Money Creation and Banking: Theory and Evidence

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Introduction

- The Fed increases huge amount of monetary base,
  - But monetary aggregates (e.g., M1) has not increases as much as monetary base.
  - The money multiplier dropped drastically.
  - Banks are holding lots of excess reserve rather than “creating” money.
- What determines the money multiplier?
  - Why banks are holding so many reserves?
  - What is the role of credit?

What I Do

Motivating Evidence

- Show the relationship between required reserve ratio and money multiplier is NOT clear whether banks are holding excess reserves or not.
- Identify two structural breaks in money creation process:
  1. one associated with interest on reserves;
  2. the other one associated with consumer credit

Model

- To understand the monetary transmission, I incorporate inside money creation via banking and unsecured credit monetary-search model.
- Calibrate the model to quantify the model prediction.

Motivating Evidence

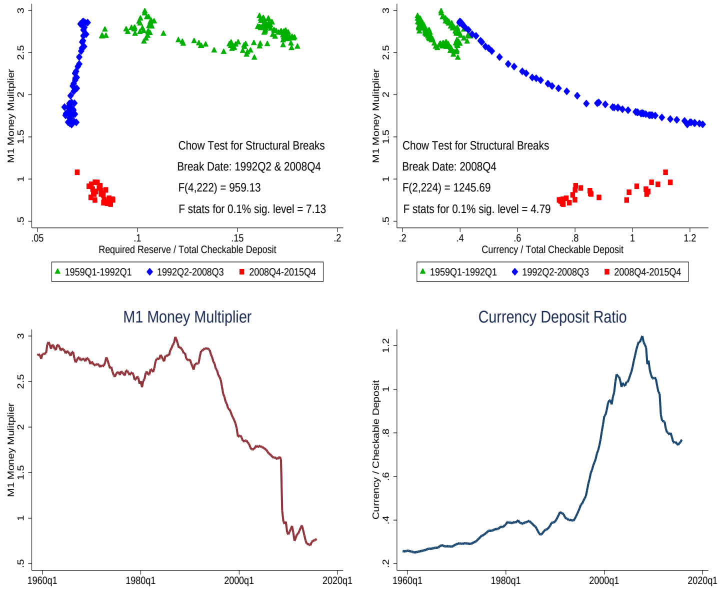

Figure 1: Money Multiplier, required reserve ratio, currency-deposit ratio

Chow Test | More Plot

Motivating Evidence

- The relationship between required reserve ratio and money multiplier is NOT clear whether banks are holding excess reserves or not.
- Two structural breaks: (i) 1992Q2 (ii) 2008Q4

Motivating Evidence

First structural break: 1992

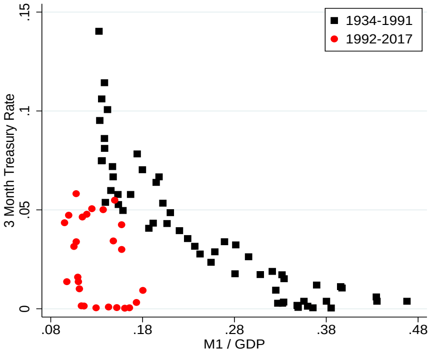

Figure 2: Money demand for M1

Motivating Evidence

First structural break: 1992

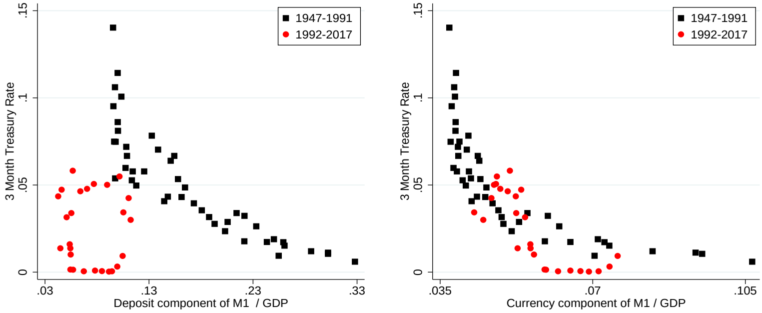

Figure 3: Money demand for M1 and its components

Motivating Evidence

- My hypothesis: the increased availability of consumer credit crowded out deposit but not cash.

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- Estimate the following as Ireland (2009) and Cagan (1956)

$$ln(m_t) = \beta_0 + \beta_1 r_t + \epsilon_t, \quad ln(d_t) = \beta_0 + \beta_1 r_t + \epsilon_t$$

money-income ratio m_t; deposit-income ratio d_t; interest rate r_t;

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$$ln(m_t) = \beta_0 + \beta_1 r_t + \epsilon_t, \quad ln(d_t) = \beta_0 + \beta_1 r_t + \epsilon_t$$

- add logarithm of uc, the ratio of unsecured credit to income.

$$ln(m_t) = \beta_0 + \beta_1 r_t + \beta_2 ln(uc_t) + \epsilon_t, \quad ln(d_t) = \beta_0 + \beta_1 r_t + \beta_2 ln(uc_t) + \epsilon_t$$

money-income ratio m_t; deposit-income ratio d_t; interest rate r_t;

Cointegration regressions and tests

Table 1: Cointegration regressions and tests

Dependent Variable:	$ln(m_t)$		$ln(d_t)$	
	OLS	CCR	OLS	CCR
	(1)	(2)	(3)	(4)
r_t	0.016^{***}	-0.027^{***}	0.049^{***}	-0.053^{***}
	(0.004)	(0.004)	(0.009)	(0.009)
$ln(uc_t)$		-0.279^{***}		-0.574^{***}
		(0.033)		(0.040)
$adjR^2$	0.109	0.970	0.229	0.962
N	112	112	112	112
Johansen $r = 0$	**15.004**	41.744	**14.934**	49.174
5% Critial Value for $r = 0$	15.41	29.68	15.41	29.68
1% Critial Value for $r = 0$	20.04	35.65	20.04	35.65
Johansen $r = 1$	0.027	**12.163**	0.26	**14.319**
5% Critial Value for $r = 1$	3.76	15.41	3.76	15.41
1% Critial Value for $r = 1$	6.65	20.04	6.65	20.04

Notes: Column (1),(3) report OLS estimates and column (2),(4) report the canonical cointegrating regression (CCR) estimates. First stage long-run variance estimation for CCR is based on Bartlett kernel and lag 1. For (1) and (2) Newey-West standard errors with lag 1 are reported in parentheses. Intercepts are included but not reported. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Johansen cointegration test results are reported in column (1)-(4). The data are quarterly from 1980Q1 to 2007Q4.

unit root test M2

Motivating Evidence

Second structural break and interest on reserves

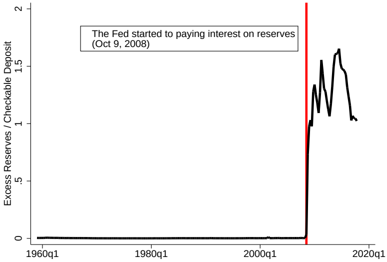

Figure 4: Excess reserves to checkable deposit ratio and interest rates

Motivating Evidence

Second structural break and interest on reserves

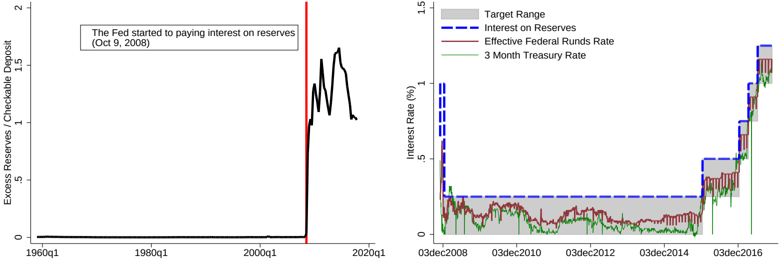

Figure 4: Excess reserves to checkable deposit ratio and interest rates

- Nakamura (2018): huge increase in reserves was simultaneous with the introduction of interest on reserves (IOR) but before the federal funds rate had hit the lower bound

Motivating Evidence

Second structural break and interest on reserves

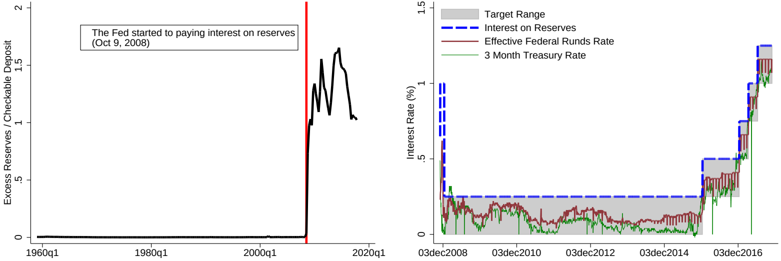

Figure 4: Excess reserves to checkable deposit ratio and interest rates

- Nakamura (2018): huge increase in reserves was simultaneous with the introduction of interest on reserves (IOR) but before the federal funds rate had hit the lower bound
- IOR has been an upper-bound for the target during most of time: Floor system? liquidity trap?

Motivating Evidence

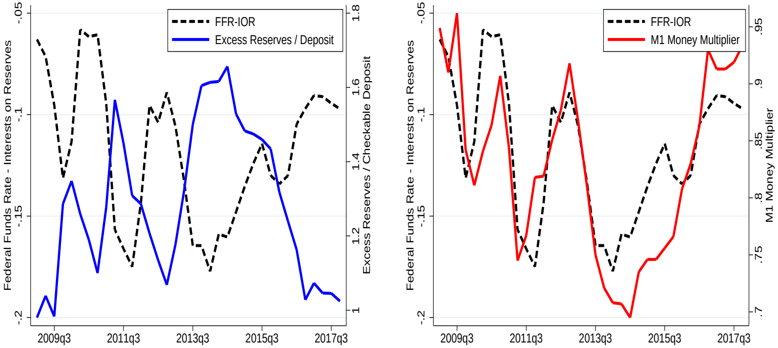

Figure 5: M1 multiplier and excess reserves in post-2008 period

Model

Environment

- Time, goods
- Buyers, sellers
- Preferences

Environment

- Time, goods
    1. $t = 0, 1, 2..., \infty$
    2. Each period has two subperiod:
       - Centralized Market (CM)
       - Decentralized Market (DM): bilateral trade
    3. Perishable DM/CM goods.
- Buyers, sellers
- Preferences

Environment

- Time, goods
- Buyers, sellers
  1. Buyer: measure 1; maximize life time utility;
  2. Seller: measure 1; maximize life time utility;
- Preferences

Environment

- Time, goods
- Buyers, sellers
- Preferences

$$\text{Buyer: } U(X) - H + u(q)$$

$$\text{Seller: } U(X) - H - c(q)$$

  - discount factor: β DM consumption q;
    CM consumption X; CM disutility for production H;

Different DM meetings

1. DM1: sellers only accept cash
2. DM2: sellers accept cash / claim on deposits / private bank note
3. DM3: sellers accept cash / claim on deposits / private bank note / unsecured credit
   (buyer's unsecured credit limit is exogenously given by $\bar{\delta}$)

- Type j DM meeting with prob σ_j
- $\sigma_1 + \sigma_2 + \sigma_3 = 1$
- In the CM, agents get to know which DM meeting they are going to

Central bank

- M is monetary base issued by the central bank.
- M is distributed to the economy in two ways: (1) C as cash in circulation; (2) R as reserves held by banks.

$$M = C + R$$

- i_r: Interest on Reserves; μ: money growth rate; T: lump-sum transfer (or tax),
- The central bank's budget constraint can be written as

$$\mu\phi M = \phi(M - M_{-1}) = T + i_r \phi R$$

- ϕ: price of money in terms of CM goods;

Bank

- measure n of active banks; max profit in each period;
  free entry with entry cost, k
- accepts deposits, $\tilde{d}$;
  issues claims on deposit (give deposit rate, i_d);
  can keep deposits as reserves, $\tilde{r}$;
  may earn some interest on reserves $i_r \geq 0$
- lends bank loans $\tilde{\ell}$; earns interest i_l
  issue same amount of private banknotes $\tilde{b} = \tilde{\ell}$;
- lending is constrained by reserves and reserve requirement;

$$\tilde{\ell} \leq \bar{\ell} = \frac{1-\chi}{\chi}\tilde{r}$$

- cost for operating claims on deposit, $\gamma(\tilde{d})$;
- costly enforcement to repay ℓ, $\eta(\tilde{\ell})$;

Bank's problem

- A risk-neutral bank max its profit by receiving deposits and lending loans.

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$$\max_{\tilde{r},\tilde{d}} \qquad - i_d \tilde{d}$$

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  loan, $\tilde{\ell}$, enforcement cost $\eta(\cdot)$

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- A risk-neutral bank max its profit by receiving deposits and lending loans.

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- A risk-neutral bank max its profit by receiving deposits and lending loans.

$$\max_{\tilde{r},\tilde{d}} \quad i_r \tilde{r} - i_d \tilde{d} - \gamma(\tilde{d})$$

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loan, $\tilde{\ell}$, enforcement cost $\eta(\cdot)$

Bank's problem

- A risk-neutral bank max its profit by receiving deposits and lending loans.

$$\max_{\tilde{r},\tilde{d},\tilde{\ell}} \quad i_r\tilde{r} - i_d\tilde{d} - \gamma(\tilde{d}) + i_l\ell$$

$$s.t. \;\; \tilde{r} \leq \tilde{d}$$

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$$s.t. \;\; \tilde{r} \leq \tilde{d} \quad \& \quad \underbrace{\frac{1-\chi}{\chi}\tilde{r}}_{\text{lending limit}} \geq \tilde{\ell}$$

- interest on reserves i_r. deposit operating cost $\gamma(\cdot)$.
  loan, $\tilde{\ell}$, enforcement cost $\eta(\cdot)$

Bank's problem

- $r = d$
- Two cases
  1. bank's lending is not binding.

$$0 = i_r - i_d - \gamma'(\tilde{r}) \tag{1}$$
$$0 = i_\ell - \eta'(\tilde{\ell}). \tag{2}$$

     bank's unconstrained optimal lending, ℓ^*, satisfies: $i_\ell = \eta'(\ell^*)$
  2. bank's lending is binding.

$$0 = i_r - i_d - \gamma'(\tilde{r}) + \left[i_\ell - \eta'(\tilde{\ell})\right]\frac{1-\chi}{\chi}. \tag{3}$$

- The bank's ex post profit equals to the entry cost, k

$$(i_r - i_d)\tilde{r} + i_\ell\tilde{\ell} - \gamma(\tilde{r}) - \eta(\tilde{\ell}) = k$$

DM trade

- Bargaining is characterized by payment and quantity (p, q).
- Kalai (1977)'s proportional bargaining
  $\Rightarrow p = z(q) = (1 - \theta)u(q) + \theta c(q)$
- Payment p is constrained by their liquidity position L.

$$
\begin{aligned}
z(q_1) &= p_1 \leq L_1 = m_1 \\
z(q_2) &= p_2 \leq L_2 = m_2 + d_2(1 + i_d) + b_2 \\
z(q_3) &= p_3 \leq L_3 = m_3 + d_3(1 + i_d) + b_3 + \bar{\delta}
\end{aligned}
$$

- m: money; d: deposit; $\bar{\delta}$: unsecured credit limit;
  b: private banknote issued by a bank; i_d: deposit rate
- all variables are expressed in terms of CM consumption good.

Buyers' CM problem

CM value function for buyer

$$W^B(m,d,b,\ell,\delta) = \sum \sigma_j W_j^B(m,d,b,\ell,\delta)$$

CM value function for j type DM meeting buyer

$$W_j^B(m,d,b,\ell,\delta) = \max_{X,H,\hat{m}_j,\hat{d}_j,\hat{\ell}_j,\hat{b}_j} U(X) - H + \beta V_j^B(\hat{m}_j,\hat{d}_j,\hat{b}_j,\hat{\ell}_j)$$

subject to

$$(1+\pi)\hat{m}_j + (1+\pi)\hat{d}_j + X = m + (1+i_d)d + b - \delta - (1+i_l)\ell + H + \tau$$
$$\hat{b}_j = \hat{\ell}_j$$

π: inflation rate; τ: lump-sum transfer/tax to buyer;

DM buyer's problem

DM1 value function

$$V_1^B(m, d, b, \ell) = u(q) + W^B(m - \tilde{m}, d, b, \ell, 0)$$
$$p = \tilde{m}$$

DM2 value function

$$V_2^B(m, d, b, l) = u(q) + W^B(m - \tilde{m}, d - \tilde{d}, b - \tilde{b}, \ell, 0)$$
$$\text{where } p = \tilde{m} + (1 + i_d)\tilde{d} + \tilde{b}$$

DM3 value function

$$V_3^B(m, d, b, l) = u(q) + W^B(m - \tilde{m}, d - \tilde{d}, b - \tilde{b}, \ell, \delta)$$
$$\text{where } p = \tilde{m} + (1 + i_d)\tilde{d} + \tilde{b} + \delta \qquad \delta \leq \bar{\delta}$$

Equilibrium

- The market clearing conditions are

$$
\begin{aligned}
\sigma_2 \ell_2 + \sigma_3 \ell_3 &= n\tilde{\ell} = \ell \\
\sigma_2 d_2 + \sigma_3 d_3 &= n\tilde{r} = r = \phi R \\
\sigma_1 m_1 + \sigma_2 m_2 + \sigma_3 m_3 &= m = \phi C
\end{aligned}
$$

- Focus on stationary equilibrium where real balances are constant:

$$\phi/\phi^+ = M^+/M = C^+/C = 1 + \mu$$

- By the Fisher equation, $i \equiv (1+\mu)/\beta - 1$

Equilibrium

Definition (**Stationary Monetary Equilibrium**)

Given monetary policy, (i, i_r, χ) and credit limit $(\bar{\delta})$, a stationary monetary equilibrium is consists of real quantities $(m_j, d_j, \ell_j)_{j=1}^{3}$, consumption quantities (q_1, q_2, q_3), and prices (i_l, i_d), such that:

1. $(i_d, i_l, q_1, q_2, q_3)$ solves agents' problem and bank's problem
2. The bank lending constraint satisfies, $\tilde{\ell} = \min(\bar{\ell}, \ell^*)$ where $\bar{\ell} = \frac{1-\chi}{\chi}\tilde{r}$ and $i_l = \eta'(\ell^*)$
3. Asset markets clear

Three types of equilibrium

- $\ell^* \geq \bar{\ell} > 0$: A scarce-reserves equilibrium

$$\tilde{\ell} = \bar{\ell} = \frac{1-\chi}{\chi}\tilde{r} < \ell^*$$

- $\bar{\ell} > \ell^* \geq 0$: A ample-reserves equilibrium

$$\tilde{\ell} = \ell^* < \bar{\ell} = \frac{1-\chi}{\chi}\tilde{r}$$

- $\bar{\ell} = 0$: A no-banking equilibrium

$$\tilde{\ell} = \bar{\ell} = \frac{1-\chi}{\chi}\tilde{r} = 0$$

Some Results

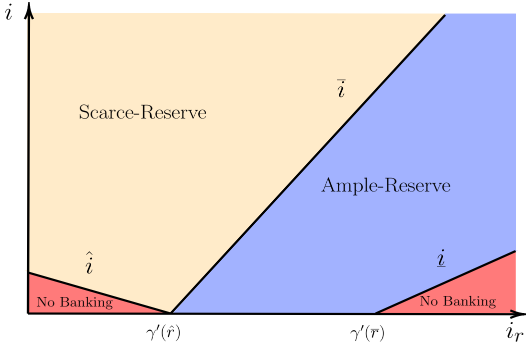

Figure 6: Monetary equilibrium regions in (i, i_r) space

- There exists an unique monetary equilibrium.
- Three types of equilibrium:
  (i) ample-reserve, (ii) scarce-reserve, (iii) no-banking.

Interest on reserves and money demand

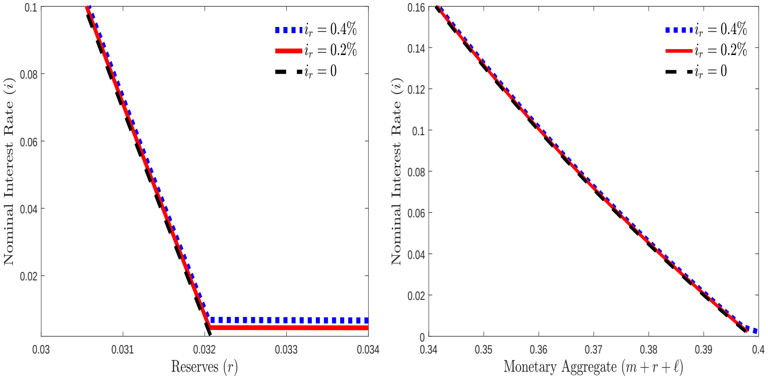

Figure 7: Demand for reserves and the monetary aggregate

Credit limit

In scarce and ample reserve equilibrium, better credit condition decrease the real balance of reserves i.e.,

$$\frac{\partial r}{\partial \bar{\delta}} < 0$$

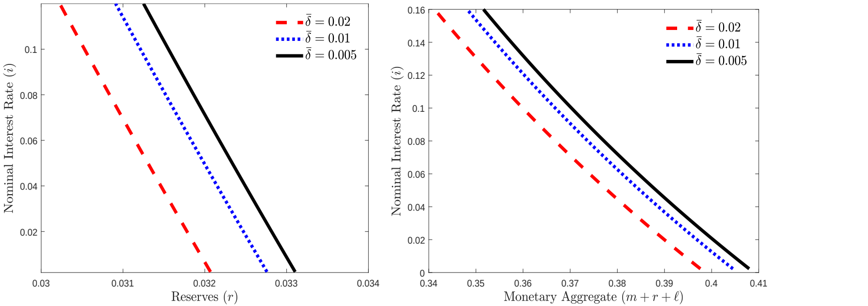

Figure 8: Demand for reserves and the monetary aggregate with different credit limits

Money multiplier

Define money multiplier $\zeta \equiv (m + r + \ell)/(m + r)$ then we have following results:

Proposition

In the ample-reserve and scarce-reserve equilibrium, better credit condition lowers money multiplier as long as $m > 0$ and $\chi < 1$ and i.e.,

$$\frac{\partial \zeta}{\partial \bar{\bar{\delta}}} < 0 \quad \text{if } m > 0 \ \& \ \chi < 1.$$

In ample reserve equilibrium, for small m, we have

$$\frac{\partial \zeta}{\partial i} > 0, \quad \frac{\partial \zeta}{\partial i_r} < 0.$$

Quantitative Analysis

Parameterization

- The utility functions for DM and CM are $u(q) = Bq^{1-\gamma}/(1-\gamma)$ and $U(X) = \log(X)$.
- Cost function for DM is $c(q) = q$.
- $\eta(\tilde{\ell}) = E\tilde{\ell}^2$, $\gamma(\tilde{d}) = A\tilde{d}^a$
- In the model, the equilibrium is characterized by three policy variables (i, i_r, χ) and credit limit, $\bar{\delta}$.
- $\frac{\sigma_3\bar{\delta}}{X^*+\sigma_1 z(q_1)+\sigma_2 z(q_2)+\sigma_3 z(q_3)} = \frac{\text{Unsecured Credit}}{\text{GDP}} \Rightarrow \bar{\delta}$
- Model generates equilibrium by using $(i, i_r, \chi, \frac{\text{Unsecured Credit}}{\text{GDP}})$
- Calibration is based on 1968-2007. Compare in-sample fit (1968-2007) and out-of-sample fit (2008-2018)

Sensitivity analysis for measure of monetary policy

Parameterization

Table 2: Model parametrization

Parameter	Value	Target/source	Data	Model
External Parameters				
Deposit cost curvature, a	1.2	Set Directly		
DM3 matching prob, σ_3	0.69	SCF 1970-2007		
Internal Parameters				
bargaining power, θ	0.454	avg. retail markup	1.384	1.384
enforcement cost level, E	0.001	avg. UC/DM	0.387	0.370
deposit operating cost level, A	0.0017	avg. R/Y	0.014	0.017
entry cost, k	0.0011	avg. Π/Y	0.0016	0.0011
DM1 matching prob, σ_1	0.187	avg. C/D	0.529	0.523
DM utility level, B	0.825	avg. C/Y	0.044	0.044
DM utility curvature, b	0.398	semi-elasticity of C/Y to i	-3.713	-3.712

Note: C, R, DM, D, UC, Y denote currency in circulation, reserves, DM transactions, deposit, unsecured credit and nominal output, respectively. Π denotes the net income of banks.

Fitted money demand for currency | Sensitivity analysis for measure of monetary policy | Sensitivity analysis

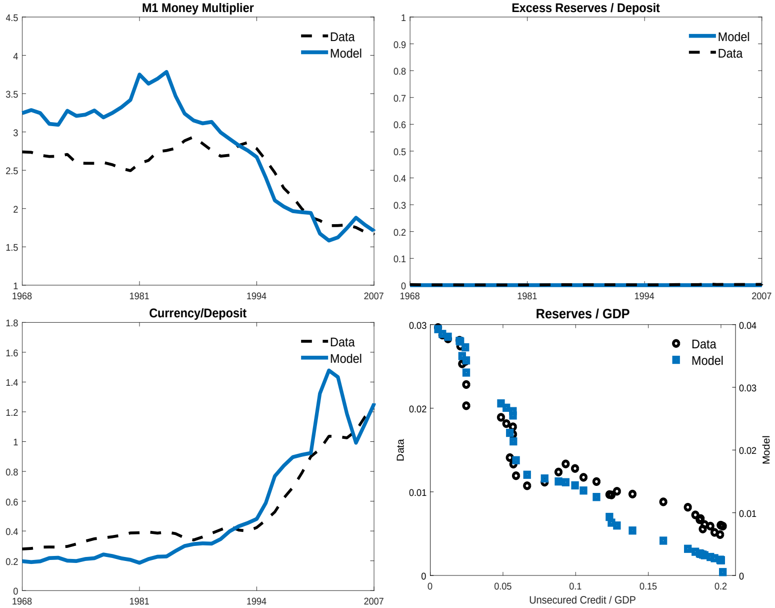

Figure 9: In-sample fit: 1968-2007

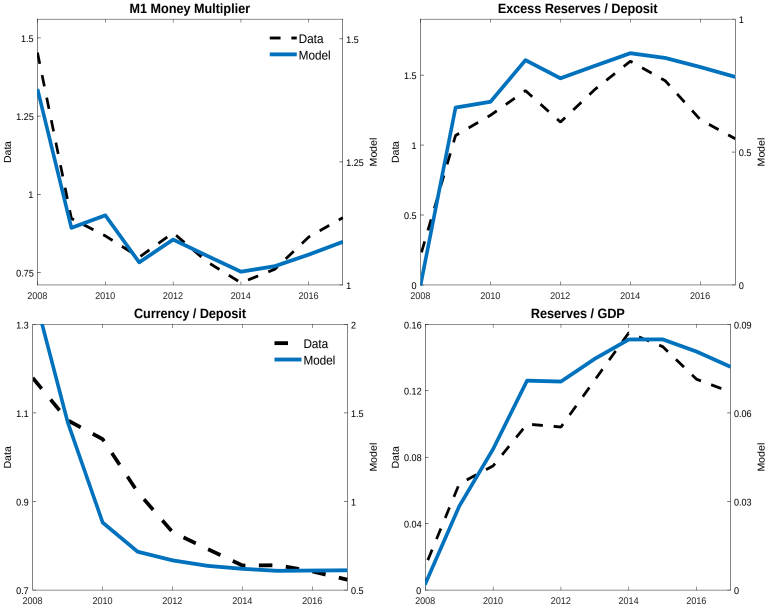

Figure 10: Out-of-sample fit: 2008-2017

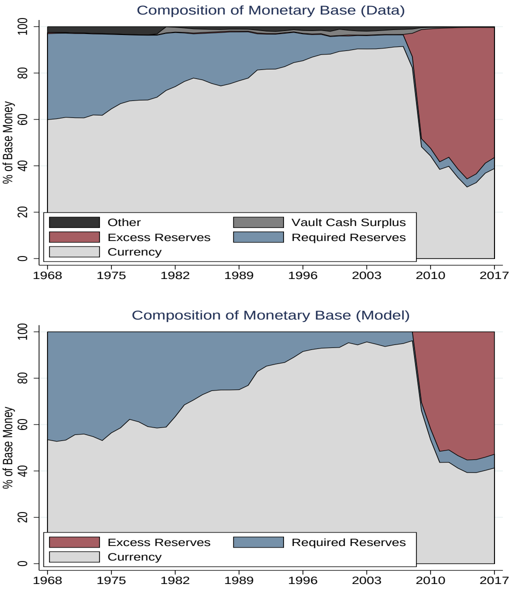

Figure 11: Composition of monetary base: data vs. model

Model-implied regression

Table 3: Model-implied regression coefficients, model vs. data

Dependent Variable:	Reserves/GDP (1968-2007)		M1 Money Multiplier (2009-2017)		Excess Reserve/Deposit (2009-2017)	
	Data (1)	Model (2)	Data (3)	Model (4)	Data (5)	Model (6)
Unsecured Credit/GDP	-0.125***	-0.200				
	(0.010)					
3 Month T-bill Rate	-0.001***	-0.001	0.686***	0.864	-1.561***	-1.697
	(0.000)		(0.184)		(0.498)	
Interest on Reserves			-0.648***	-0.848	1.461**	1.688
			(0.210)		(0.567)	
$adjR^2$	0.830	0.814	0.656	0.918	0.577	0.997

Notes: Columns (1)-(2) report the canonical cointegrating regression (CCR) estimates. First stage long-run variance estimation for CCR is based on Bartlett kernel and lag 1. Columns (3)-(6) report OLS estimates. For (3) and (5) Newey-West standard errors with lag 1 are reported in parentheses. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Intercepts are included but not reported.

More Quantitative Results

- Welfare effects are different across the agents. welfare
- Counterfactual analysis counterfactual analysis

Conclusion

- I construct monetary-search model of banking to investigate the money creation process.
- Use of unsecured credit crowds out inside money.
- Under empirically relevant conditions, money creation is not constrained by reserve requirements but still depends on the federal fund rates and interests on reserves.
- Quantitatively, the calibrated model can account for the behavior of money creation.

Thank You!

Appendix

Chow test

$$\begin{aligned}\text{Money multiplier}_t =& \beta_0 + \beta_1(\text{RequiredReserves/Deposit})_t \\ &+ \mathbf{1}_{t \geq 1992Q2}[\gamma_0 + \gamma_1(\text{RequiredReserves/Deposit})_t] \\ &+ \mathbf{1}_{t \geq 2008Q4}[\delta_0 + \delta_1(\text{RequiredReserves/Deposit})_t] + \epsilon_t\end{aligned}$$

F-statistics are obtained by testing $\gamma_0 = \gamma_1 = \delta_0 = \delta_1 = 0$.

$$\begin{aligned}\text{Money multiplier}_t =& \beta_0 + \beta_1(\text{Currency/Deposit})_t \\ &+ \mathbf{1}_{t \geq 2008Q4}[\delta_0 + \delta_1(\text{Currency/Deposit})_t] + \epsilon_t\end{aligned}$$

F-statistics are obtained by testing $\delta_0 = \delta_1 = 0$.

Back

Chow test for structural breaks

Table 4: Require Reserve Ratio

Dependent Variable: Money Multiplier	
RR	-0.601
	(0.365)
RR $\times$ $\mathbf{1}_{t \geq 1992Q2}$	132.279***
	(0.031)
RR $\times$ $\mathbf{1}_{t \geq 2008Q4}$	-147.943***
	(8.574)
$\mathbf{1}_{t \geq 1992Q2}$	9.091***
	(0.557)
$\mathbf{1}_{t \geq 2008Q4}$	0.074***
	(0.611)
Constant	2.813***
	(0.053)
Obs.	228
R^2	0.963
DF for numerator	4
DF for denominator	222
F Statistic for Chow test	1711.32
F Statistic for 1% sig. level	3.40
F Statistic for 0.1% sig. level	4.79

Back

Chow test for structural breaks

Table 5: Currency Deposit Ratio

Dependent Variable: Money Multiplier	
CD	-1.301***
	(0.027)
CD $\times$ $\mathbf{1}_{t \geq 2008Q4}$	-52.018***
	(4.995)
$\mathbf{1}_{t \geq 2008Q4}$	3.061***
	(0.409)
Constant	3.159***
	(0.015)
Obs.	228
R^2	0.974
DF for numerator	2
DF for denominator	224
F Statistic for Chow test	1245.69
F Statistic for 1% sig. level	4.70
F Statistic for 0.1% sig. level	7.13

Back

Unit Root Test

Table 6: Unit root test

	Phillips-Perron test	
	$Z(\rho)$	$Z(t)$
$ln(m)$	0.567	0.297
$ln(d)$	1.275	1.054
$ln(uc)$	-1.114	-1.710
r	-7.721	-2.471
$\Delta ln(m)$	-46.623***	-5.335***
$\Delta ln(d)$	-42.267***	-5.060***
$\Delta ln(uc)$	-41.998***	-5.107***
Δr	-94.183***	-9.263***

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Table 7: Unit root test and additional CCR estimates

(a) Unit root test

	Phillips-Perron test	
	$Z(\rho)$	$Z(t)$
`Tbill3`	-7.683	-1.967
`ffr`	-8.683	-2.121
UC/Y	-0.315	-0.450
R/Y(Data)	-1.735	-2.240
R/Y(Model)	-1.094	-1.861
Δ`Tbill3`	-24.363***	-4.514***
Δ`ffr`	-25.127***	-4.747***
$\Delta UC/Y$	-24.204***	-4.202***
$\Delta R/Y$(Data)	-26.473***	-4.329***
$\Delta R/Y$(Model)	-33.542***	-5.176***

(b) Canonical cointegrating regression

Dependent Variable:	Reserves/GDP (1968-2007)
UC/Y	-0.122***
	(0.004)
`ffr`	-0.064***
	(0.009)
Constant	3.058***
	(0.095)
Obs.	40
R^2	0.854
adj R^2	0.846
Long run S.E.	0.141

Notes: All series are demeaned before implementing the unit root test because the magnitude of the initial value can be problematic, as pointed out by Elliott & Müller (2006) and Harvey et al. (2009). ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively.

Back to model-implied regreession

Table 8: Johansen test for cointegration

(a) UC/Y, Tbill3 and R/Y (Data)

Max rank	$\lambda_{trace}(r)$	5% CV	1% CV
0	39.5289	29.68	35.65
1	**6.3521**	15.41	20.04
2	1.7359	3.76	6.65

Max rank	$\lambda_{max}(r, r+1)$	5% CV	1% CV
0	33.1768	20.97	25.52
1	**4.6162**	14.07	18.63
2	1.7359	3.76	6.65

(b) UC/Y, Tbill3 and R/Y (Model)

Max rank	$\lambda_{trace}(r)$	5% CV	1% CV
0	46.8658	29.68	35.65
1	**10.2012**	15.41	20.04
2	3.2950	3.76	6.65

Max rank	$\lambda_{max}(r, r+1)$	5% CV	1% CV
0	36.6646	20.97	25.52
1	**6.9063**	14.07	18.63
2	3.2950	3.76	6.65

Back to model-implied regreession

Table 9: Johansen test for cointegration

(a) UC/Y, ffr and R/Y (Data)

Max rank	$\lambda_{trace}(r)$	5% CV	1% CV
0	42.2554	29.68	35.65
1	**6.1539**	15.41	20.04
2	1.7615	3.76	6.65

Max rank	$\lambda_{max}(r, r+1)$	5% CV	1% CV
0	36.1015	20.97	25.52
1	**4.3924**	14.07	18.63
2	1.7615	3.76	6.65

(b) UC/Y, ffr and R/Y (Model)

Max rank	$\lambda_{trace}(r)$	5% CV	1% CV
0	46.4585	29.68	35.65
1	**10.1184**	15.41	20.04
2	3.2950	3.76	6.65

Max rank	$\lambda_{max}(r, r+1)$	5% CV	1% CV
0	36.3401	20.97	25.52
1	**6.9882**	14.07	18.63
2	3.1302	3.76	6.65

Back to model-implied regreession

Money demand for M2 and its components

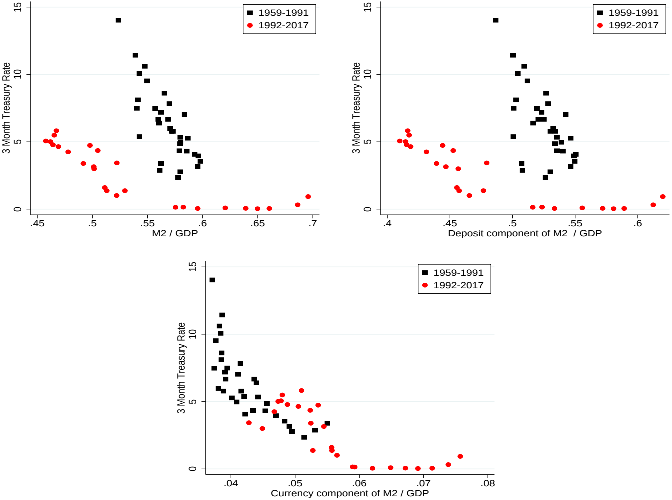

Figure 12: Money demand for M2 and its components

Cointegration regressions and tests (M2)

Table 10: Cointegration regressions and tests (M2)

Dependent Variable:	$ln(m_t)$		$ln(d_t)$	
	OLS	CCR	OLS	CCR
	(1)	(2)	(3)	(4)
r_t	0.009***	−0.019***	0.013***	−0.020***
	(0.002)	(0.002)	(0.002)	(0.003)
$ln(uc_t)$		−0.182***		−0.225***
		(0.024)		(0.027)
$adjR^2$	0.133	0.306	0.201	0.288
N	112	112	112	112
Johansen $r = 0$	**18.582**	40.396	**19.210**	39.421
5% Critial Value for $r = 0$	15.41	29.68	15.41	29.68
1% Critial Value for $r = 0$	20.04	35.65	20.04	35.65
Johansen $r = 1$	2.762	**13.177**	2.713	**13.364**
5% Critial Value for $r = 1$	3.76	15.41	3.76	15.41
1% Critial Value for $r = 1$	6.65	20.04	6.65	20.04

Notes: Column (1),(3) report OLS estimates and column (2),(4) report the canonical cointegrating regression (CCR) estimates. First stage long-run variance estimation for CCR is based on Bartlett kernel and lag 1. For (1) and (2) Newey-West standard errors with lag 1 are reported in parentheses. Intercepts are included but not reported. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. Johansen cointegration test results are reported in column (1)-(4). The data are quarterly from 1980Q1 to 2007Q4.

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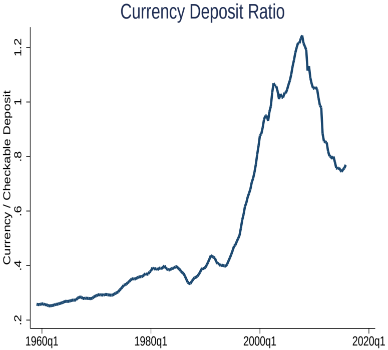
More plots



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Fitted money demand for currency

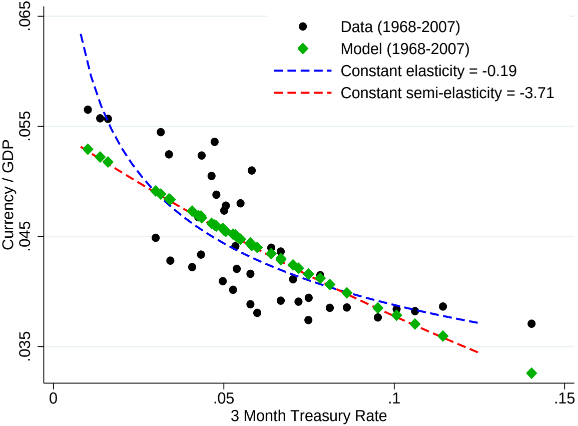

Figure 13: Money demand for currency

Model parametrization

Sensitivity analysis

Table 11: Using different measure of monetary policy

Interest	3 Month T-bill		CP		Federal Funds	
	Data	Model	Data	Model	Data	Model
Targets						
avg. retail markup	1.384	1.384	1.384	1.384	1.384	1.388
avg. C/Y	0.044	0.044	0.044	0.044	0.044	0.043
avg. R/Y	0.014	0.017	0.014	0.017	0.014	0.017
avg. C/D	0.529	0.520	0.529	0.520	0.529	0.512
avg. UC/DM	0.387	0.370	0.387	0.370	0.387	0.371
avg. Π/Y	0.0016	0.0011	0.0016	0.0011	0.0016	0.0011
semi-elasticity of C/Y	-3.716	-3.724	-3.713	-3.712	-3.020	-3.719

Note: C, R, DM, UC, Y denote currency in circulation, reserves, DM transactions, unsecured credit and nominal GDP, respectively.

Model parametrization

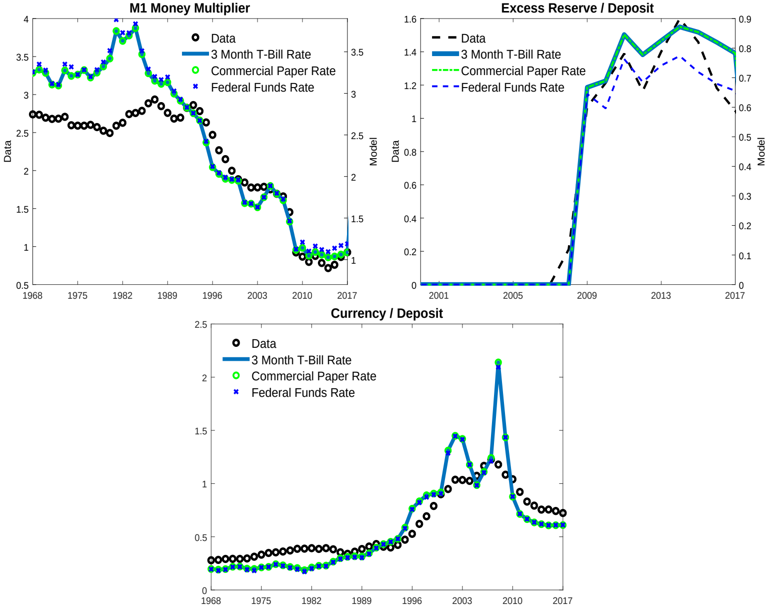

Figure 14: Model Fit using different measure of monetary policy

Model parametrization

Sensitivity analysis

Table 12: Alternative parametrizations

	Data	Baseline	Model 1	Model 2
External Parameters				
a		1.2	1.15	1.25
σ_3		0.69	0.69	0.69
Calibration targets				
avg. retail markup	1.384	1.384	1.384	1.384
avg. C/Y	0.044	0.044	0.044	0.044
avg. R/Y	0.014	0.017	0.017	0.017
semi-elasticity of C/Y	-3.713	-3.712	-3.712	-3.712
avg. C/D	0.529	0.520	0.520	0.520
avg. UC/DM	0.387	0.370	0.370	0.370
avg. Π/Y	0.0016	0.0011	0.0011	0.0011

Note: C, R, DM, UC, Y denote currency in circulation, reserves, DM transactions, unsecured credit and nominal GDP, respectively.

Model parametrization

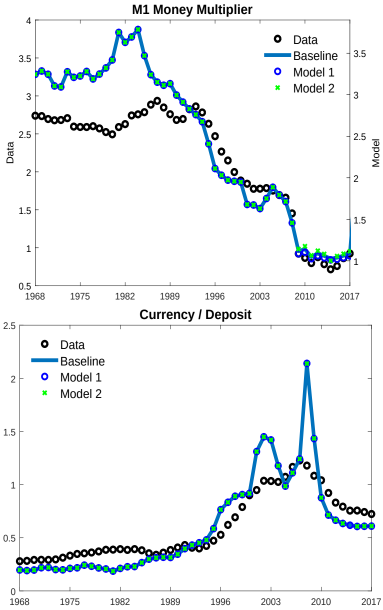

Figure 15: Model fit with different specifications

Model parametrization

Welfare I

- I measure the welfare of the seller in j type DM meeting using her DM trade surplus.

$$J_j^S(i, \chi, i_r) = (1-\theta)[u(q_j) - c(q_j)]$$

- and the welfare of the buyer who trades in the j type DM meeting is DM trade surplus with the cost for acquiring the cash and reserves.

$$J_j^B(i, \chi, i_r) = -im_j(i, \chi, i_r) - (i - i_d)r_j(i, \chi, i_r) + (1-\theta)[u(q_j) - c(q_j)]$$

- Then, I can define the total welfare as a weighted sum of each agents' welfare.

$$J(i, \chi, i_r) = \sum_{j=1}^{3} \sigma_j [J_j^B(i, \chi, i_r) + J_j^S(i, \chi, i_r)]$$

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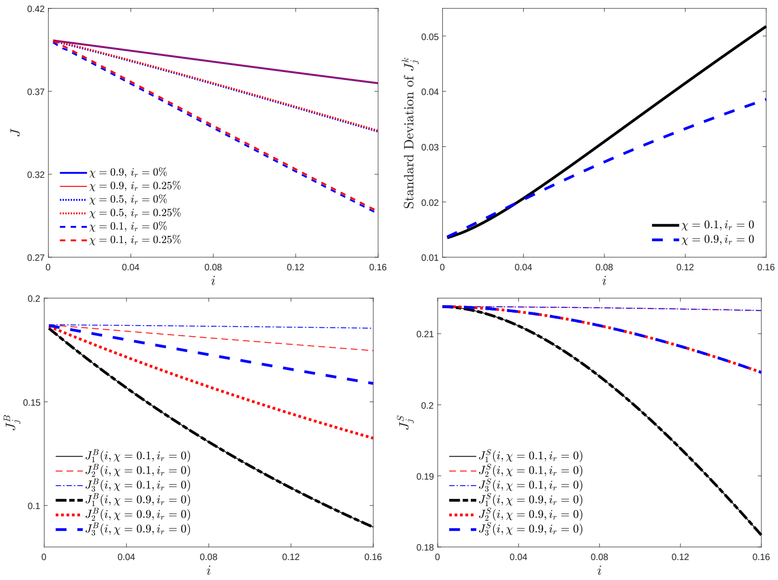
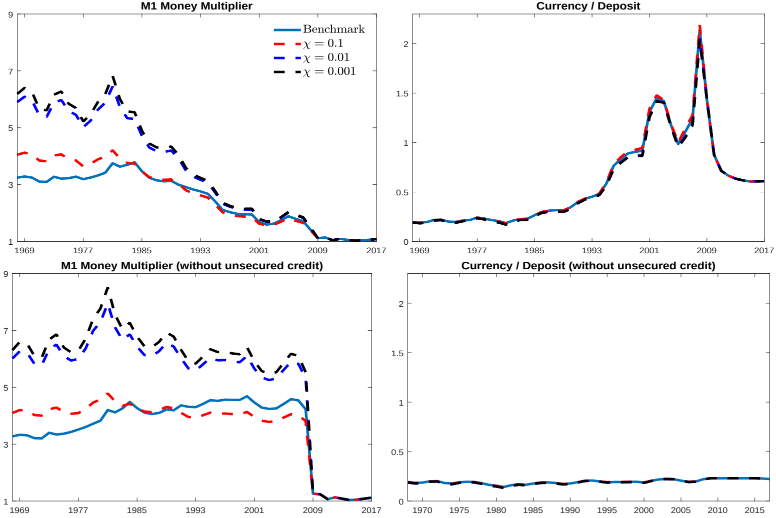

0.42
0.37
0.32
0.27
J
$\chi = 0.9,\ i_r = 0\%$
$\chi = 0.9,\ i_r = 0.25\%$
$\chi = 0.5,\ i_r = 0\%$
$\chi = 0.5,\ i_r = 0.25\%$
$\chi = 0.1,\ i_r = 0\%$
$\chi = 0.1,\ i_r = 0.25\%$
0
0.04
0.08
0.12
0.16
i
Standard Deviation of J_j^k
0.05
0.04
0.03
0.02
0.01
$\chi = 0.1, i_r = 0$
$\chi = 0.9, i_r = 0$
J_j^B
0.2
0.15
0.1
$J_1^B(i, \chi = 0.1, i_r = 0)$
$J_2^B(i, \chi = 0.1, i_r = 0)$
$J_3^B(i, \chi = 0.1, i_r = 0)$
$J_1^B(i, \chi = 0.9, i_r = 0)$
$J_2^B(i, \chi = 0.9, i_r = 0)$
$J_3^B(i, \chi = 0.9, i_r = 0)$
J_j^S
0.21
0.2
0.19
0.18
$J_1^S(i, \chi = 0.1, i_r = 0)$
$J_2^S(i, \chi = 0.1, i_r = 0)$
$J_3^S(i, \chi = 0.1, i_r = 0)$
$J_1^S(i, \chi = 0.9, i_r = 0)$
$J_2^S(i, \chi = 0.9, i_r = 0)$
$J_3^S(i, \chi = 0.9, i_r = 0)$

Counterfactual Analysis I



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