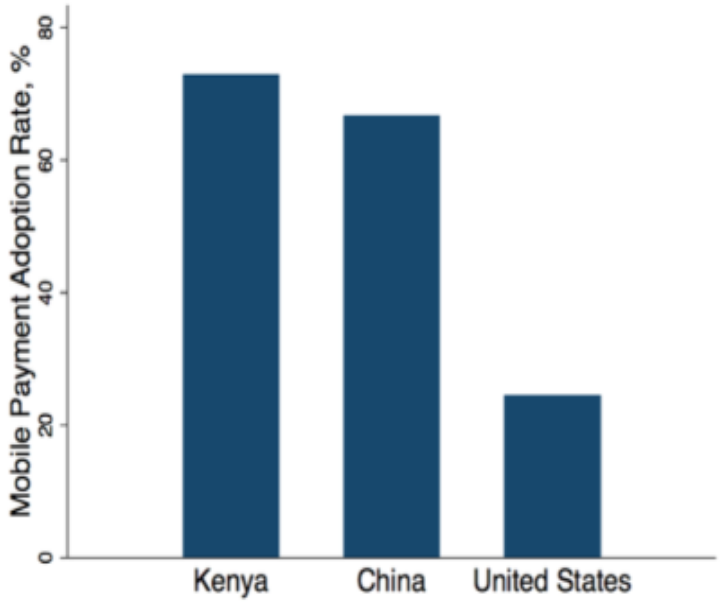
Motivation

- The U.S. has fallen behind in adopting mobile payments.



(A) Card Payment Adoption Rate



(B) Mobile Payment Adoption Rate

Research & Policy Questions

- How have mobile payments been adopted in other countries?
- Why did some developing countries leapfrog in adopting mobile payments?
- Have advanced economies lost their leadership in payments?
- What government policies should be considered to facilitate mobile payment development?

Analysis and Findings

- We compile a novel dataset to compare cross-country adoption patterns of card and mobile payments.
  - Leapfrogging in mobile payment adoption is a common pattern.
  - Unlike card, mobile payment adoption shows a non-monotonic relationship with per capita income.
  - Advanced economies favor mobile payments complementary to cards, while developing countries favor those substituting cards.

Analysis and Findings (Cont'd)

- We construct a theory to explain cross-country adoption patterns.
  - Payment technologies (cash, card, mobile) arrive sequentially.
  - Newer payment technologies lower variable costs of conducting payment transactions, but they require a fixed cost to adopt.
  - Rich consumers (countries) enjoy adopting card payments early on, but their sunk investment on card hinders mobile adoption.
  - Card-intensive (cash-intensive) countries favor mobile payments complementing (substituting) cards.

Analysis and Findings (Cont'd)

- Our estimated model matches cross-country adoption patterns of card and mobile payments well, and yields welfare and policy implications.
  - Falling behind in mobile payment adoption does not necessarily mean falling behind in overall payment efficiency.
  - Lagging adoption in rich countries is because the incremental benefit of switching from card to mobile is not large enough.
  - Greater technological advances are needed for advanced economies to catch up in the mobile payment race.
  - Policy interventions require prudent social cost-benefit analysis.

Related Literature

- *IO theories on payments system*
- *Empirical studies on payment adoption*
- *Rise of digital payment and fintechs*
- *Technology diffusion and financial development*

Outline

- Introduction
- Background and stylized facts
- An estimated model
- Welfare and policy analysis
- Further discussions
- Conclusion

Mobile Payment

- **Definition**: A mobile payment is a money payment through a mobile phone, regardless of whether the phone actually accesses the mobile network to make the payment (Crowe et al. 2010).

Two Mobile Payment Technologies

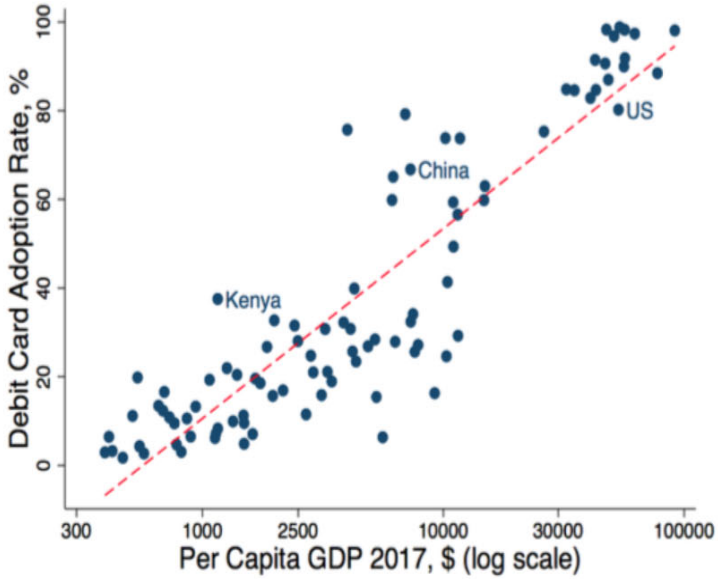
- Card-substituting mobile payment (e.g., M-PESA)
  - Relies on a network of agents to bypass the banking system.
  - Uses SMS/USSD text messages to transfer money.
  - Mostly used in developing countries.
- Card-complementing mobile payment (e.g., Apple Pay)
  - Connects credit cards, debit cards, and bank accounts to mobile devices to send and receive money.
  - Uses NFC to communicate with the POS terminal.
  - Mostly used in advanced economies.

Data

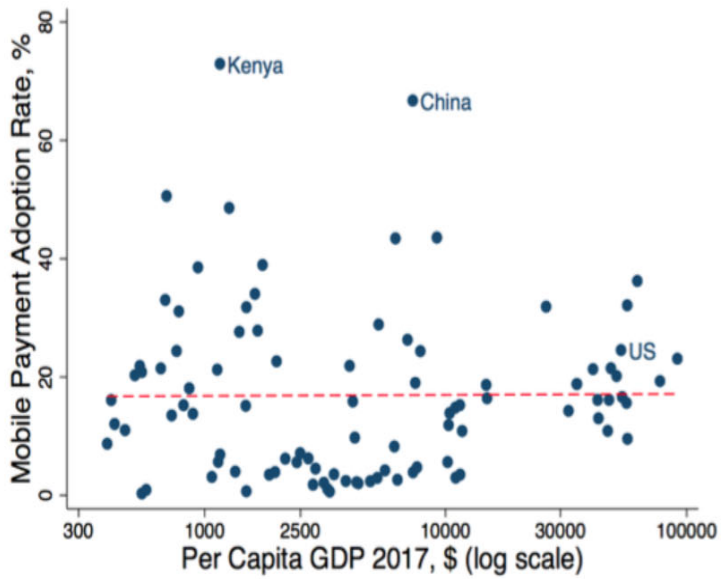
- We compile a novel dataset on card and mobile payment adoption in 94 countries.
  - The adoption of card-substituting mobile payments in 2017 from the Global Findex Database of the World Bank (76 countries).
  - The adoption of card-complementing mobile payments around 2017 from eMarketer (23 countries).
  - The adoption of debit cards in 2017 from the Global Findex Database of the World Bank.

Cross-Country Patterns

- Card adoption increases with per capita GDP, while mobile payment adoption shows no clear relationship with income.



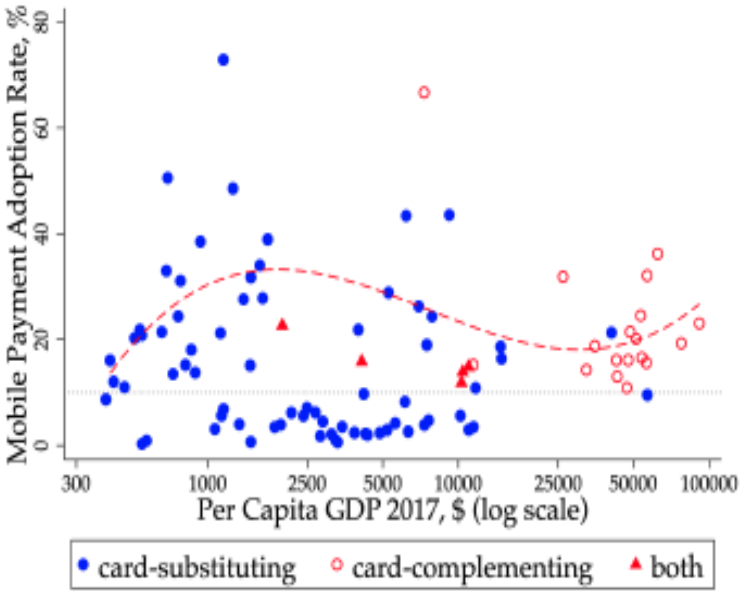
(A) Debit Card Adoption



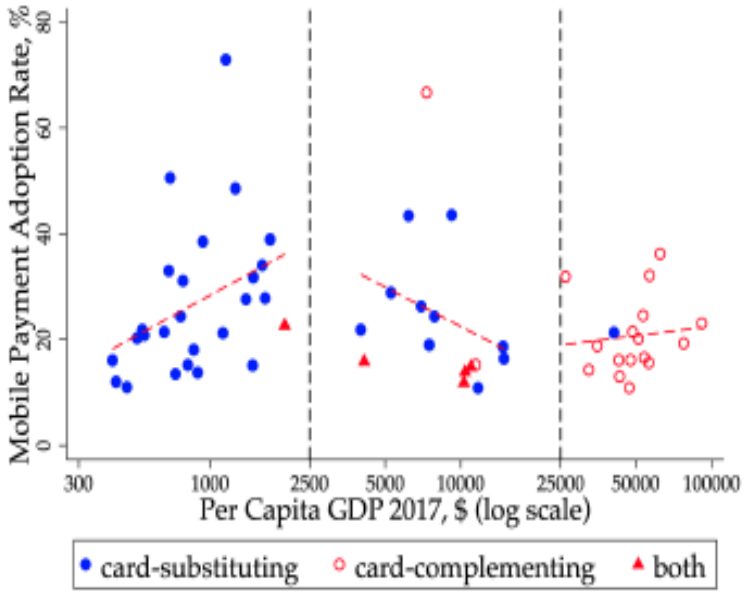
(B) Mobile Payment Adoption

Cross-Country Patterns (Cont'd)

- A pattern starts to emerge as we delve further into the data.



(A) Nonparametric fit



(B) Linear fit

Four Stylized Facts

1. Positive relationship between per capita income and card adoption.
2. Non-monotonic relationship between per capita income and mobile payment adoption.
3. Some low-income countries overtake high-income countries in adopting mobile payments.
4. Low- and middle-income countries favor card-substituting mobile payments; high-income countries favor card-complementing ones.

Model Setup

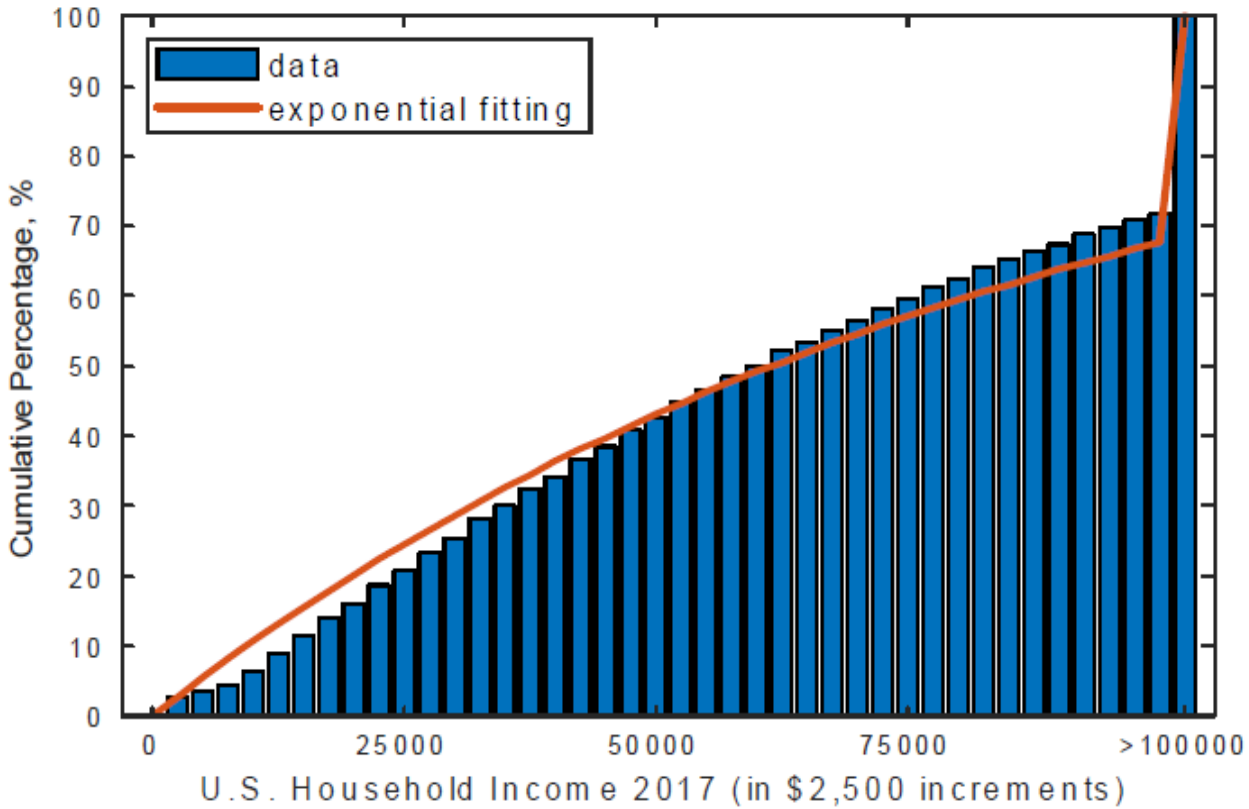
- Three payment technologies arrive sequentially, in the order of cash, card, and mobile.
- Cash is accessible to everyone in an economy, with a variable cost τ_h per dollar of transaction.
- Card and mobile require a fixed cost of adoption but lower variable costs of doing transactions comparing with cash.
  - k_d and k_m: one-time fixed adoption costs for card and mobile.
  - τ_d and τ_m: variable payment costs for using card and mobile.
  - Technology progress between cash, card, and mobile is captured by $\tau_h > \tau_d > \tau_m$ and $k_d > k_m$.

Model Setup (Cont'd)

- Time is discrete with an infinite horizon.
- We consider an endowment economy, where an agent receives an exogenous income I_t at time t.
- Income I_t follows an exponential distribution across the population in the economy, with the cdf function $G_t(I_t) = 1 - \exp(-I_t/\lambda_t)$.
- Each agent's income I_t grows at a constant rate g, i.e., $I_{t+1} = I_t(1+g)$, so does the mean income of the economy, i.e., $\lambda_{t+1} = \lambda_t(1+g)$.
- An agent has a linear utility $u = c$, where c is her consumption.
- Payment and merchant services are provided by competitive markets, so a consumer always uses her favorite payment method at social cost.

Exponential Income Distribution

- Exponential distribution fits income data well.



Model Equilibrium – Cash

- Only cash is available before electronic payments arrive.
- The value function V_h of an agent depends on her income I_t:

$$V_h(I_t) = (1 - \tau_h)I_t + \beta V_h(I_{t+1}),$$

where

$$I_{t+1} = I_t(1 + g),$$

and β is the discount rate.

- Therefore,

$$V_h(I_t) = \frac{(1 - \tau_h)\, I_t}{1 - \beta(1 + g)}.$$

Model Equilibrium – Card

- Card technology arrives as an exogenous shock at time T_d.
- The value functions of an agent who has adopted card or not:

$$\begin{aligned} V_d(I_t) &= (1-\tau_d)I_t + \beta V_d(I_{t+1}), \\ V_h(I_t) &= (1-\tau_h)I_t + \beta \max\{V_h(I_{t+1}), V_d(I_{t+1}) - k_d\}. \end{aligned}$$

- These pin down an income threshold I_d for card adoption:

$$I_t \geq I_d = \frac{(1-\beta)k_d}{(\tau_h - \tau_d)}.$$

  i.e., the flow benefit $(\tau_h - \tau_d)I_t \geq$ the flow cost $(1-\beta)k_d$.

- Card adoption rate, $F_{d,t}$, increases in per capita income.

$$F_{d,t} = 1 - G_t(I_d) = \exp\left(-\frac{(1-\beta)k_d}{(\tau_h - \tau_d)\lambda_t}\right).$$

Model Equilibrium – Mobile

- Card-substituting mobile payment arrives at a time T_m, offering lower variable cost $\tau_m < \tau_d < \tau_h$ and a lower fixed cost $k_m < k_d$.
- An income threshold $I_m (< I_d)$ for cash users to adopt mobile:

$$I_t \geq I_m = \frac{(1-\beta)k_m}{(\tau_h - \tau_m)}.$$

- Another income threshold $I_{m'} (\geq I_d)$ for card users to adopt mobile:

$$I_t \geq I'_m = \frac{(1-\beta)k_m}{(\tau_d - \tau_m)}.$$

- Mobile adoption rate, $F_{m,t}$, is non-monotonic in per capita income.

$$F_{m,t} = F_{h\to m,t} + F_{d\to m,t} = \exp\left(-\frac{I_m}{\lambda_t}\right) - \exp\left(-\frac{I_d}{\lambda_{T_m-1}}\right) + \exp\left(-\frac{I'_m}{\lambda_t}\right).$$

Model Equilibrium – Mobile (Cont'd)

- Card-complementing mobile payment also arrives at T_m, allowing card users to pay k_m^a ($< k_m$) to add mobile feature (i.e., $\tau_m < \tau_d < \tau_h$).
- Card users would prefer the card-complementing technology because $k_m^a < k_m$, while cash users would prefer the card-substituting one because $k_m < k_d + k_m^a$.
- The decision rule for cash users stays unchanged, but there is a new income threshold $I_m^a (< I_m')$ for card users to adopt mobile.

$$I_t \geq I_m^a = \frac{(1-\beta)k_m^a}{(\tau_d - \tau_m)}.$$

- Mobile adoption, $F_{m,t}$, again is non-monotonic in per capita income.

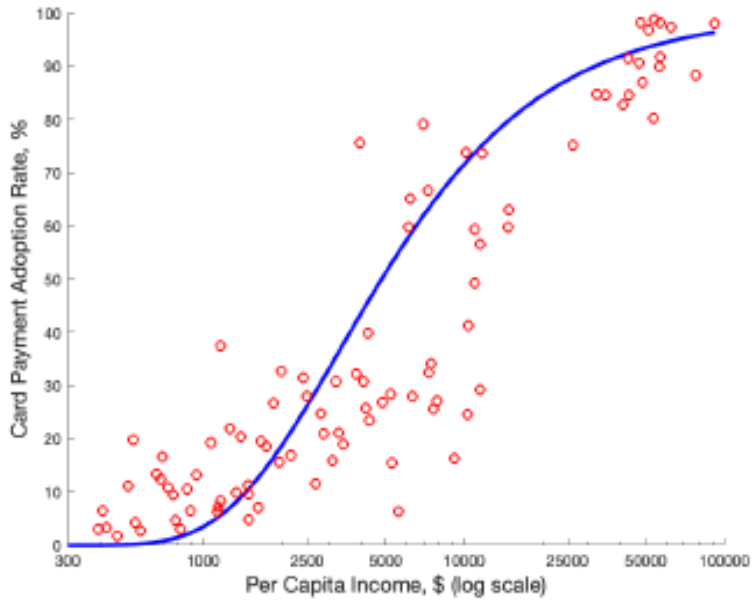
$$F_{m,t} = F_{h\to m,t} + F_{d\to m,t} = \exp\left(-\frac{I_m}{\lambda_t}\right) - \exp\left(-\frac{I_d}{\lambda_{T_m-1}}\right) + \exp\left(-\frac{I_m^a}{\lambda_t}\right).$$

Parameter Estimation

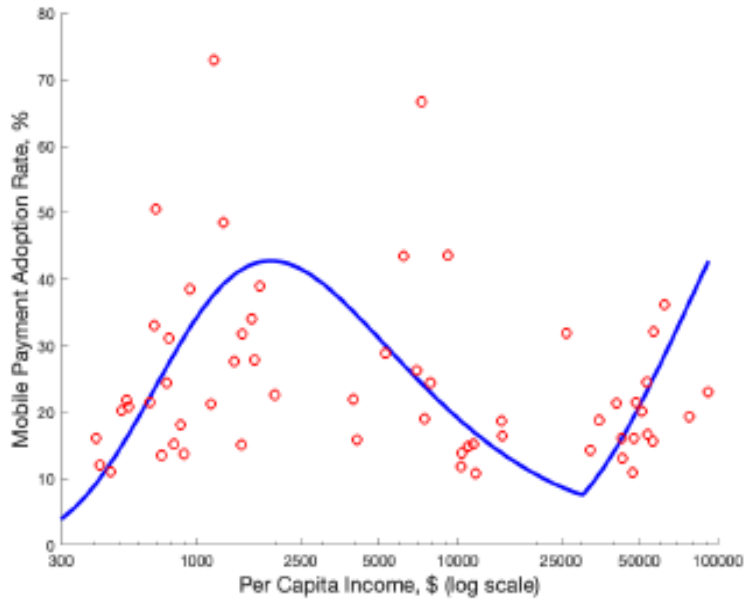
Panel A: Parameters based on a priori information			
Discount factor	Income growth	Cash var. cost	Card var. cost
β	g	τ_h	τ_d
0.95	2%	2.3%	1.4%
Panel B: Parameters based on estimation			
Card fixed cost	Mobile var. cost	Mobile fixed cost	Mobile add-on cost
k_d	τ_m	k_m	k_m^a
589.83	1.395%	175.76	78.17
(238.82)	(0.143%)	(94.33)	(39.09)

Data Fitting

- Match three stylized facts: (1) Positive income effect on card adoption; (2) Non-monotonic income effect on mobile payment adoption; (3) Overtaking in mobile payment adoption.



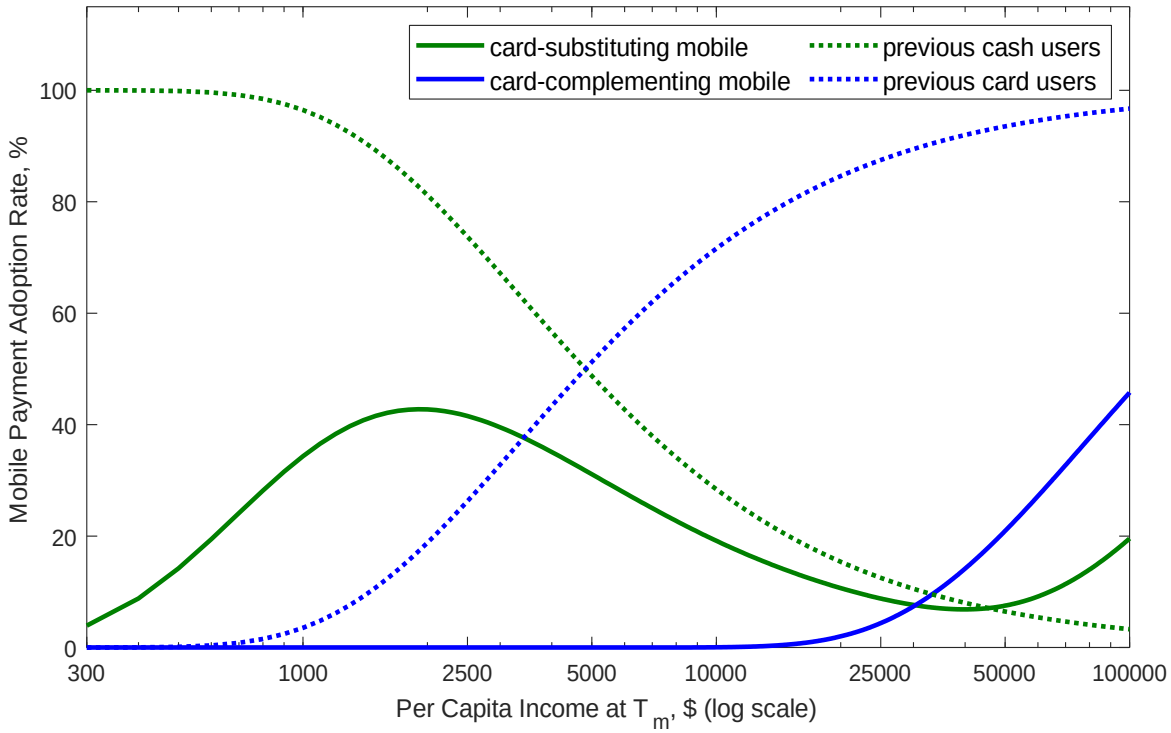
(A) Card Payment Adoption



(B) Mobile Payment Adoption

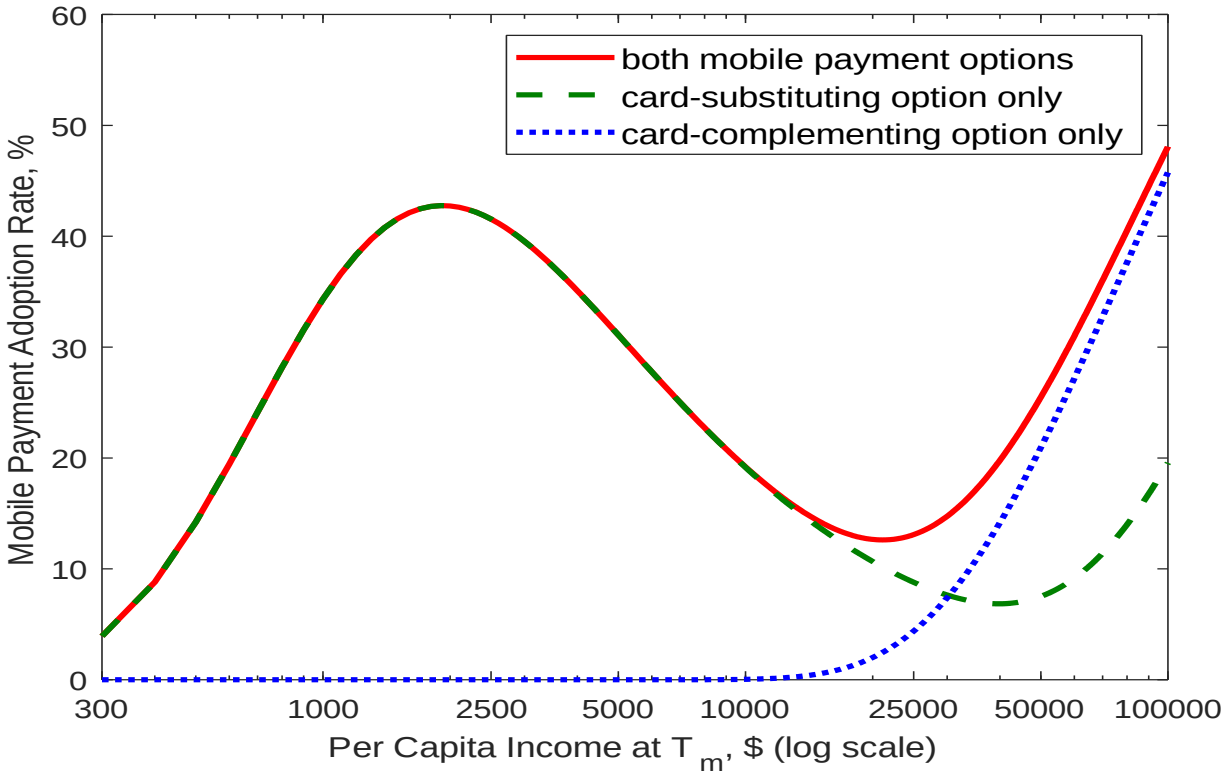
Data Fitting

- Also match the fourth fact: (4) Advanced (developing) countries prefer card-complementing (card-substituting) mobile solutions.



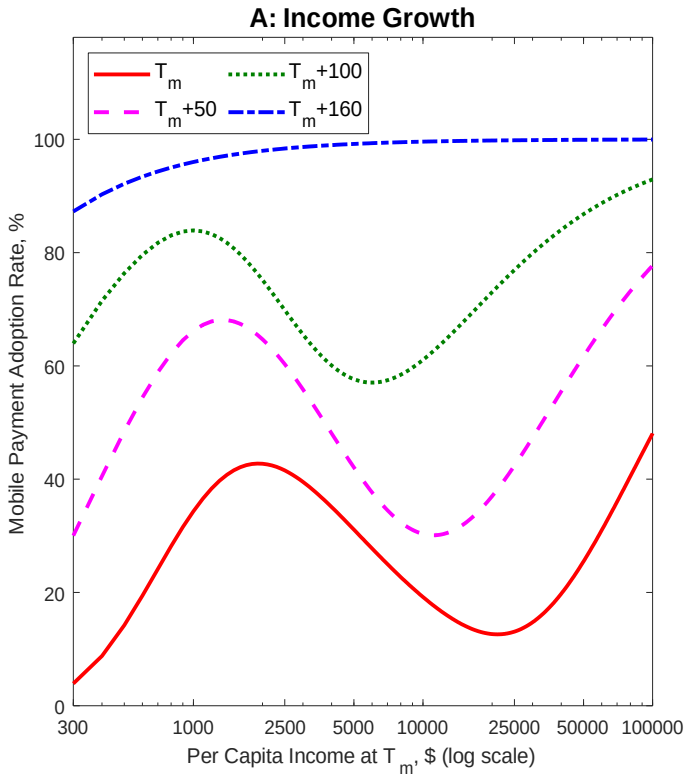
Mobile Payment Options

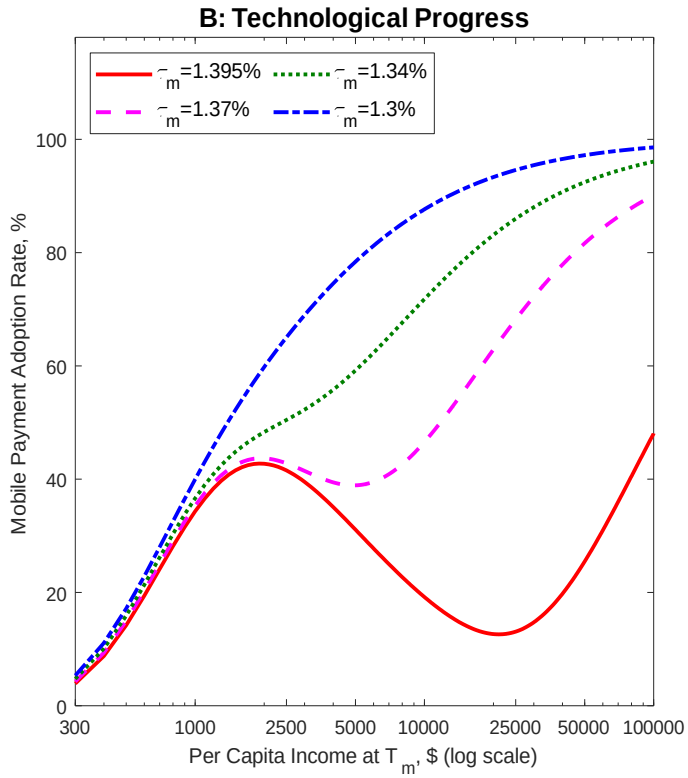
- Mobile adoption patterns under alternative technology options



Income Growth and Technological Progress

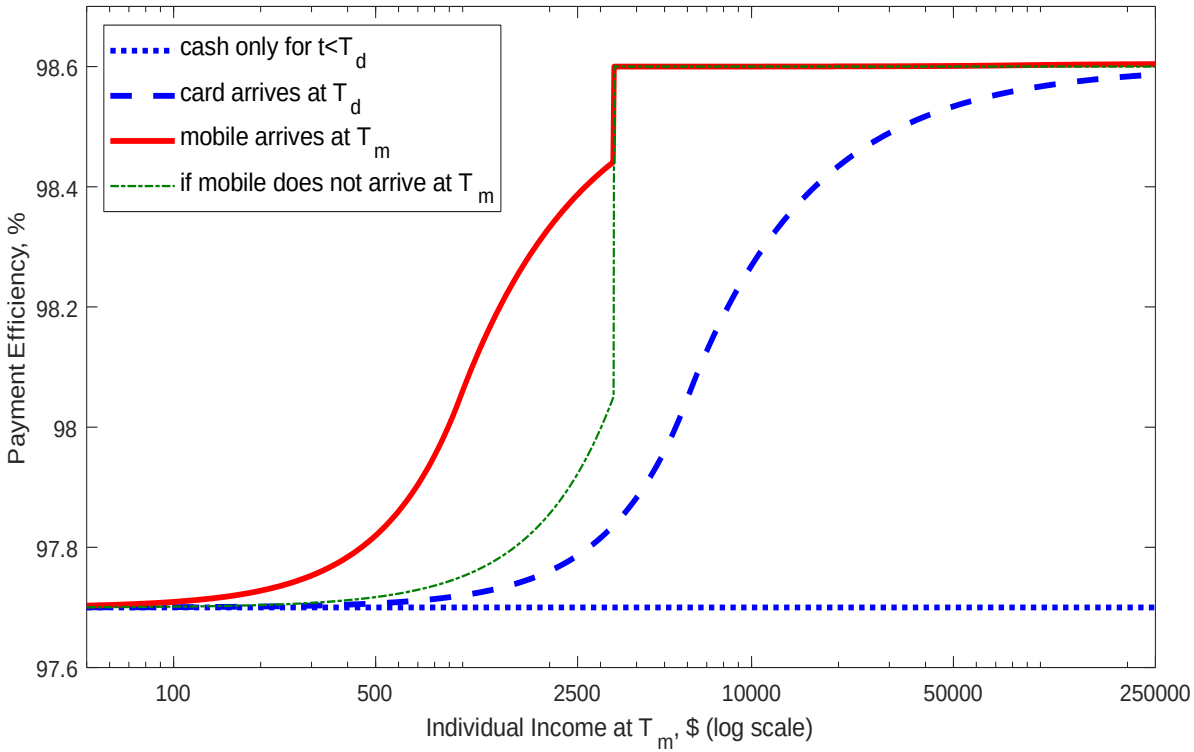
- Income growth or technological progress pushes up mobile payment adoption.





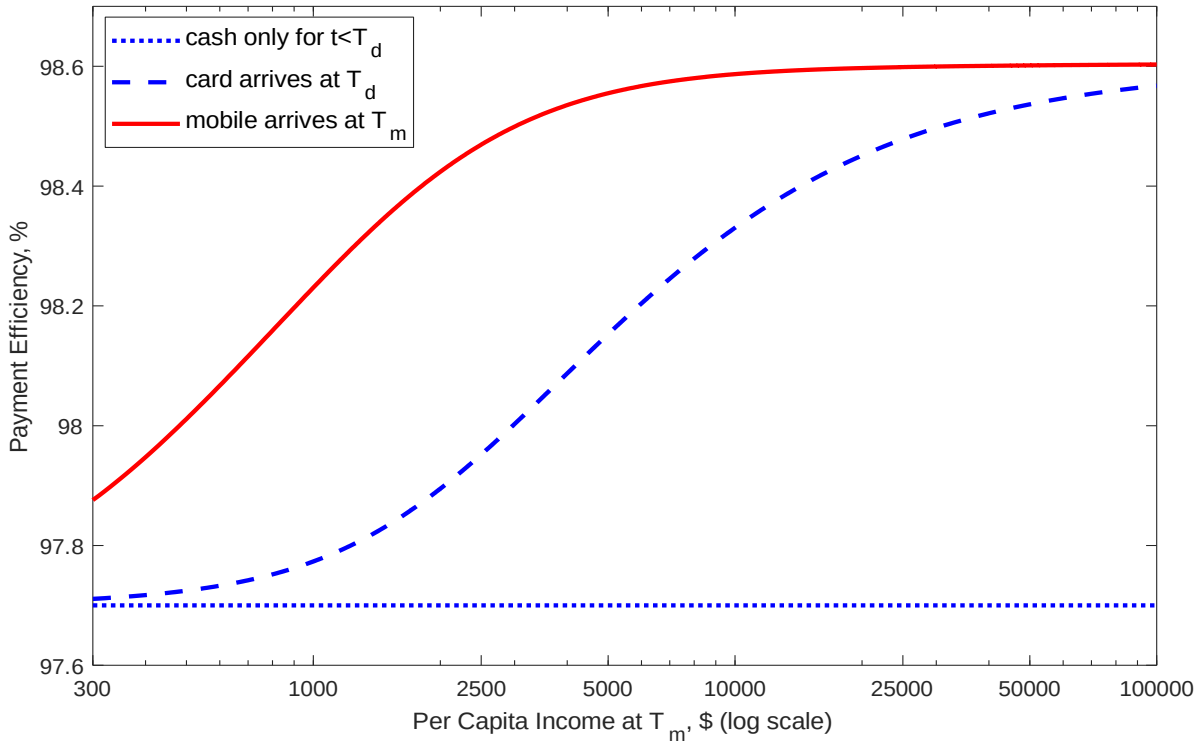
Payment Efficiency: Individual Agents

- Individual-agent payment efficiency: $x_t(I) = \omega_t(I) / (\frac{I}{1-\beta(1+g)})$.



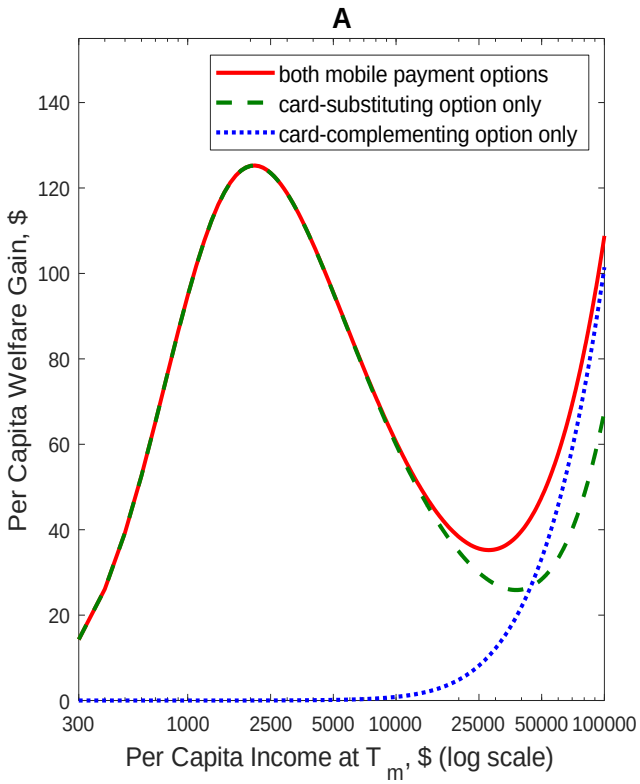
Payment Efficiency: Aggregate Economies

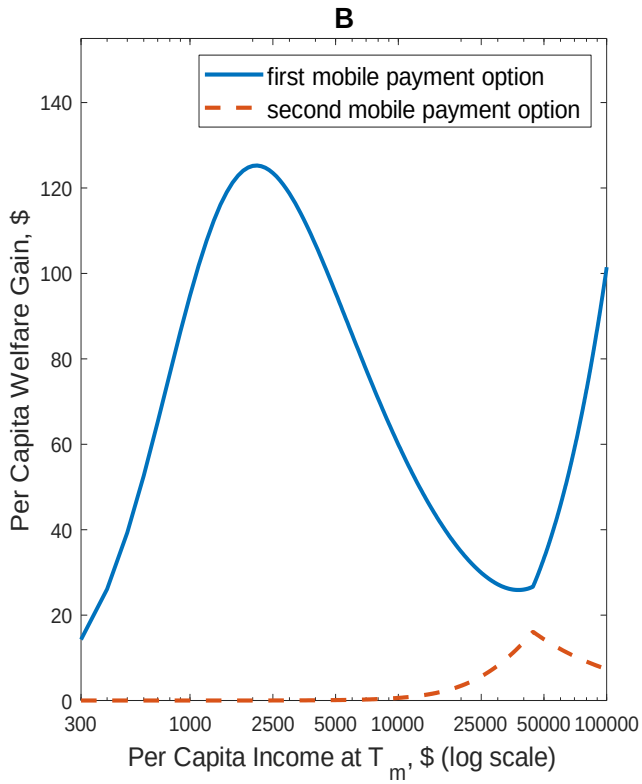
- Economy-wide payment efficiency: $X_t = W_t / (\frac{\lambda_t}{1-\beta(1+g)})$.



Social Benefits of Mobile Payments

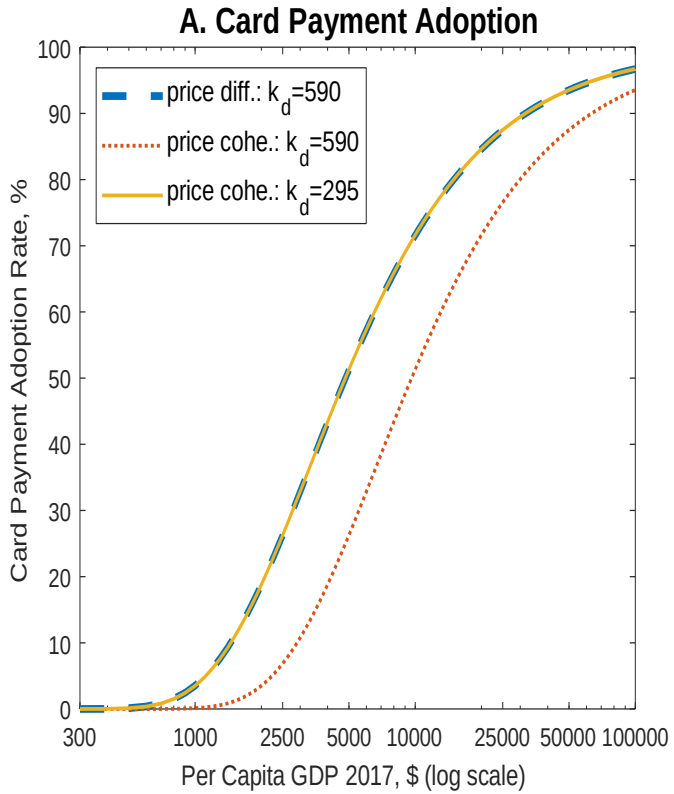
- Quantify the social benefit of introducing mobile payments.

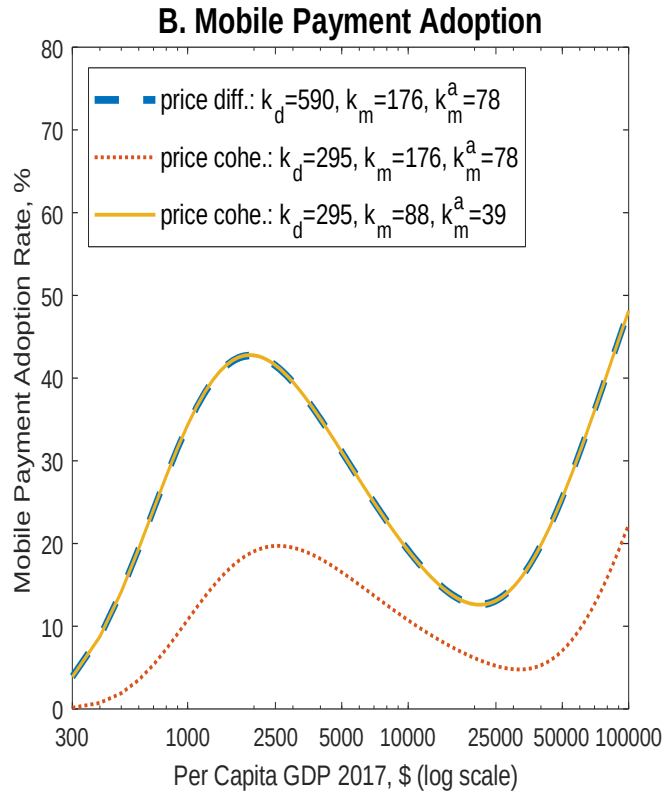




Two-Sided Market Externalities

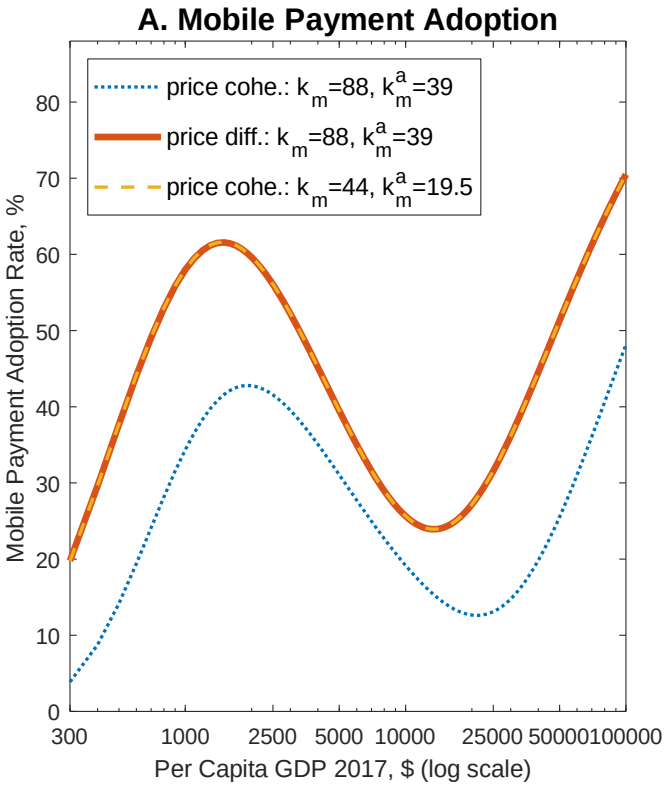
- In a two-sided payment market, merchants typically charge consumers the same retail price no matter how they pay. Consequently, consumers do not internalize the payment externalities they generate.

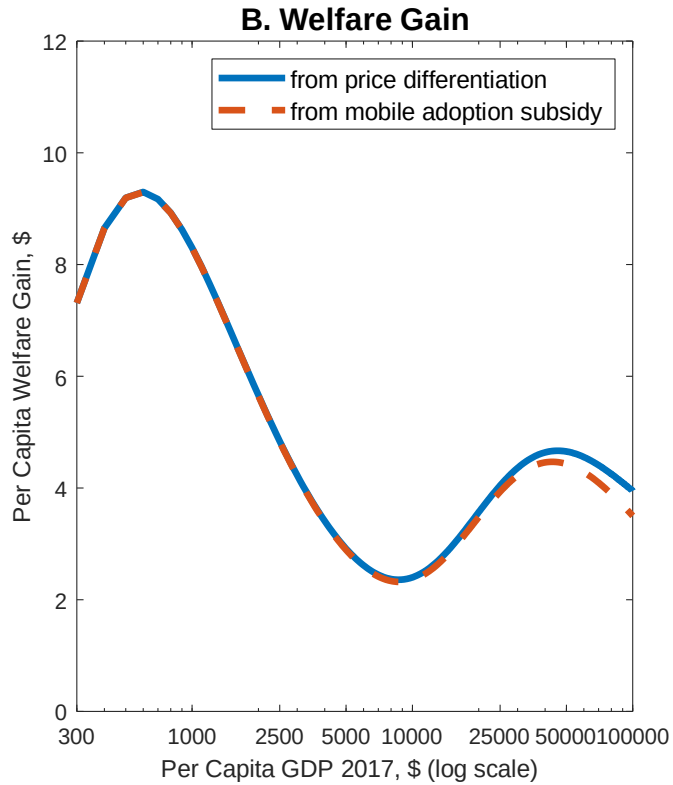




Two-Sided Market Externalities

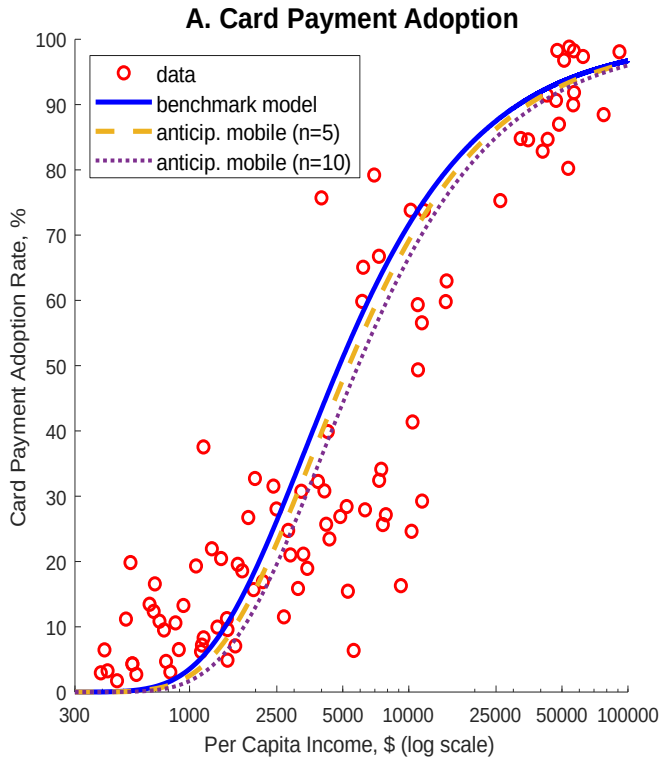
- Given two-sided market externalities, subsidizing mobile payment adoption is socially beneficial.

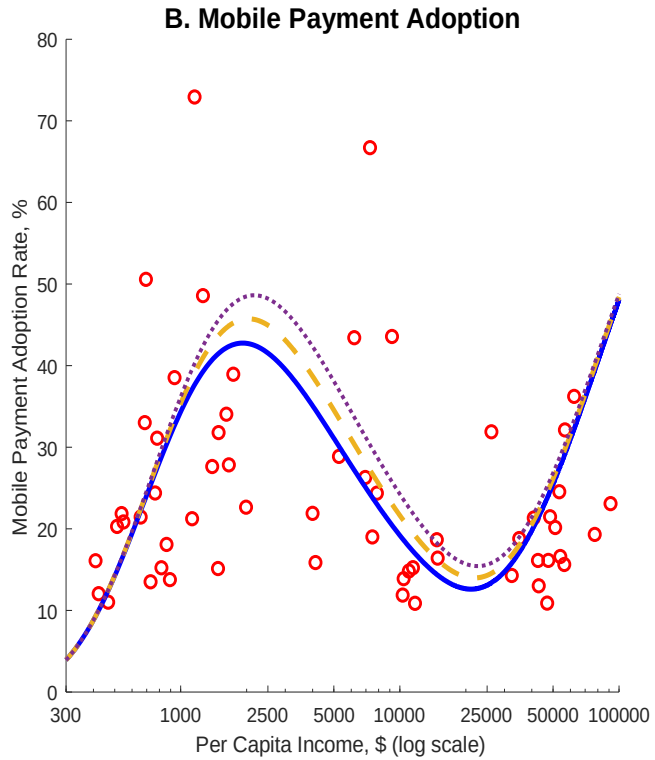




Anticipation for Mobile Payments

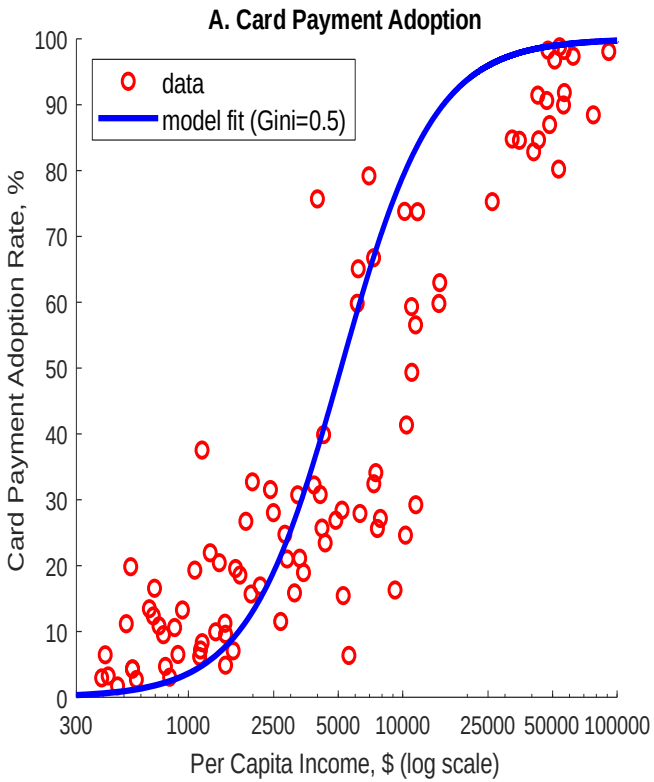
- Anticipating mobile payments would postpone card adoption and boost mobile payment adoption, but the quantitative impact is small.

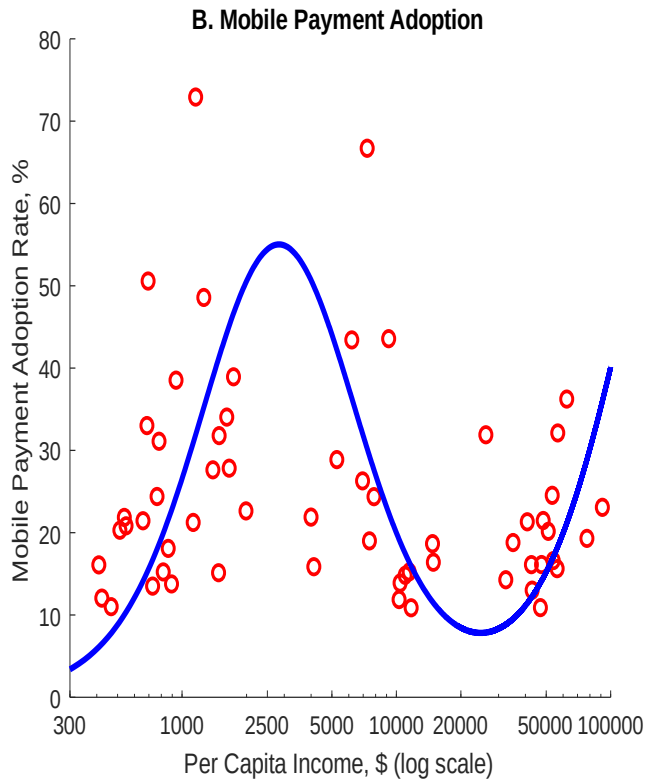




Alternative Income Distribution

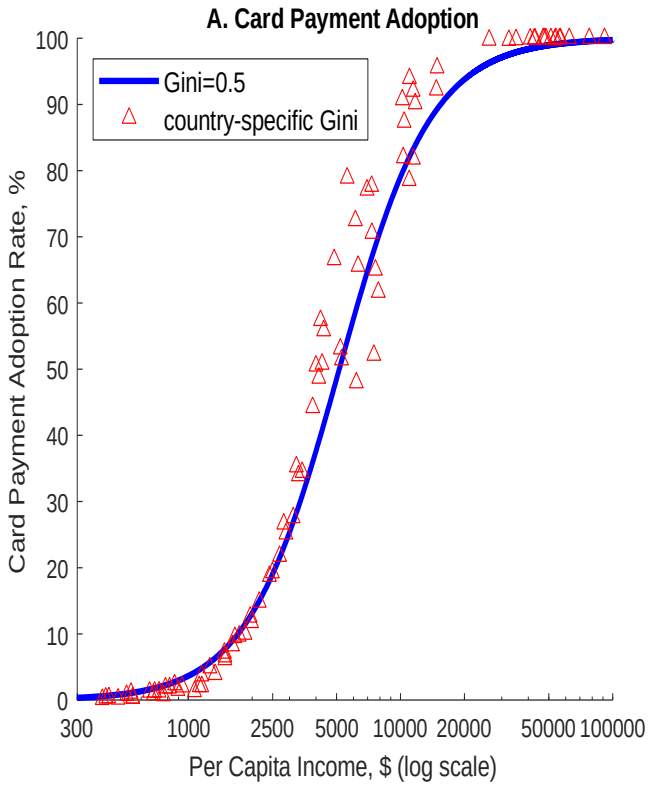
- Re-simulate the model with a log-logistic income distribution and Gini=0.5.

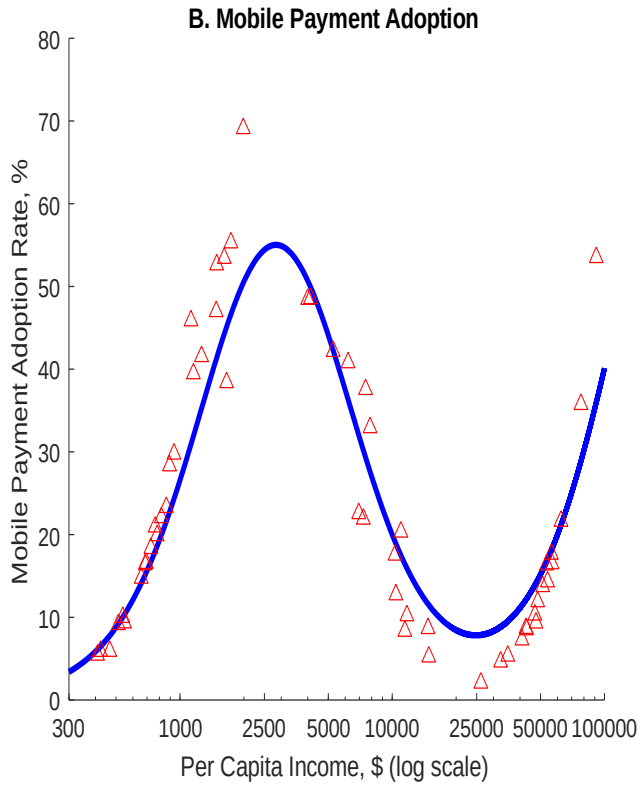




Alternative Income Distribution

- Re-simulate the model with a log-logistic income distribution and country-specific Gini coefficients.





Conclusion

- We compile a novel dataset to compare cross-country adoption patterns of card and mobile payments.
- We construct a dynamic model with sequential payment innovations to explain the stylized facts.
- Our estimated model matches the data well and also explains why countries favor different mobile payment solutions.
- Based on the model, we conduct welfare and policy analysis.