# Two-sided Market, R&D and Payments System Evolution

Bin Grace Li[a], James McAndrews[b] and Zhu Wang[c]

[a]International Monetary Fund
[b]TNBUSA Inc.
[c]Federal Reserve Bank of Richmond

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- U.S. payments system is migrating to electronic forms
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  - The share of cash and checks continues to decline
  - Credit, debit cards and other e-payments on the rise
- The diffusion of electronic payments is a slow process
  - Most e-payment means were introduced decades ago
  - Market share didn't surpass paper payments until 2000s
- Competitive efficiency issues, especially on card payments
  - Merchants fees high and rising (>$60 billion in 2010)
  - Fed has regulated debit card interchange fees since 2011
  - Other countries also regulate interchange (e.g. Australia, EU)

# Stylized Facts

- Slow diffusion of electronic payments

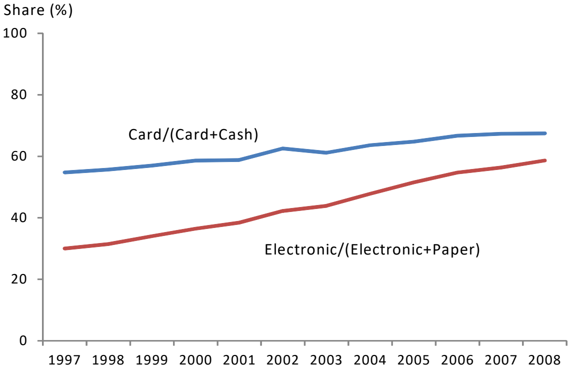


Fig. 1. Relative Share in Transaction Values.

# Stylized Facts

- Consumer adoption correlates with income

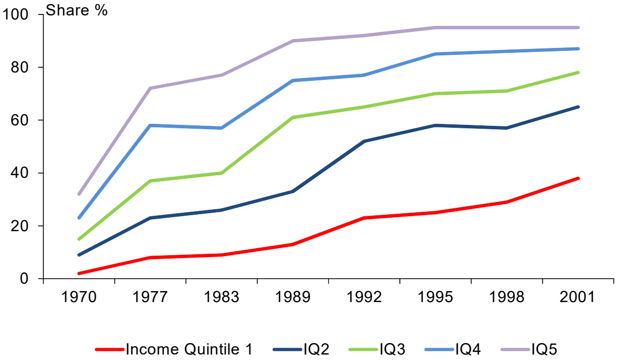


Fig. 2. Share of U.S. Households Holding Credit Cards.

# Stylized Facts

- Merchant acceptance correlates with transaction value

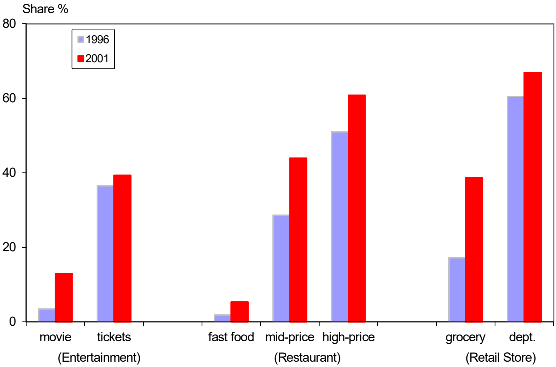


Fig. 3. Share of Transactions Using Payment Cards.

# Stylized Facts

- Increasing merchant fees for accepting electronic payments

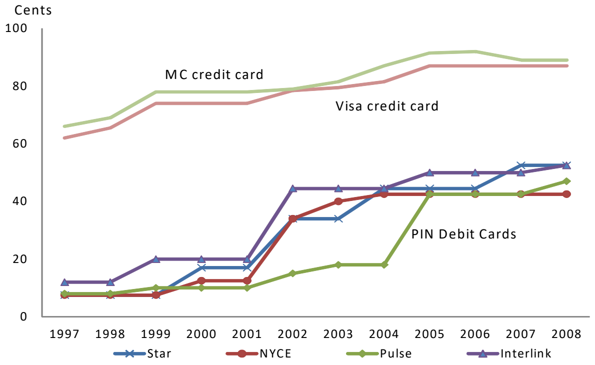


Fig. 4. Payment Card Interchange Fees for a $50 Transaction.

# Research Questions

- **Slow diffusion**: Why does it take so long for more efficient electronic payments to replace paper payments?
- **Asymmetric pricing**: Why are the fees increasing (decreasing) to merchants (consumers) for using electronic payments?
- **Social optimality**: What would be the socially optimal pricing, adoption and usage of electronic payments?
- **Regulatory impact**: How would different ways of regulation affect payments system performance?

# A New Theory

- We lay out a two-sided market environment where consumers with heterogenous income and merchants of heterogenous size make payment adoption and usage decisions under network externalities.
- Electronic payments require a high fixed cost of adoption but low marginal cost of use, so they are more cost-saving to high-income consumers and large-size merchants.
- This setting is embedded in a fully dynamic model in which a monopoly electronic payment network sets usage fees and conducts R&D to lower costs.
- We calibrate the model to U.S. payment card pricing, adoption and usage data, and conduct welfare and policy analysis.

# Main Findings

- The model generates pricing, adoption and usage pattern of electronic payments that are consistent with data.
- Market power of electronic payment networks explains the slow adoption and asymmetric price changes.
- A Ramsey social planner would proceed differently and achieve higher adoption and usage of electronic payments.
- Regulating usage fees by marginal cost may reduce social welfare in a dynamic setting, while a merchant fee cap regulation improves consumer welfare without causing much dynamic inefficiency.

# The Literature

- Money-search models (e.g., Lagos and Wright 2005)
  - Rely on information economics and mechanism design.
  - Show payment arrangements overcome frictions of exchange.
  - Do not explain the slow diffusion of electronic payments.
  - Do not address competitive efficiency issues in payments.

# The Literature

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  - Rely on information economics and mechanism design.
  - Show payment arrangements overcome frictions of exchange.
  - Do not explain the slow diffusion of electronic payments.
  - Do not address competitive efficiency issues in payments.
- Two-sided market theories (e.g., Rochet & Tirole, 2002, 2011)
  - Focus on the industrial organization of payments systems.
  - Usage externalities lead to inefficiently high merchant fees.
  - Do not explain adoption and ignore technology progress.
  - Ad hoc payment benefits and fixed consumer demand.

# Outline

- Motivation and findings
- Model setup
- Market equilibrium
- Model calibration
- Welfare and policy analysis
- Concluding remarks

# Model Elements

- Consumers
  - Cobb-Douglas preference, heterogenous income.
- Merchants
  - Contestable market, heterogenous size.
- Electronic and paper payments: “card” *vs.* “cash”
  - High fixed cost of adoption, low marginal cost of usage.
- Electronic payment service provider
  - A monopoly which sets usage fees and conducts R&D.

# A Cash Economy

- Merchants in a contestable market each sells a differentiated good $\alpha$:

$$p_{\alpha,h} = \frac{\mu_\alpha}{1-\tau_m}.$$

- A consumer with income $I$ purchases $x_\alpha$ units of good $\alpha \in (0, \overline{\alpha})$:

$$\ln U_I = Max \int_0^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln x_{\alpha,I} dG(\alpha) \quad s.t. \quad \int_0^{\overline{\alpha}} (1+\tau_c) p_{\alpha,h} x_{\alpha,I} dG(\alpha) \leq I.$$

- Consumer $I$'s demand for good $\alpha$:

$$x^*_{\alpha,I} = \frac{\alpha I}{(1+\tau_c) p_{\alpha,h} E(\alpha)}.$$

- Total market demand for good $\alpha$:

$$x_\alpha = \int_0^{\overline{I}} x_{\alpha,I} dF(I) = \frac{\alpha E(I)}{(1+\tau_c) p_{\alpha,h} E(\alpha)}.$$

# Introducing the Payment Card

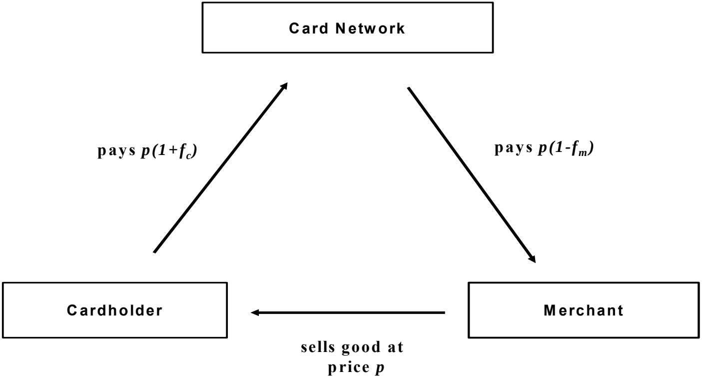


Fig. 5. Payment Card System.

# Introducing the Payment Card

- Card service is provided by a monopoly.
- The costs for serving merchants and consumers are $d_m$ and $d_c$.
- Merchants and consumers are each charged a fee $f_m$ or $f_c$.
- Merchants and consumers each incur an adoption cost $K_m$ or $K_c$.
- The card is a more efficient payment means, which requires

$$\tau_m + \tau_c > d_m + d_c = d.$$

# Within-Period Decisions

- At a point in time, with the card service cost $d$ given, we solve for a three-stage game:
  - Stage I. The monopoly card network sets the card fees $f_m$ and $f_c$.
  - Stage II. After observing $f_m$ and $f_c$, merchants and consumers decide simultaneously whether to accept or hold the card, and merchants post retail prices.
  - Stage III. Consumers decide whether to purchase, which merchants to purchase from, and what payment device to use.
- In making the decisions, consumers and merchants maximize utility or profits, and the card network maximizes profit.

# Dynamic Decisions

- The industry evolves over time due to
  - Exogenous forces: Mean consumer income $E(I_t)$ grows, together with changes of card adoption costs $K_{m,t}$ and $K_{c,t}$.
  - Endogenous forces: The card network makes R&D investment $R_t$ to reduce card service costs such that

$$d_{t+1} = \Gamma(d_t, R_t),$$

    where $\partial\Gamma/\partial d_t > 0$ and $\partial\Gamma/\partial R_t < 0$.
- Given the initial value of $d_0$ and the laws of motion for $E(I_t)$, $K_{m,t}$ and $K_{c,t}$, the card network chooses a sequence of $(f_{m,t}, f_{c,t}, R_t)$ to maximize the present value of profits.

# Within-Period Analysis

- Merchants' Choices

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  - Large merchants ($\alpha \geq \alpha_1$) accept cards and charge price $p_{\alpha,d} \leq p_{\alpha,h}$

$$\alpha_1 = \frac{E(\alpha)K_m}{[E_{I \geq I_0}(I - K_c)](\frac{1-f_m}{1+f_c} - \frac{1-\tau_m}{1+f_c})}.$$

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  - Intermediate merchants ($\alpha_0 \leq \alpha < \alpha_1$) specialize. They either accept cards and charge $p_{\alpha,d}$, where $\frac{1+\tau_c}{1+f_c} p_{\alpha,h} \geq p_{\alpha,d} > p_{\alpha,h}$, or they do not accept cards and charge $p_{\alpha,h}$

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  - Small merchants ($\alpha < \alpha_0$) do not accept cards and charge $p_{\alpha,h}$.

# Within-Period Analysis

- Consumers' Choices

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  - A consumer with income $I$ compares utility between adopting card ($U^d_{I,d}$) or not ($U^h_{I,d}$):

$$\ln U^d_{I,d} = \int_0^{\alpha_0} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha(I-K_c)}{(1+\tau_c)p_{\alpha,h}E(\alpha)} dG(\alpha) + \int_{\alpha_0}^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha(I-K_c)}{(1+f_c)p_{\alpha,d}E(\alpha)} dG(\alpha),$$

$$\ln U^h_{I,d} = \int_0^{\alpha_1} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha I}{(1+\tau_c)p_{\alpha,h}E(\alpha)} dG(\alpha) + \int_{\alpha_1}^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha I}{(1+\tau_c)p_{\alpha,d}E(\alpha)} dG(\alpha).$$

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  - The threshold income level $I_0$ for card adoption

$$I \geq I_0 = \frac{\left(\frac{1+\tau_c}{1+f_c}\right)^{E_{\alpha\geq\alpha_0}(\alpha)/E(\alpha)} k_c}{\left(\frac{1+\tau_c}{1+f_c}\right)^{E_{\alpha\geq\alpha_0}(\alpha)/E(\alpha)} - \exp\left(\int_{\alpha_0}^{\alpha_1} \frac{\alpha}{E(\alpha)} \ln\left(\frac{p_{\alpha,d}}{p_{\alpha,h}}\right) dG(\alpha)\right)}.$$

# Within-Period Analysis

- Two-sided Market Interaction
  - Denote $Z_1 = (\frac{1-f_m}{1+f_c} - \frac{1-\tau_m}{1+f_c})$ and $Z_0 = (\frac{1-f_m}{1+f_c} - \frac{1-\tau_m}{1+\tau_c})$.
  - Given card fees ($f_c$ and $f_m$) that satisfy $\tau_c \geq f_c$ and $\frac{1-f_m}{1+f_c} \geq \frac{1-\tau_m}{1+\tau_c}$, there exist card adoption thresholds ($\alpha_0$, $\alpha_1$, $I_0$):

$$\alpha_0 = \frac{E(\alpha)K_m}{[E_{I\geq I_0}(I-k_c)]Z_0}, \qquad \alpha_1 = \frac{Z_0}{Z_1}\alpha_0 \quad \textit{if} \quad f_m \leq \tau_m,$$

$$I_0 = \frac{(\frac{1+\tau_c}{1+f_c})^{E_{\alpha\geq\alpha_0}(\alpha)/E(\alpha)} K_c}{(\frac{1+\tau_c}{1+f_c})^{E_{\alpha\geq\alpha_0}(\alpha)/E(\alpha)} - \exp(\int_{\alpha_0}^{\alpha_1} \frac{\alpha}{E(\alpha)} \ln \frac{(1-\tau_m)\alpha}{(1-f_m)\alpha-(1+f_c)\alpha_0 Z_0} dG(\alpha))}.$$

# Within-Period Analysis

- Within-Period Equilibrium
  - The card network, anticipating card adoption and usage decisions in Stages II and III, set card fees $(f_c, f_m)$ at Stage I to maximize its profit:

$$\pi(d; E(I), K_m, K_c) = \max_{f_c, f_m} \frac{E_{\alpha \geq \alpha_0}(\alpha) E_{I \geq I_0}(I - K_c)}{E(\alpha)(1 + f_c)} (f_c + f_m - d).$$

  - The card network maximizes profit, consumers maximize utility, merchants break even, and goods and payments markets clear.

# Dynamic Analysis

- Dynamic Problem
  - Over time, the market evolves due to exogenous changes in $(E(I_t)$, $K_{m,t}$, $K_{c,t})$ and endogenous choices of $R_t$.
  - The value function of the card network is

$$\begin{aligned} V(d_t; E(I_t), K_{m,t}, K_{c,t}) \quad &= \quad \max_{R_t} \pi(d_t; E(I_t), K_{m,t}, K_{c,t}) - R_t \\ & \quad\quad +\beta V(d_{t+1}; E(I_{t+1}), K_{m,t+1}, K_{c,t+1}) \end{aligned}$$

$$s.t. \quad d_{t+1} = \Gamma(d_t, R_t),$$

$$\pi(d_t; E(I_t), K_{m,t}, K_{c,t}) \geq R_t.$$

# Dynamic Analysis

- Dynamic Solution
  - Rewrite the R&D function into an inverse function

$$R_t = \Psi(d_t, d_{t+1})$$

  - The dynamic problem is equivalent to

$$\begin{aligned} V(d_t; E(I_t), K_{m,t}, K_{c,t}) &= \max_{d_{t+1}} \pi(d_t; E(I_t), K_{m,t}, K_{c,t}) - \Psi(d_t, d_{t+1}) \\ &\quad + \beta V(d_{t+1}; E(I_{t+1}), K_{m,t+1}, K_{c,t+1}). \end{aligned}$$

  - The optimal path follows a second-order difference equation

$$\Psi_2(d_t, d_{t+1}) = \beta[\pi'(d_{t+1}; E(I_{t+1}), K_{m,t+1}, K_{c,t+1}) - \Psi_1(d_{t+1}, d_{t+2})].$$

# Functional Forms

- F1. Merchant size $\alpha$ is uniformly distributed, and $I_t$ is exponentially distributed with $F(I_t) = 1 - e^{(-\lambda_t I_t)}$ and $E(I_t) = 1/\lambda_t$.
- F2. The mean consumer income has a constant growth rate $g_I$: $\lambda_{t+1} = \lambda_t/(1 + g_I)$.
- F3. Card adoption costs are proportional to the mean income: $K_{m,t} = k_m E(I_t) = k_m/\lambda_t$ and $K_{c,t} = k_c E(I_t) = k_c/\lambda_t$.
- F4. The R&D function $\Gamma$ takes the form:

$$\frac{1}{d_{t+1}} - \frac{1}{d_t} = (\frac{R_t \lambda_t}{\phi})^{\gamma} d_t^{-\gamma-1} \text{ with } 1 > \gamma > 0.$$

# Within-Period Eqm: Characterization

- Two-sided market interaction leads to multiple equilibria

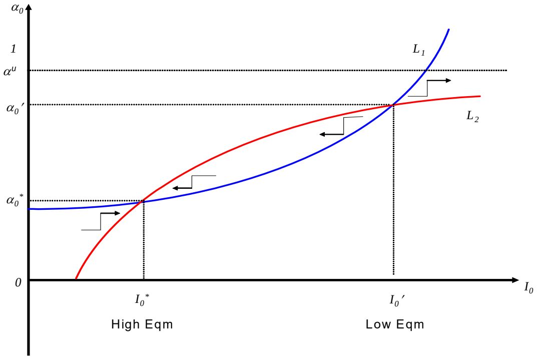


Fig. 6. Interaction of Merchants and Consumers in Card Adoption.

# Within-Period Eqm: Characterization

- Network within-period profit function can be simplified: $\pi(d;\lambda) = \frac{1}{\lambda}(a_0 - a_1 d)$.

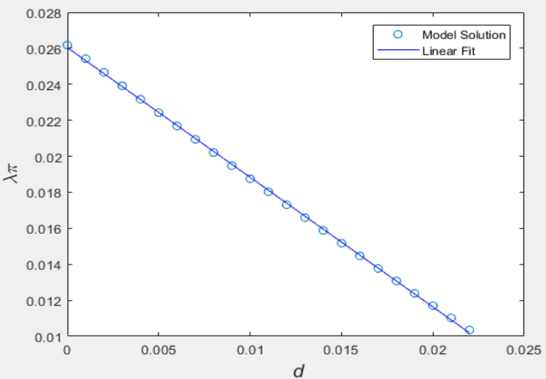


Fig. 7. Network Profit Function and Linear Fitting.

# Dynamic Eqm: Characterization

- The R&D function implies an investment function

$$R_t = \phi \frac{d_t}{\lambda_t} \left[ \frac{d_t}{d_{t+1}} - 1 \right]^{\frac{1}{\gamma}} \text{ with } 1 > \gamma > 0,$$

which is strictly increasing and convex in technological progress $(d_t / d_{t+1})$ and constant returns to scale in $(d_t, d_{t+1})$.

- The dynamic problem of the card network becomes

$$V(d_t; \lambda_t) = \max_{d_{t+1}} \frac{1}{\lambda_t}(a_0 - a_1 d_t) - \phi \frac{d_t}{\lambda_t} \left[ \frac{d_t}{d_{t+1}} - 1 \right]^{\frac{1}{\gamma}} + \beta V(d_{t+1}; \lambda_{t+1}),$$

which can be explicitly solved for a balanced-growth path.

# Data and Industry Background

- Given the functional forms, we choose parameter values to match U.S. payment card data from 1997-2008.
- Credit cards, introduced in 1950s, started to gain popularity in 1970s. Debit cards, introduced in 1980s, stared to pick up in the mid-1990s. Visa and MasterCard became dominant players in both markets.
- Since the late 1990s, with the wide adoption of credit cards and rapid expansion of debit cards, the card fees have raised great controversies.
- By the late 1990s, 73% of U.S. households had adopted credit cards, but nearly half cardholders only used the payment function. Debit cards provide payment but not credit function.
- In 2008, credit cards were used in 26.5 billion transactions worth \$2.1 trillion, while debit cards had 34 billion transactions worth \$1.3 trillion.

# Parameterization

| Parameter Definition | | Value |
|---|---|---|
| Merchant cost of handing cash | $\tau_m$ | 4.0% |
| Consumer cost of handing cash | $\tau_c$ | 2.5% |
| Merchant cost of adopting card | $k_m$ | 2.5% |
| Consumer cost of adopting card | $k_c$ | 0.3% |
| Merchant cost of goods | $\mu_\alpha$ | 1 |
| Initial value of card service costs | $d_0$ | 2.25% |
| R&D function curvature | $\gamma$ | 0.5 |
| R&D efficiency parameter | $\phi$ | 10 |
| Initial value of mean income | $1/\lambda_0$ | 21,215 |
| Growth rate of mean income | $g_I$ | 2% |

# Calibration Results

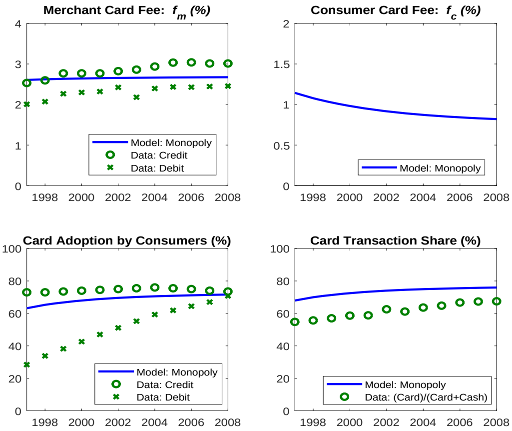


Fig. 8. Targeted Moments.

# Calibration Results (Cont'd)

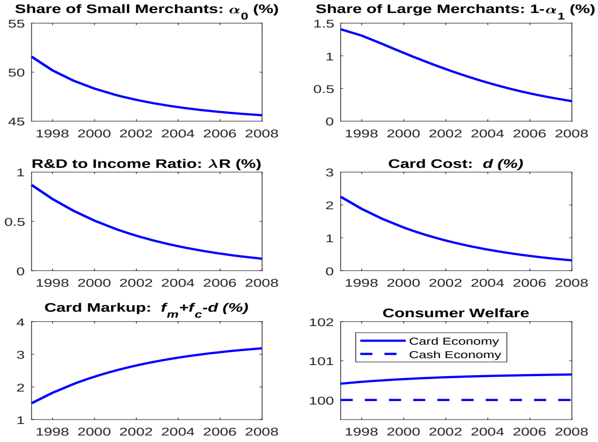


Fig. 9. Untargeted Moments.

# Card is Welfare Improving for Everyone

- In a cash economy, a consumer $I$ enjoys utility

$$\ln U_{I,h} = \int_0^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha I}{E(\alpha)(1+\tau_c)p_{\alpha,h}} dG(\alpha).$$

- In a card economy, a card-adopting consumer ($I \geq I_0$) enjoys utility

$$\ln U^d_{I,d} = \int_0^{\alpha_0} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha(I-K_c)}{E(\alpha)(1+\tau_c)p_{\alpha,h}} dG(\alpha) + \int_{\alpha_0}^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha(I-K_c)}{E(\alpha)(1+f_c)p_{\alpha,d}} dG(\alpha),$$

while a nonadopter ($I < I_0$) enjoys utility

$$\ln U^h_{I,d} = \int_0^{\alpha_1} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha I}{(1+\tau_c)p_{\alpha,h}E(\alpha)} dG(\alpha) + \int_{\alpha_1}^{\overline{\alpha}} \frac{\alpha}{E(\alpha)} \ln \frac{\alpha I}{(1+\tau_c)p_{\alpha,d}E(\alpha)} dG(\alpha).$$

# Ramsey Social Planner

- Within-Period Decision
  - Within each period, for any given $d$ and $R$, the Ramsey social planner chooses $(f_c, f_m)$ to maximize consumer welfare subject to a balanced budget:

$$U(d, R; E(I), K_m, K) = \underset{f_c, f_m}{Max} \int_{I_0}^{\infty} U_{I,d}^{d} dG(I) \; + \int_{0}^{I_0} U_{I,d}^{h} dG(I)$$

$s.t.$ merchant and consumer adoption and usage equations,

and $\pi(d; E(I), K_m, K_c) \geq R.$

# Ramsey Social Planner

- Dynamic Decision
  - Over time, the Ramsey social planner chooses the sequence of $(f_{c,t}, f_{m,t}, R_t)$ to maximize the present value of consumer surplus

$$\begin{aligned} V(d_t; E(I_t), K_{m,t}, K_{c,t}) &= \max_{R_t} U(d_t, R_t; E(I_t), K_{m,t}, K_{c,t}) \\ &+\beta V(d_{t+1}; E(I_{t+1}), K_{m,t+1}, K_{c,t+1}) \end{aligned}$$

$$s.t.\ d_{t+1} = \Gamma(d_t, R_t),$$

where $\Gamma$ is the R&D function.

# Ramsey Social Planner

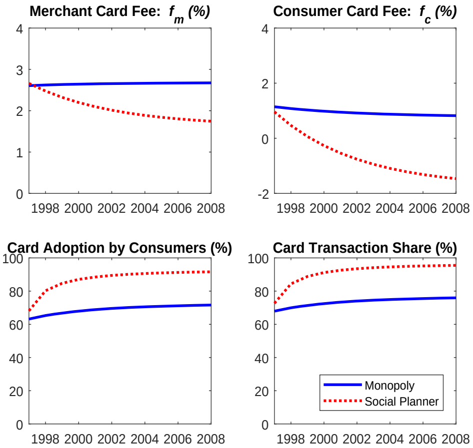


Fig. 10. Monopoly Network vs. Ramsey Social Planner.

# Ramsey Social Planner

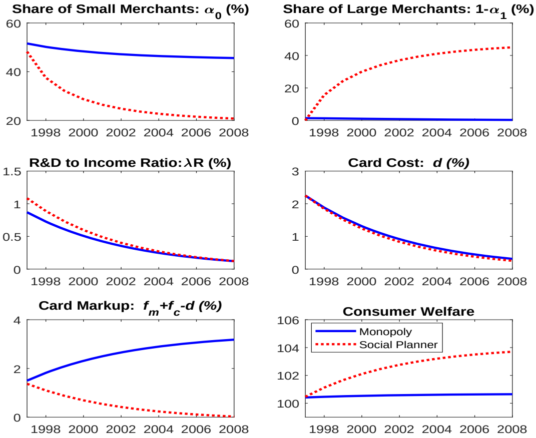


Fig. 11. Monopoly Network vs. Ramsey Social Planner (cont'd).

# Ramsey Social Planner

- What explain the differences between the Ramsey social planner and the monopoly network?
  - For the monopoly network, charging a high merchant fee (i) leads to high retail prices of goods and allows the network to extract more rents; and (2) reduces cross subsidies from card users to cash users through large merchants.
  - The Ramsey social planner values consumers' real purchases rather than nominal card spending, and cares about cash users.
  - Regarding R&D decisions, the monopoly only sees the benefit of increased profit, which is a subset of social welfare, so the monopoly makes less R&D investment than the social planner.

# Ramsey Social Planner

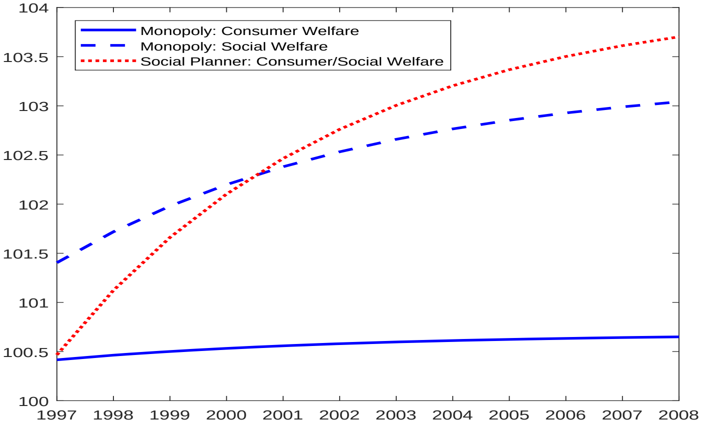


Fig. 12. Social Welfare Comparison.

# Policy Analysis

- Evaluating two popular regulatory approaches
  - Marginal-cost pricing regulation:

$$f_m + f_c = d_m + d_c.$$

  - Merchant fee cap regulation:

$$f_m < \overline{f_m}.$$

# Policy Analysis

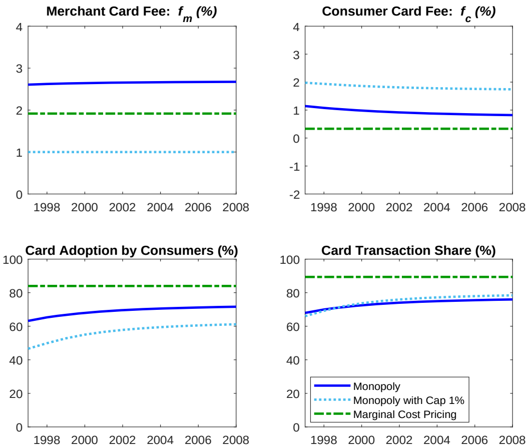


Fig. 13. Policy Experiments.

# Policy Analysis

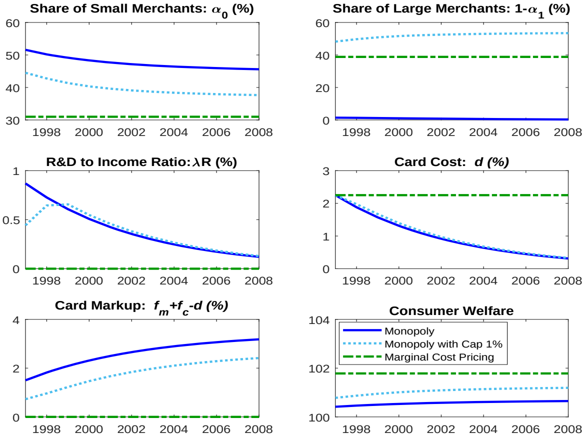


Fig. 14. Policy Experiments (cont'd).

# Policy Analysis

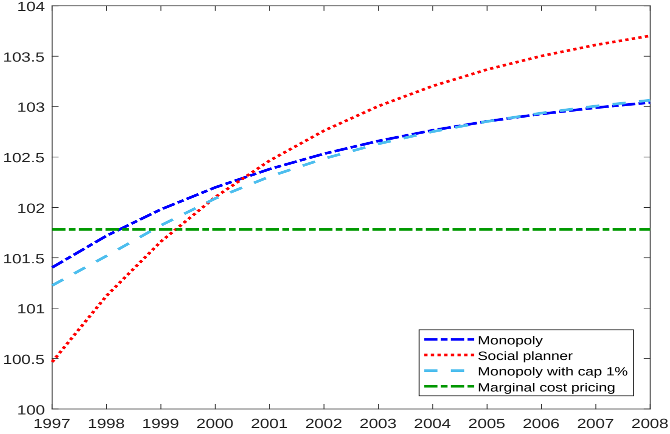


Fig. 15. Social Welfare Comparison of Policy Experiments.

# Policy Analysis

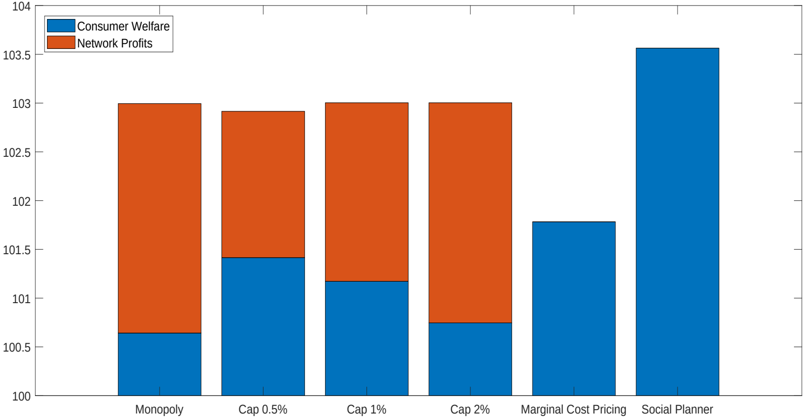


Fig. 16. Present Value Comparison of Consumer and Social Welfare.

# Takeaways

- We provide a new analysis of payments system evolution and the accompanying competitive efficiency issues.
  - The model generates pricing, adoption and usage pattern of electronic payments that are consistent with data.
  - Market power of electronic payment networks explains the slow adoption and asymmetric fee changes.
  - A Ramsey social planner would achieve higher adoption and usage of electronic payments.
  - Regulating usage fees by marginal cost may reduce social welfare in a dynamic setting, while a merchant fee cap may improve consumer welfare without causing much dynamic inefficiency.