Managing Aggregate Liquidity:

The Role of a Central Bank Digital Currency

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Introduction

- Should central banks issue *digital currency*?
  - an electronic liability of the central bank (outside money)
    - could be an account balance or a cryptographic token
  - exchangeable on demand for existing forms of currency
  - can we held by a wide range of actors, including individuals
- If so, how should this currency be designed?
- Issue has been discussed by policy makers in many places
  - Canada, Sweden, Eurozone, China, others
  - U.S. (Dudley: "It's something we are starting to think about.")
- Raises a number of interesting (and difficult) questions

- There is a growing literature on the topic
  - expository: Bech and Garratt (2017)
  - discussions: BIS (2018), Berentsen (2018), Bordo and Leven (2017), Engert and Fung (2017), Fung and Halaburda (2016), Kahn, Rivandeneyra and Wong (2017), Ketterer and Andrade (2016), and others
  - policy speeches: Broadbent (2016), Mersch (2017), others
  - models: Barrdear and Kumhof (2016), Davoodalhosseini (2018)
  - plus blog posts, etc.
- However, the basic macroeconomic impacts are still not well understood
  - represents a potentially radical change in the monetary system
  - research is still in the early phases

- BIS (2018) divides possible concerns into four areas:
  - payment systems
  - monetary policy implementation and transmission
  - structure of the financial system
  - financial stability
- Our focus: possible disintermediation of banks
  - if many bank depositors switch to a CBDC ...
  - how will that affect bank lending? aggregate investment?
- Motivated in part by Bordo and Levin (2017)
  - they argue strongly in favor of a CBDC (and a particular design)
  - but are completely silent on this issue

Our approach

Study the effect of introducing a CBDC in a setting where:

- Both central bank money and deposits are used in exchange
  - as in Lagos and Wright (2005), many others
  - quantity and “quality” of available media of exchange matter
  - the potential exists for a CBDC to crowd out bank deposits
- Banks use deposits to finance productive investment
  - a decline in deposits can affect credit conditions, investment
- Financial frictions potentially limit investment
  - borrowing constraint as in Kiyotaki and Moore (1997) and others
  - allow for possibility that the level of investment is inefficient

Results

- A problem of *aggregate liquidity management* arises in our model
  - policies that help overcome the trading frictions ...
  - ... may worsen the investment friction
  - policy maker would like to balance these two competing concerns
- CBDC is a useful liquidity management tool
  - CBDC = a new form of outside money that can earn interest
  - better medium of exchange ⇒ helps overcome trading friction
  - choice of interest rate allows policy maker to influence the severity of the investment friction at the margin
- A CBDC can always raise welfare in our model
  - optimal interest rate depends on configuration of parameters

Outline

1. The environment

2. Equilibrium with no digital currency (baseline)

3. Introducing digital currency

4. Conclusions (so far)

1. The Environment

Time and agents

- Builds on the structure in Lagos & Wright (2005)
  - $t = 0,1,2, \ldots$
- Two sub-periods in each period
  - a centralized market (CM) — bank-financed investment, production
  - then a decentralized market with bilateral trade (DM) — liquidity affects production, exchange
- Three types of agents

1) buyers
2) sellers

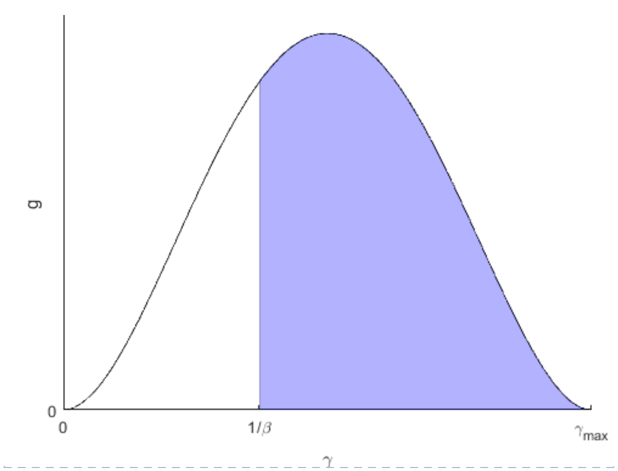
trade in the DM

3) bankers — finance (and operate) CM investment

- Plus a central bank that issues currency (physical and digital)

Bankers

- Live for two periods (new generation born each period)
- Only participate in the centralized market
- Have access to an indivisible production technology
  - requires input of 1 unit in CM when young
  - banker j: generates output γ_j in CM when old
  - $\gamma_j \sim [0, \overline{\gamma}]$ with cumulative distribution G and density function g
    - $\overline{\gamma} > \frac{1}{\beta} \Rightarrow$ some are productive
- No endowment $\Rightarrow$ must borrow
- Consume only when old
  - risk neutral

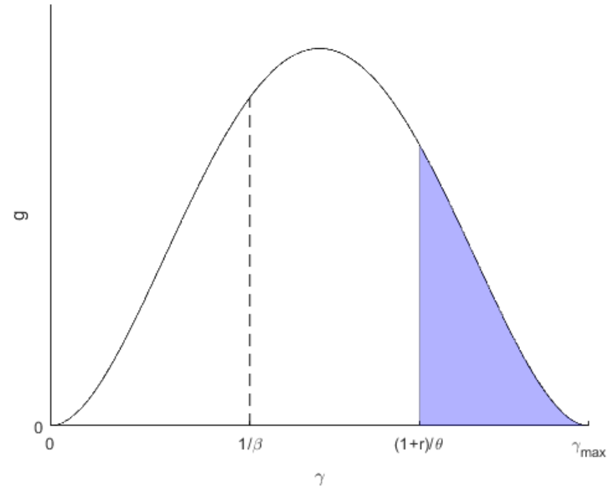


- Bankers can raise funds by issuing *deposits* in the CM
  - market for deposits is competitive; interest rate = $1 + r_t$
  - operating is profitable for banker j if:

$$\gamma_j \geq 1 + r_t$$

- Imperfect pledgeability:
  - bankers can abscond with a fraction $(1-\theta)$ of their output; need:

$$\boxed{1 + r_t \leq \theta \gamma_j}$$



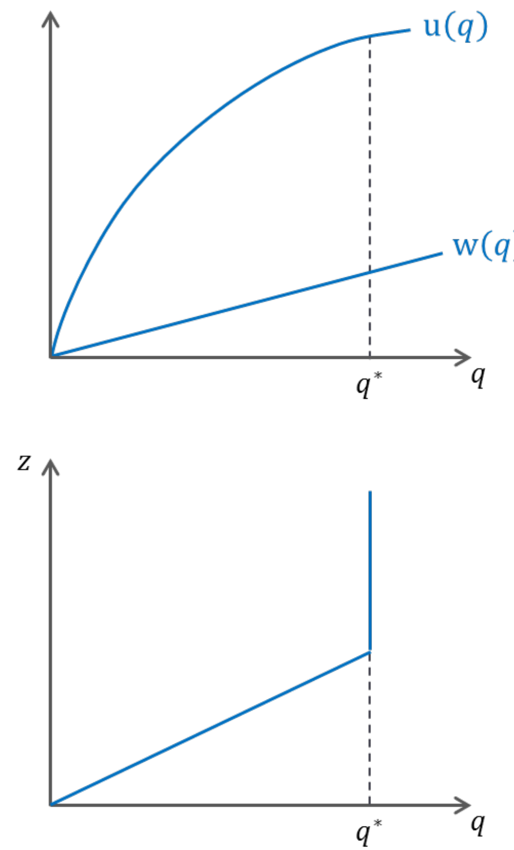
  - some productive projects may remain unfunded
  - as in Kiyotaki & Moore (1997, 2005), others

Buyers and sellers

- Buyers: like to consume the DM good $U^b = x_t^b + u(q_t)$
- Sellers: can produce the DM good $U^s = x_t^s - w(q_t)$
  - each is randomly matched in the DM with prob. $\alpha = 1$
  - discount rate: $\beta < 1$
- No bilateral credit in DM trades (due to anonymity)
  - purchases must be made with a medium of exchange
- Two types of sellers
  - type 1: only can accept cash
    - transactions where anonymity, low costs are important
  - type 2: only can accept deposits
    - large-value or long-distance transactions, for example

Buyers and sellers

- Buyer learns type of meeting in advance
  - exits the CM holding either cash or deposits
- When matched, buyer and seller bargain over quantity, price
  - assume buyer has all bargaining power (for simplicity)
- Outcome depends on buyer's liquid assets (z)
  - "liquid" = accepted by this seller
  - if small, buyer is liquidity constrained
  - if large, buyer consumes efficient quantity q^*



Central bank

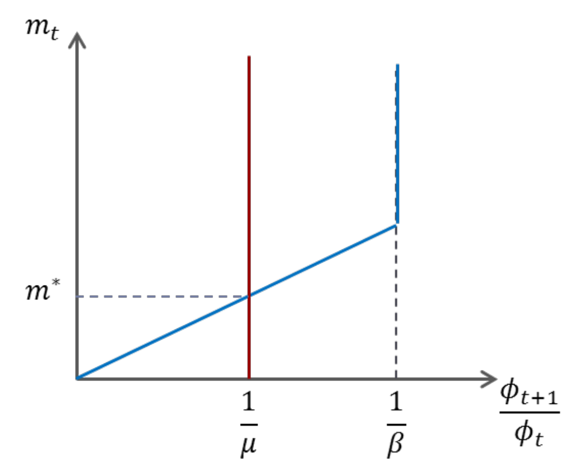
- The central bank supplies physical currency (M_t) and digital currency (E_t)
  - ϕ_t = real value of money (i.e., $\frac{\text{goods}}{\$}$); inflation rate= $\frac{\phi_t}{\phi_{t+1}}$
- Implements an inflation target: $\frac{\phi_t}{\phi_{t+1}} = \mu$ for all t (given)
  - stands ready to buy/sell CM goods at the desired price
  - and to exchange physical for digital currency one-for-one
  - financed as needed by lump-sum taxes/transfers
- Digital currency earns nominal interest rate $1 + i^e$
- Budget constraint:

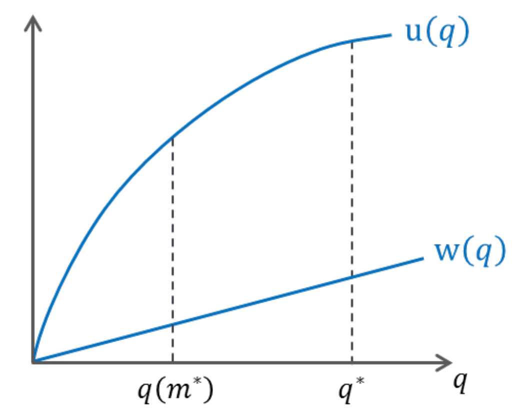
$$\phi_{t+1}(M_{t+1} + E_{t+1}) = \phi_t(M_t + (1 + i^e)E_t) + \tau_{t+1}$$

2. Equilibrium with no digital currency (baseline)

Cash buyers

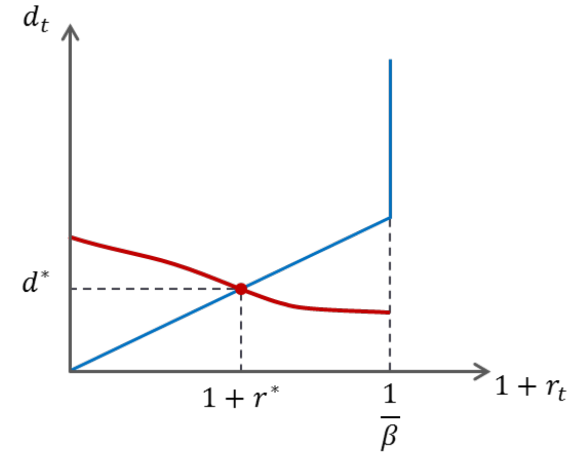
- Buyer entering a cash meeting chooses m_t based on rate of return
  - increasing function
  - vertical when return $= \frac{1}{\beta}$
- Monetary policy determines this return (inverse of the inflation rate)
  - hence determines equilibrium real balances m^*
- Real balances determine the amount of DM production, trade
  - if $\mu > \beta$, then $q(m^*) < q^*$
- Dichotomy: outcome is independent of deposit meetings



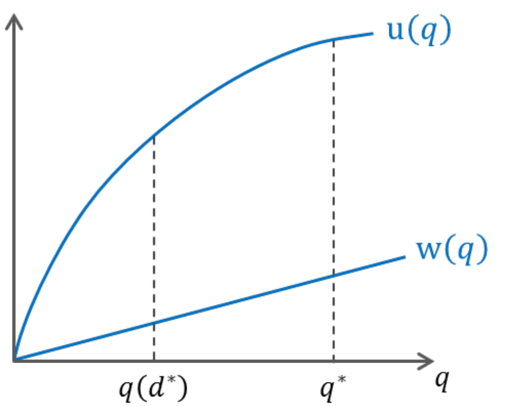


Deposit buyers

- Buyer entering a deposit meeting chooses d_t based on rate of return
  - increasing function
  - vertical when return $= \frac{1}{\beta}$



- Supply of deposits from banks will determine $1 + r$
  - and equilibrium real balances d^*
- Real deposits determine the amount of DM production, trade

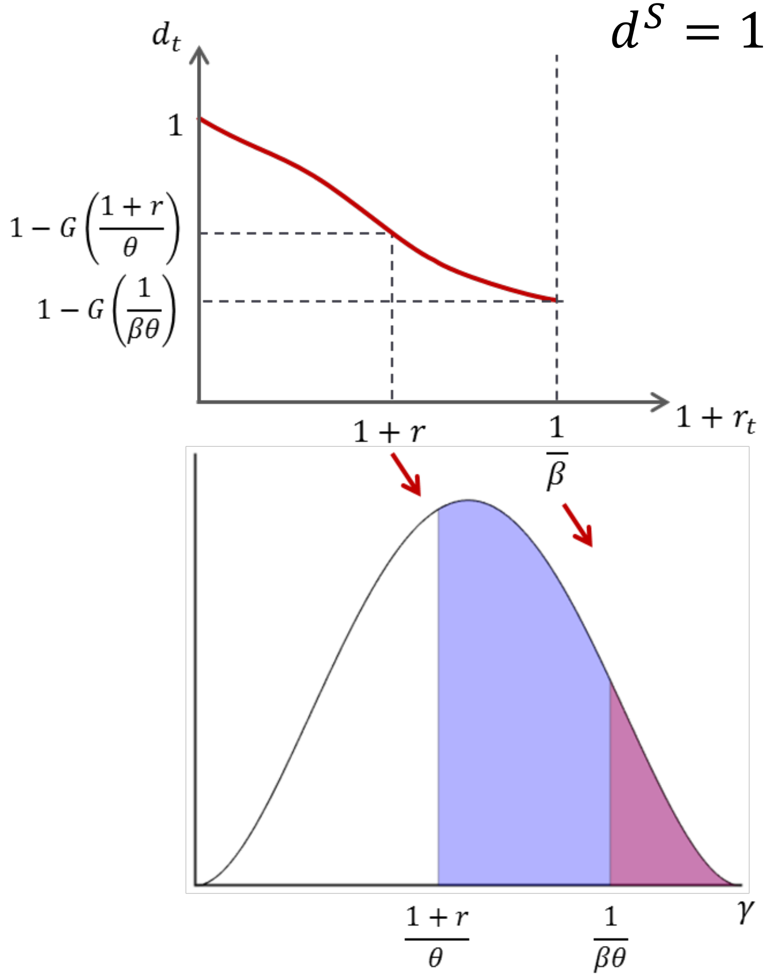


Q: What determines the supply of deposits?

Supply of deposits

- Supply of deposits depends on the distribution of projects

$$d^S = 1 - G\left(\frac{1+r_t}{\theta}\right)$$

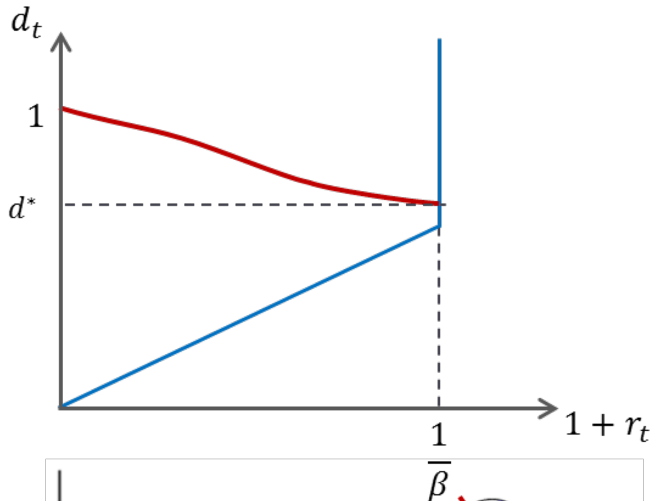


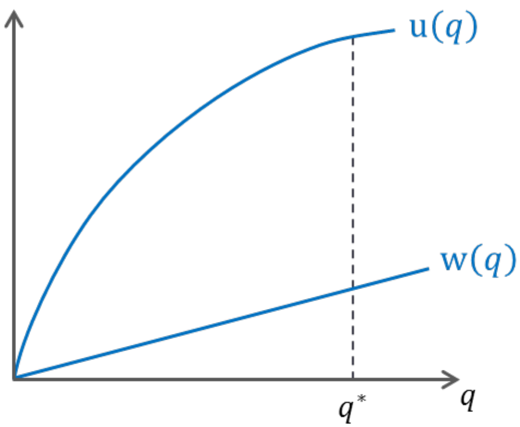
- When $1 + r_t = 0 \Rightarrow$ all projects are funded
  - supply of deposits is $d^S = 1$
- As r_t increases, fewer projects are viable
  - bankers issue fewer deposits

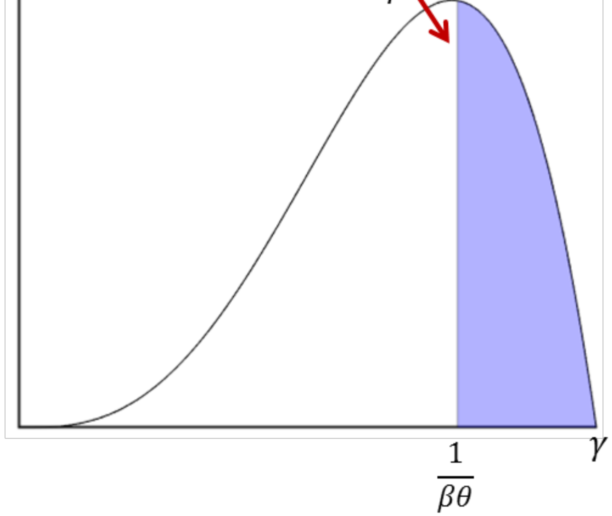
$\Rightarrow$ supply curve slopes downward

Equilibrium: three cases

A) High-return projects are plentiful

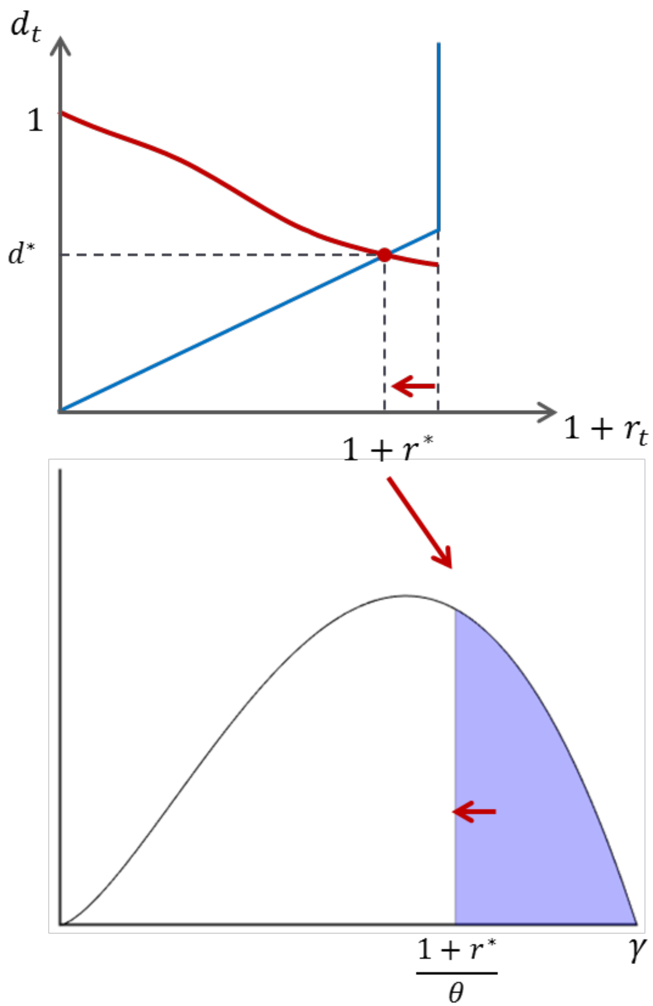


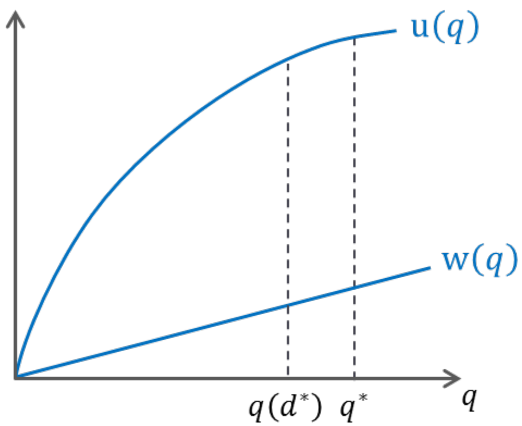




- Results:
  - $1 + r_0 = \frac{1}{\beta}$ (same as illiquid bond)
  - $q = q^*$ in deposit meetings
  - $\hat{\gamma} = \frac{1}{\theta\beta} > \frac{1}{\beta}$ (inefficiently high)

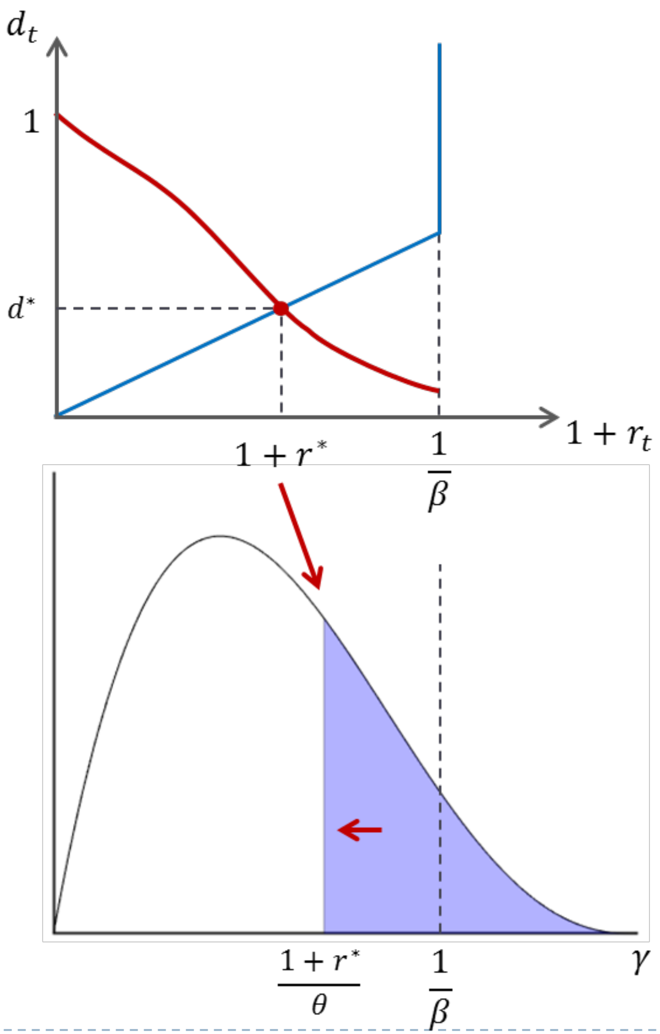
B) High-return projects are (somewhat) scarce

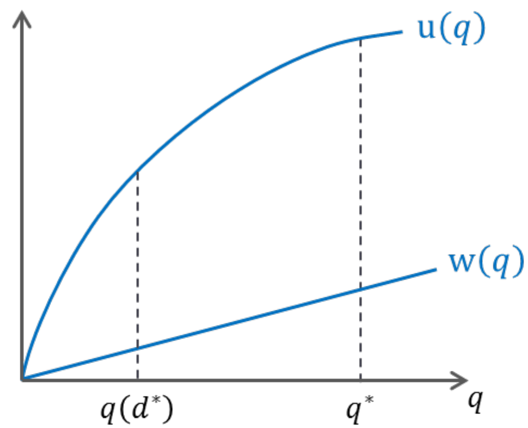




- Results:
  - $\frac{\theta}{\beta} < 1 + r_0 < \frac{1}{\beta}$ (liquidity premium)
  - $q < q^*$ in deposit meetings (worse)
  - $\frac{1}{\beta} < \hat{\gamma} < \frac{1}{\theta\beta}$ (better)

C) High-return projects are very scarce





- Results:
  - $1 + r_0 < \frac{\theta}{\beta}$ (↑ liquidity premium)
  - $q \ll q^*$ in deposit meetings (worse)
  - $\hat{\gamma} < \frac{1}{\beta}$ (too low!)

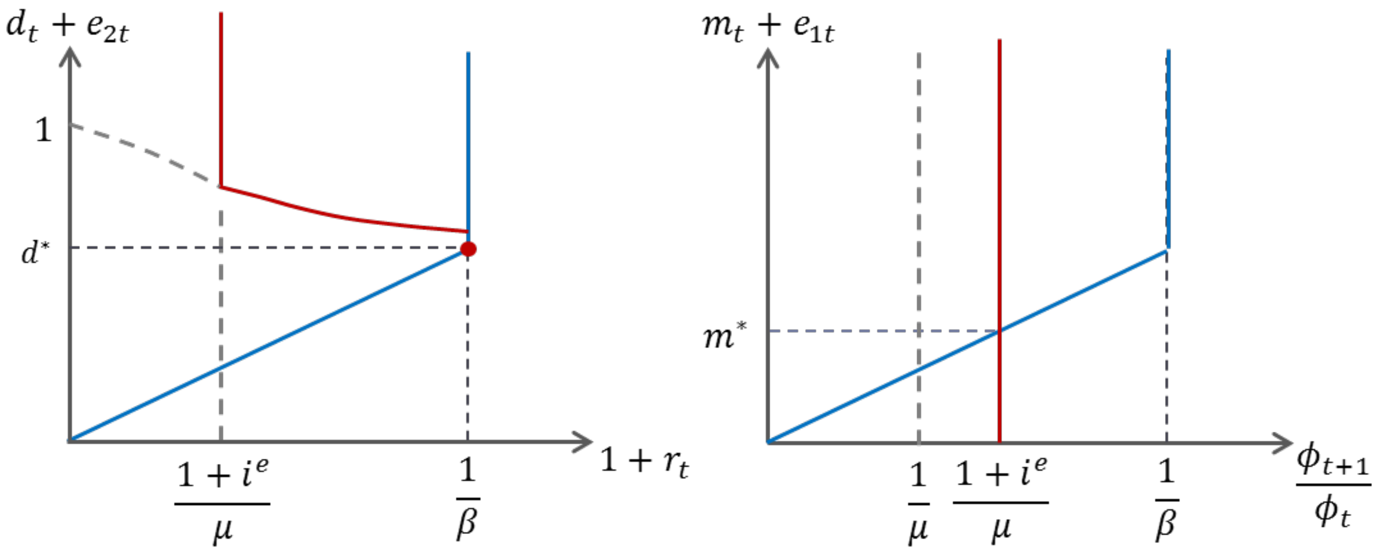
3. Introducing digital currency

What is a CBDC?

- CBDC is a form of outside money that can potentially:
  - earn interest at rate $1 + i^e$ (with i^e positive or negative)
  - be used in a different set of meetings as physical currency
- In the paper, we study three different possible "designs" in which the CBDC can be used in:
  - cash meetings only (anonymity, low fees)
  - deposit meetings only (accounts at the central bank?)
  - all meetings (a better technology) ⟵ today: focus on this case
- Ask:
  - how introducing a CBDC affects allocations, welfare
  - how the central bank should set the interest rate $1 + i^e$

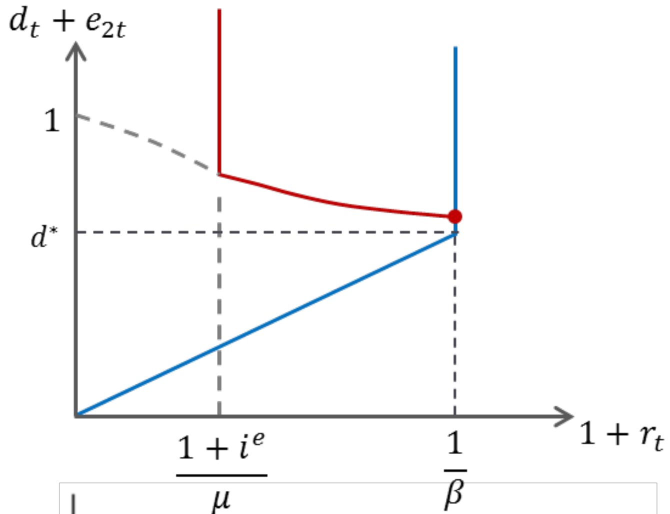
Effect on asset supply

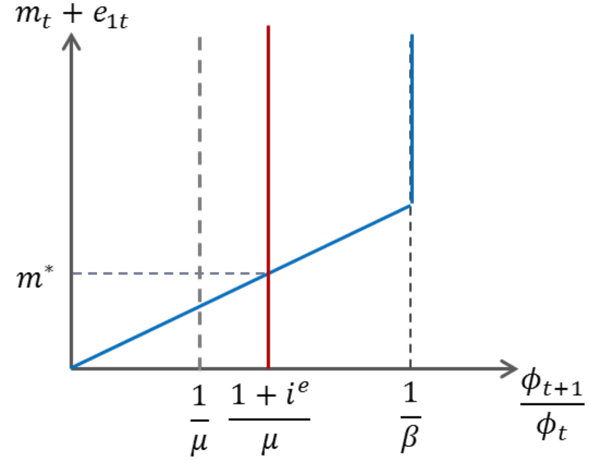
- In cash meetings, CBDC replaces physical cash if $i^e > 0$
  - raises real money balances m^* and DM trade q^*

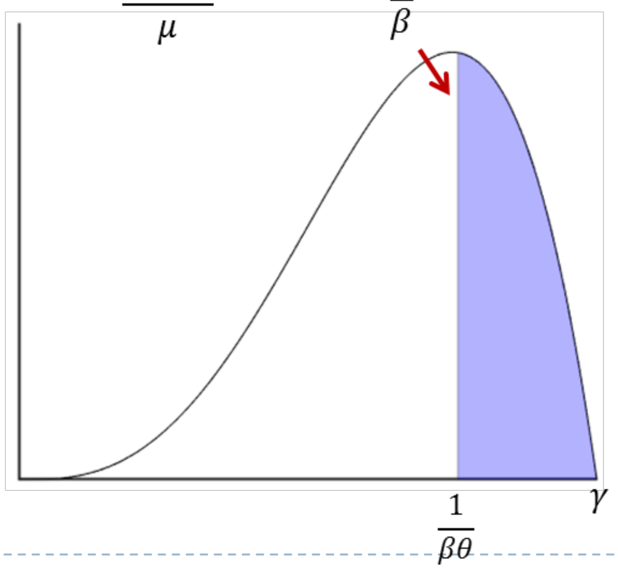


- In deposit meetings, CBDC places a lower bound on $1 + r$
  - may or may not bind, depending on $(1 + i^e)$ vs. $\mu(1 + r_0)$
  - need to examine the three cases ...

A) When high-return projects are plentiful







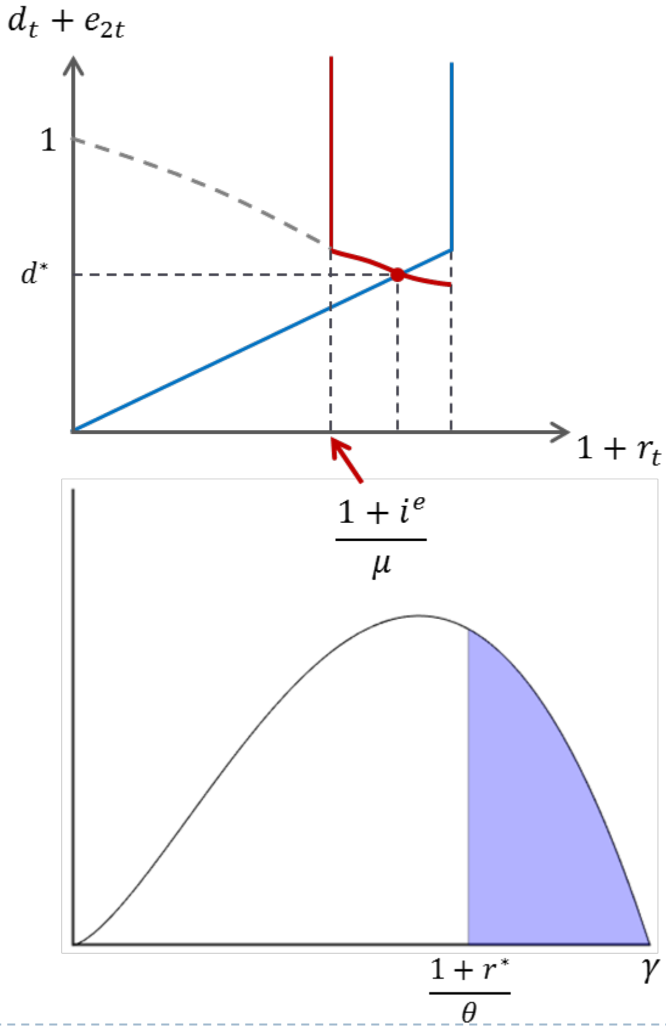
Results: For any $1 < 1 + i^e \leq \mu/\beta$

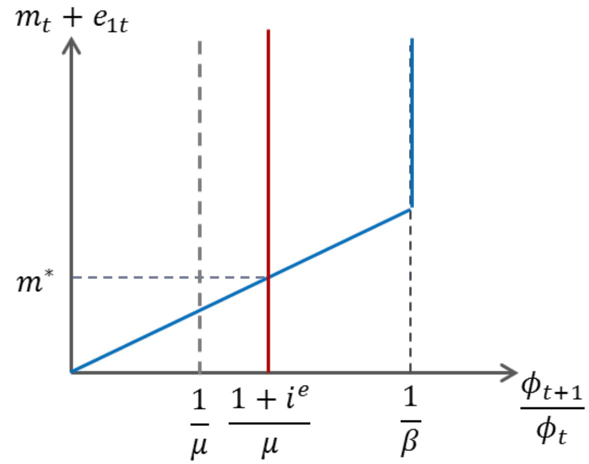
- CBDC replaces physical currency
- does not crowd out deposits or change CM investment
- always raises welfare

Optimal policy when high-return projects are plentiful:

- Central bank should set $1 + i^e = \frac{\mu}{\beta}$
  - an implementation of the Friedman rule
  - all DM production and exchange is efficient
  - matches recommendation of Bordo and Levin (2017), others?
- CM investment is inefficiently low because of the friction
  - but monetary policy cannot help solve this problem

B) When high-return projects (somewhat) scarce



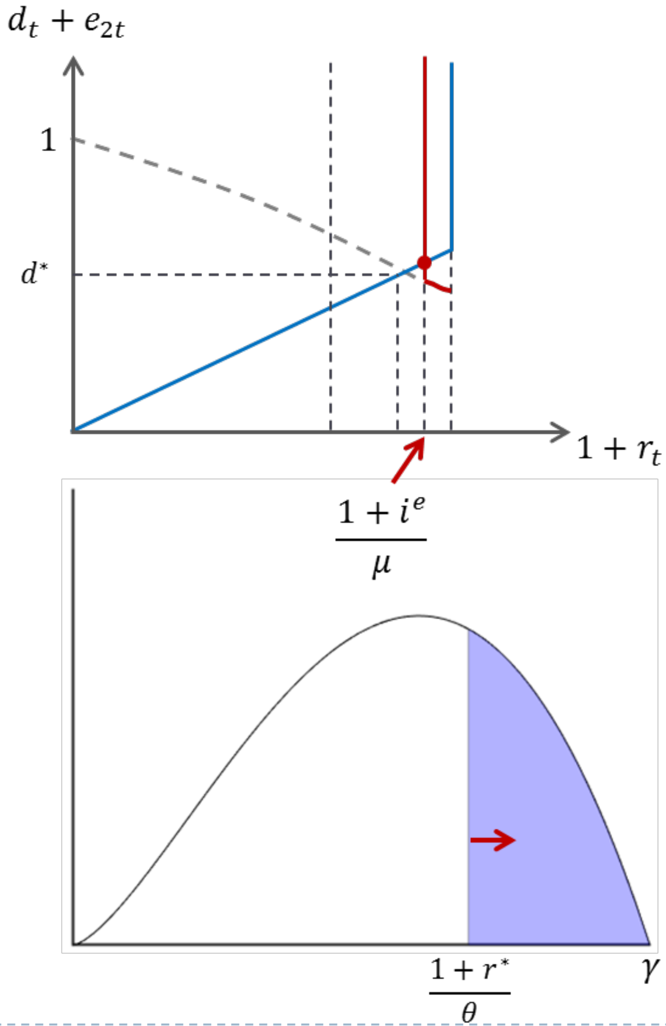


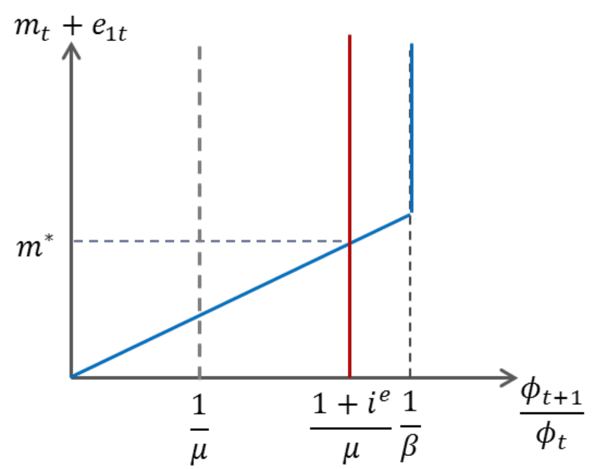
Results (i): For $1 < 1 + i^e \leq \mu\,(1 + r_0)$

- CBDC replaces physical currency
- does not crowd out deposits or change CM investment
- always raises welfare

same as before

B) When high-return projects (somewhat) scarce





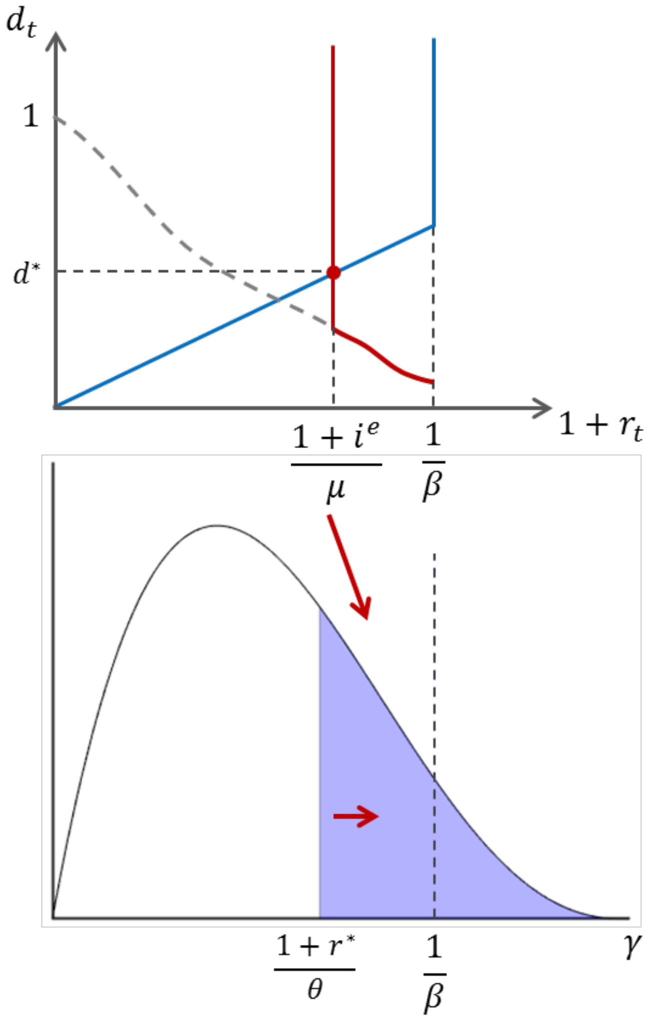
Results (ii): For $1 + i^e > \mu(1 + r_0)$

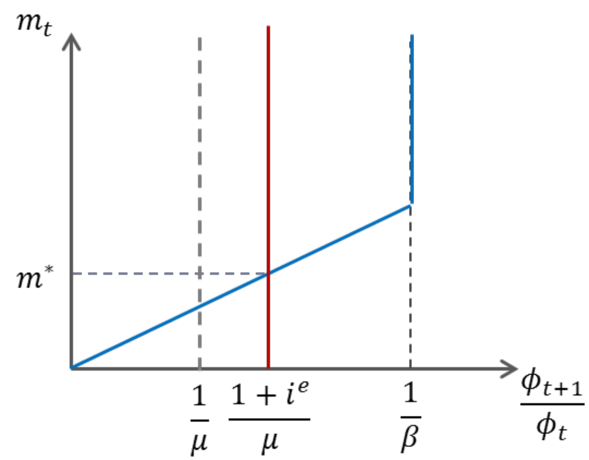
- CBDC begins to crowd out deposits
- raises q^* in all DM meetings
- increases $\hat{\gamma}$ (lower investment)
- may raise or lower welfare

Optimal policy when high-return projects are somewhat scarce:

- Central bank should at least set $1 + i^e \geq \mu(1 + r_0)$
  - below this point, increasing i^e improves cash meetings, with no effect on deposit meetings
- For $1 + i^e > \mu(1 + r_0)$, a tradeoff arises
  - higher i^e promotes DM efficiency in all meetings
  - but crowds out some productive investment
  - optimal choice of $1 + i^e$ balances these two concerns

C) When high-return projects are very scarce





Results: For $\mu(1+r_0) < 1 + i^e < \frac{\mu\theta}{\beta}$

- CBDC crowds out bank deposits
  - which is <u>good</u> in this case!
  - $\Rightarrow$ clearly raises welfare
- above $1 + i^e = \frac{\mu\theta}{\beta}$, the tradeoff arises

Optimal policy when high-return projects are very scarce:

- Optimal interest rate will satisfy $\frac{1+i^e}{\mu} > 1 + r_0$
  - will raise the equilibrium interest rate on deposits
  - and decrease equilibrium bank deposits, CM investment
- Above this point, the same a tradeoff arises
  - higher i^e promotes DM efficiency in all meetings
  - but crowds out some productive investment
  - optimal choice of $1 + i^e$ again balances these two concerns

4. Conclusions (so far)

Summarizing the results

- A CBDC can always be designed to raise welfare in our model
  - makes trade in cash meetings more efficient, but does <u>more</u>
  - provides a useful tool for managing aggregate liquidity
    - that is, influencing the liquidity premium and bank funding costs
- The shift away from bank deposits is a real concern ...
- ... but it can be managed by setting the interest rate on the CBDC appropriately
  - the model provides guidance how this rate should be set
- CBDC should earn interest at the market rate (on deposits)
  - may or may not be lower than the rate on an illiquid bond

Specifically

- In some cases, optimal policy sets $1 + i^e > \mu(1 + r_0)$
  - aim is to increase the market interest rate $1 + r$
    - that is, to reduce the liquidity premium
  - this will lead to "disintermediation" of deposits, but that is good
    - investment that is crowded out was socially unproductive
  - optimal if $\theta \approx 1$ or the current liquidity premium is large
- In other cases, optimal policy sets $1 + i^e = \mu(1 + r_0)$
  - aim to leave $1 + r$ unchanged (avoid crowding out deposits)
  - while providing a better medium of exchange
  - optimal when $\theta \ll 1$ and/or current liquidity premium is small

Caveats

1. We assumed CBDC and deposits are perfect substitutes

- But CBDC may be better than bank deposits
  - safer, lower transaction costs, etc.
- In normal times: need to adjust $1 + i^e$ accordingly
- In a crisis $\Rightarrow$ could make running on banks more attractive
  - this is a serious concern; requires more study

2. We also take the inflation rate μ as given (and not too small)

  - implicitly assume 2% inflation and $i^e = 3\%$ is better than 1% deflation (and $i^e = 0$)
  - is that reasonable? Or do we need to study these issues jointly?

End

Timeline

Summary so far

- If financial fictions are unimportant ($\theta \approx 1$):
  - set $1 + i^e$ high, so that $\frac{1+i^e}{\mu} = \frac{1}{\beta}$ (return on an illiquid bond)
  - if this leads to a shift out of bank deposits $\rightarrow$ good!
    - indication that bank lending was unduly subsidized
    - leading to the funding of undesirable projects
- If, however, financial frictions are significant ($\theta < 1$):
  - a problem of aggregate liquidity management arises
  - want a liquidity premium on deposits to mitigate the investment friction
  - but also want to have efficient production and exchange
  - CBDC is a usual tool for balancing these concerns

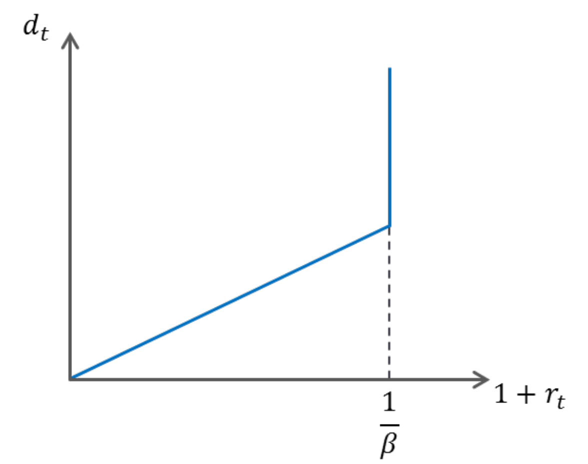
main takeaway

- [Chart detailing when there is/is not a liquidity premium and when the IODC rate is equal to the market rate]
- depends on assumption that μ is large enough $\left(> \frac{1}{1+r_0}\right)$

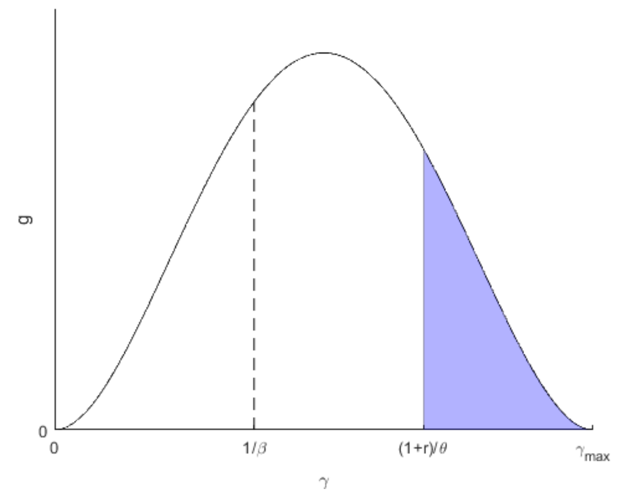
Supply of deposits

- Supply of deposits depends on the distribution of projects

$$D^S = 1 - G\left(\frac{1 + r_t}{\theta}\right)$$

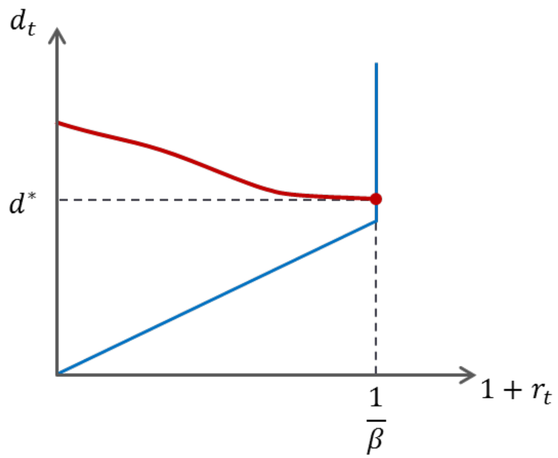


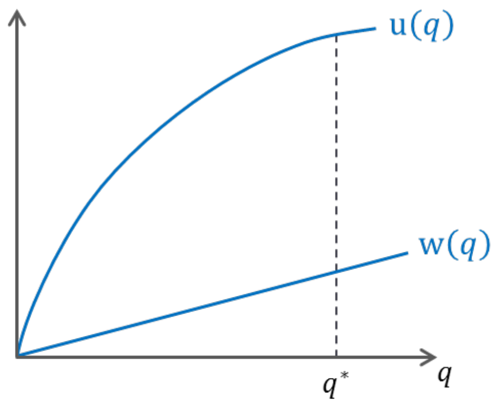
- When high-return projects are plentiful
  - deposit supply is large
  - $1 + r^* = \frac{1}{\beta}$ (same as an illiquid bond)
- When they are (somewhat scarce)
  - supply schedule is lower
  - and $1 + r^* < \frac{1}{\beta}$ (liquidity premium)
- When they are very scarce ...

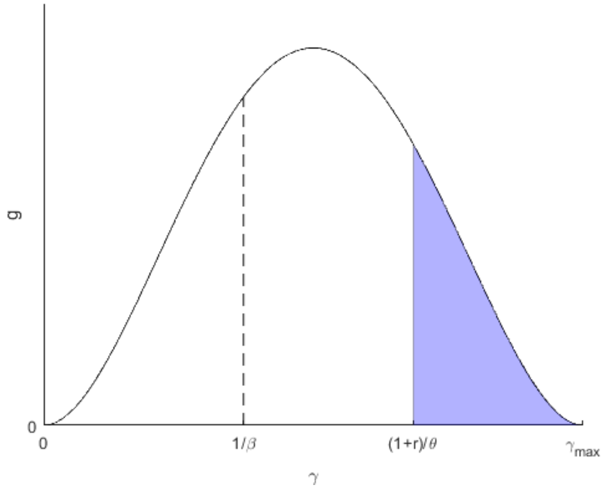


Equilibrium (A)

- When high-return projects are plentiful







- $1 + r^N = \frac{1}{\beta}$ (same as illiquid bond)
- $q = q^*$ in deposit meetings
- $\hat{\gamma} = \frac{1}{\theta\beta} > \frac{1}{\beta}$ (inefficiently low)

Cash meetings

- Buyer makes a take-it-or-leave-it offer
  - offer is a pair (q, Z) where $Z =$ money paid
- Buyers' offer will solve:

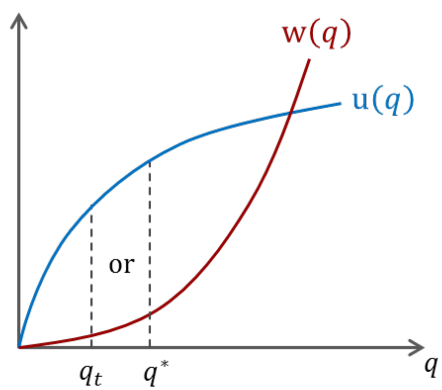
$$\max_{\{q,Z\}} \left(u(q) - \beta \left(\frac{Z}{P_{t+1}} \right) \right)$$

subject to: $\quad Z \leq M \quad$ (liquidity constraint)

$$w(q) \leq \beta \frac{Z}{P_{t+1}} \quad \text{(PC for seller)}$$

- Solution:

If:	q	Z
$\beta \frac{M}{P_{t+1}} < w(q^*)$	$q_t(M) < q^*$	M
$\beta \frac{M}{P_{t+1}} \geq w(q^*)$	q^*	$P_{t+1} w(q^*)/\beta$



Portfolio choice

- Bank acts to maximize the expected utility of buyers

- Choose portfolio in CM to solve:

$$\max_{\{M_t, b_t\}} -b_t - \frac{M_t}{P_t} + u(q_t(d_t)) - \beta z_t(d_t) + \beta\left[(1+r_t)\ell_t + \frac{M_t}{P_{t+1}}\right]$$

subject to the capital constraint: $d_t \leq \delta(1-r_t)\ell_t + \frac{P_t}{P_{t+1}} m_t$

and the terms of trade in the DM:

If:	q_t	z_t
$\beta d_t < w(q^*)$	$q_t(d_t) < q^*$	d_t
$\beta d_t \geq w(q^*)$	q^*	$w(q^*)/\beta$

- Banks will hold both money and loans only if

$$\frac{1}{\beta}\frac{P_{t+1}}{P_t} - 1 = \frac{1}{\delta}\left(\frac{1}{\beta(1+r_t)} - 1\right)$$

liquidity-adjusted returns must be equal

- Total asset demand will satisfy:

$$\frac{1}{\beta(1+r_t)} = \delta\frac{u'(q_t(M_t))}{w'(q_t(M_t))} + 1 - \delta$$

look at market return plus liquidity value

- Define money demand, loan supply: $m_t(r_t), \ell_t(r_t)$

- Loan demand in the CM is exactly as before:

$$\ell_t^D = 1 - G(\hat{\gamma}_t) \quad \text{with} \quad \hat{\gamma}_t = \frac{1+r_t}{\theta}$$

- Continue to focus on stationary equilibria

Central Bank Digital Currencies and Aggregate Liquidity

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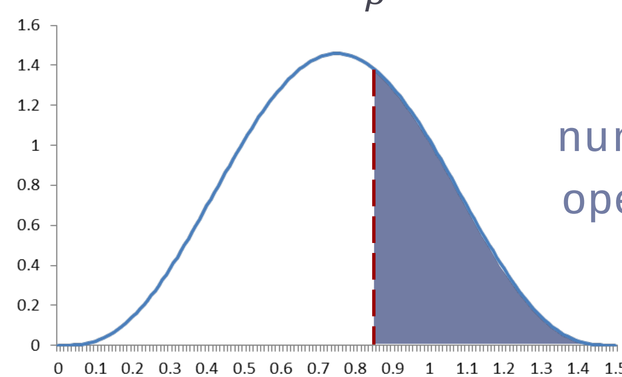
2. Efficient allocations

Efficient allocations

- Leave the credit frictions aside for now
- Planner chooses:
  - quantity produced in each DM match: q_t
  - a cutoff productivity above which entrepreneurs produce: $\hat{\gamma}_t$
- The two choices are separable (and stationary)
  - choose q to maximize the gains from DM trade $[u'(q^*) = w'(q^*)]$
  - chose $\hat{\gamma}$ so that all projects with return $\geq \frac{1}{\beta}$ are operated

number of projects operated: $1 - G\left(\frac{1}{\beta}\right)$



number of projects operated: $1 - G\left(\frac{1}{\beta}\right)$

3. Equilibrium without banks

A benchmark monetary model

- Buyers choose a portfolio of loans and money in the CM
  - assume sellers hold no assets (without loss of generality)
  - trade in DM requires the use of money

- Money supply evolves according to

$$\bar{M}_t = (1+\omega)\bar{M}_{t-1}$$

- Let P_t = general price level in period t

- Government budget constraint:

$$\frac{\bar{M}_{t-1}}{P_t} + \tau_t = \frac{\bar{M}}{P_t}$$

  - τ_t are lump-sum taxes/transfers (On whom? It doesn't matter.)

DM trade

- Assume buyers make a take-it-or-leave-it offer
  - offer is a pair (q, Z) where $Z =$ money paid
- Buyers' offer will solve:

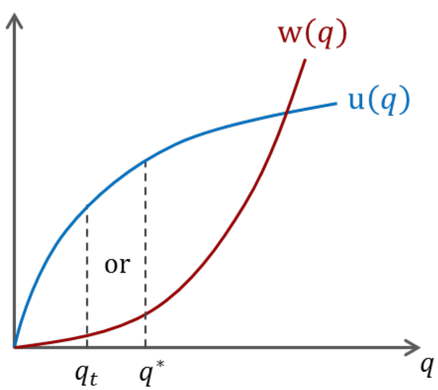
$$\max_{\{q,Z\}} \left(u(q) - \beta \left(\frac{Z}{P_{t+1}} \right) \right)$$

subject to: $Z \leq M$ (liquidity constraint)

$$w(q) \leq \beta \frac{Z}{P_{t+1}} \qquad \text{(PC for seller)}$$

- Solution:

If:	q	Z
$\beta \frac{M}{P_{t+1}} < w(q^*)$	$q_t(M) < q^*$	M
$\beta \frac{M}{P_{t+1}} \geq w(q^*)$	q^*	$P_{t+1} w(q^*)/\beta$



Buyers' portfolio choice

- Buyers choose a portfolio of money and loans in the CM

$$\max_{\{M_t,\ell_t\}} -\frac{M_t}{P_t} - \ell_t + u(q_t(M_t)) + \beta\left[\frac{M_t - Z_t(M_t)}{P_{t+1}} + (1+r_t)\ell_t\right]$$

  - subject to the terms of trade $q_t(M_t), Z_t(M_t)$ derived above

- Solution is characterized by:

these problems are essentially separable

$$M_t: \quad \frac{P_{t+1}}{P_t} = \beta\frac{u'(q_t(M_t))}{w'(q_t(M_t))}$$

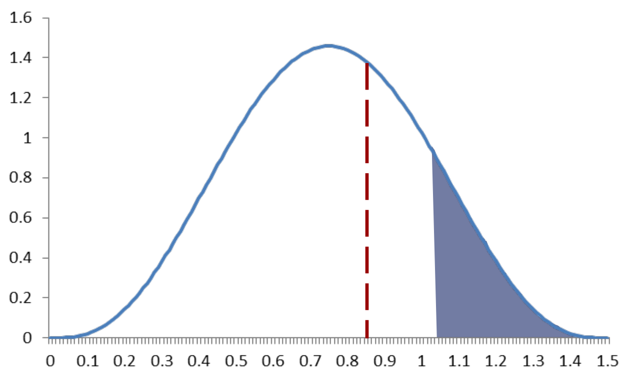
money demand depends on inflation

$$\ell_t: \quad 1 + r_t = \frac{1}{\beta}$$

loan supply is perfectly elastic

Entrepreneurs

- Entrepreneur i operates project if doing so is both:
  - profitable: $\gamma^i \geq 1 + r_t$
  - feasible: $\theta\gamma^i \geq 1 + r_t$
- $\theta < 1 \Rightarrow$ pledgeability constraint is the binding restriction
- Loan demand: $1 - G(\hat{\gamma})$
- Where: $\hat{\gamma} = \frac{1+r_t}{\theta}$



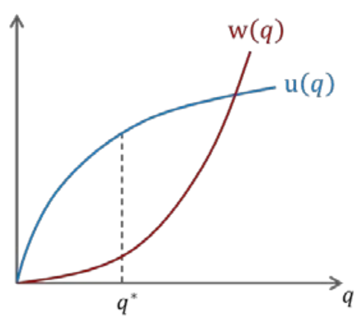
- Focus on stationary equilibria in which money has value

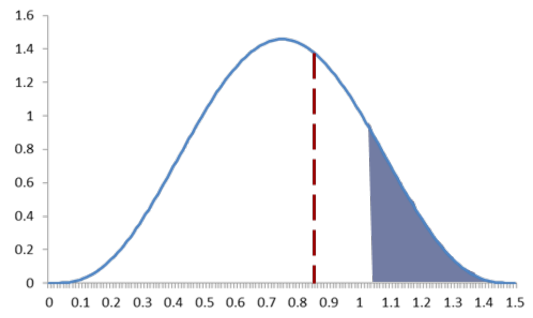
Results

Result 1: For any $\omega \in (\beta, \infty)$, there is a unique stationary monetary equilibrium with

$$\hat{\gamma} = \frac{1}{\theta\beta} \quad \text{and} \quad q = q(\omega)$$

- investment cutoff is inefficient because $\theta < 1$
- DM trade is efficient if and only if $\omega = \beta$ (Friedman rule)





Result 2: For any θ, optimal monetary policy corresponds to the Friedman rule

Result 3: Equilibrium is never efficient (first-best)