Can Currency Competition Work?

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Motivation

- The appearance of cryptocurrencies have triggered a wave of interest in privately issued monies: *Bitcoin*, *Ethereum*, and *Litecoin*
- 1 bitcoin is traded at $4,254 (as of September 12)
- Available supply: 16,560,625
- Market cap: $70.35 billion (Hershey Co market cap is 22.28 billion)
- Other 5 cryptocurrencies (*Ethereum*, *Steem*, *Ripple*, *Ethereum classic*, and *Litecoin*) have market caps over $100 million

An Intriguing Phenomenon for a Monetary Economist

- What are cryptocurrencies?
  - Cryptocurrencies are an outside money (of fiat nature) issued by a private agent
  - An intrinsically worthless asset (e.g., a Lucas tree that pays no dividend)
- Properties of cryptocurrencies:
  - Decentralized mechanism for transferring electronic tokens in bilateral trades (i.e., no trusted third party is required)
  - "Solves" double-spending problem

Inside and Outside Money

Outside money

Is either of a fiat nature (unbacked) or backed by some asset that is not in zero net supply within the private sector

Examples:

1. Gold or silver (commodity money)

2. U.S. dollar bills

3. Reserves issued by the Federal Reserve

Inside money

Is an asset backed by any form of private credit that circulates as a medium of exchange (in zero net supply within the private sector)

Examples:

1. Bills of exchange

2. Bank notes

3. Bank deposits

4. Checkable mutual funds

Friedman versus Hayek

- **Friedman** (1959): Government should provide outside money to construct the foundation of the monetary structure. Private banks issue inside money as required by market forces.
  - Friedman's "good reasons"

- **Hayek** (1976): Supply of outside money can be left to private market participants. Governments abuse the monopoly on outside money creation.
  - Market discipline provides incentives for agents to create "good" brands of money

Research Questions

- Will a system of privately issued outside monies deliver price stability?
- Will the market provide the (socially) optimum quantity of money?
- Will one currency drive all others from the market? Or will several of these currencies coexist along the equilibrium path?
- Do private monies require a commodity backing?
- Can private monies and a government-issued money coexist?

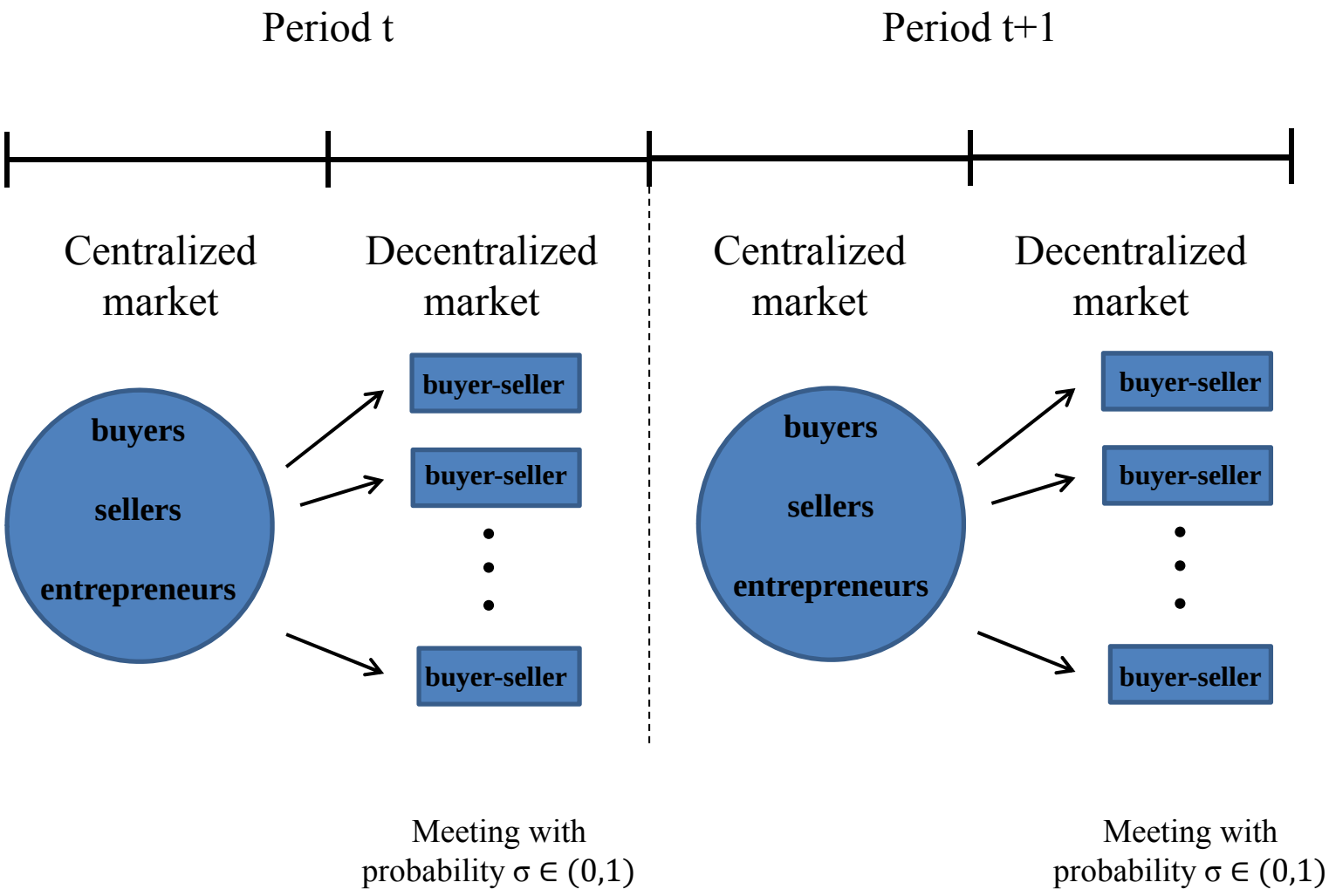
Literature

- **Free banking:** Selgin and White (1994); White (1995)
- **Search-theoretic models of exchange:** Lagos and Wright (2003, 2005)
- **Inside money:** Cavalcanti, Erosa, Temzelides (1999); Cavalcanti and Wallace (1999); Williamson (1999)
- **Privately issued outside money:** Berentsen (2006); Martin and Schreft (2006)
- **Liquidity provision by productive firms:** Holmstrom and Tirole (2011); Dang, Gorton, Holmstrom, Ordonez (2014)

Road Map

- Study positive and normative properties of purely private arrangement
- Introduce government-supplied outside money
  - Implementation of monetary policy
  - Can the government implement an efficient allocation when competing with private currencies?
- Automata
- Productive capital

Model


Period t
Period t+1
Centralized market
Decentralized market
Centralized market
Decentralized market
buyers
sellers
entrepreneurs
buyer-seller
buyer-seller
buyer-seller
buyers
sellers
entrepreneurs
buyer-seller
buyer-seller
buyer-seller
Meeting with probability σ ∈ (0,1)
Meeting with probability σ ∈ (0,1)

Model

- Discrete time $t = 0, 1, 2, ...$
- Continuum of buyers and sellers
- N types of entrepreneurs: $[0, 1]$-continuum of each type
- Each period contains two subperiods
- Centralized market (CM) in the first subperiod

Model

- Decentralized market (DM) in the second subperiod
  - Buyer is randomly matched with a seller with probability $\sigma \in (0, 1)$ and vice versa
  - Entrepreneurs remain idle
- Two perishable commodities
  - CM good is produced in the first subperiod
  - DM good is produced in the second subperiod

Model

- Buyers and sellers can produce the CM good using a linear technology that requires labor
- Buyer wants to consume the DM good but cannot produce it
- Seller can produce the DM good but does not want to consume it
- Entrepreneur cannot produce either good

Model

- There exists a technology to create (electronic) tokens
  - Their authenticity can be verified at zero cost (cryptography techniques)
  - No counterfeiting
- $N \in \mathbb{N}$ distinct types of tokens with identical production functions
- $c : \mathbb{R}_+ \to \mathbb{R}_+$ denotes the cost function associated with the minting of tokens

Model

- A buyer's preferences are represented by

$$U^b\left(x_t^b, q_t\right) = x_t^b + u\left(q_t\right)$$

- A seller's preferences are represented by

$$U^s\left(x_t^s, q_t\right) = x_t^s - w\left(q_t\right)$$

- Entrepreneur has preferences represented by

$$U^e\left(x_t^i, \mathbf{\Delta}_t^i\right) = x_t^i - c\left(\mathbf{\Delta}_t^i\right)$$

Model

- Buyers and sellers are anonymous
  - Their identities are unknown and trading histories are privately observable
  - Precludes credit in the DM
- The total amount of each type of token is publicly observable

Portfolio Problem

- Solve portfolio problem to obtain *money demand* function
- Let $\phi_t^i \in \mathbb{R}_+$ denote the real value of token i in terms of the CM good
- Value function in the CM is

$$W^b\left(\mathbf{M}_{t-1}^b, t\right) = \max_{\left(x_t^b, \mathbf{M}_t^b\right) \in \mathbb{R} \times \mathbb{R}_+^N} \left[x_t^b + V^b\left(\mathbf{M}_t^b, t\right)\right]$$

  subject to the budget constraint

$$\boldsymbol{\phi}_t \cdot \mathbf{M}_t^b + x_t^b = \boldsymbol{\phi}_t \cdot \mathbf{M}_{t-1}^b$$

Portfolio Problem

- Value function in the DM is

$$V^b\left(\mathbf{M}_t^b, t\right) = \sigma\left[u\left(q\left(\mathbf{M}_t^b, t\right)\right) + \beta W^b\left(\mathbf{M}_t^b - \mathbf{d}\left(\mathbf{M}_t^b, t\right), t+1\right)\right] + (1-\sigma)\beta W^b\left(\mathbf{M}_t^b, t+1\right)$$

- Terms of trade are given by

$$q\left(\mathbf{M}_t^b, t\right) \in \mathbb{R}_+$$

and

$$\mathbf{d}\left(\mathbf{M}_t^b, t\right) = \left(d^1\left(\mathbf{M}_t^b, t\right), ..., d^N\left(\mathbf{M}_t^b, t\right)\right) \in \mathbb{R}_+^N$$

Portfolio Problem

- Terms of trade are determined by Nash bargaining

- Solve

$$\max_{(q,\mathbf{d})\in\mathbb{R}_{+}^{N+1}} \left[u\left(q\right)-\beta\times\boldsymbol{\phi}_{t+1}\cdot\mathbf{d}\right]^{\theta}\left[-w\left(q\right)+\beta\times\boldsymbol{\phi}_{t+1}\cdot\mathbf{d}\right]^{1-\theta}$$

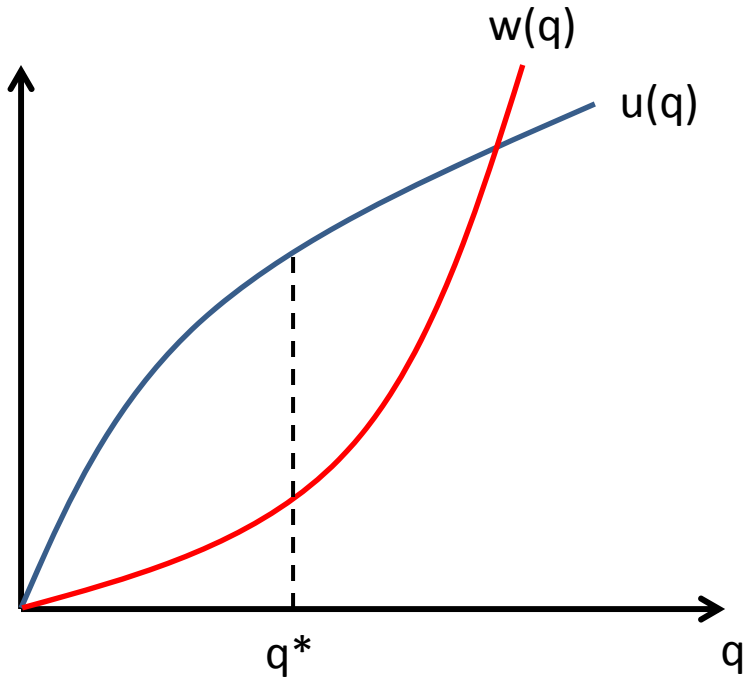
subject to

$$u\left(q\right)-\beta\times\boldsymbol{\phi}_{t+1}\cdot\mathbf{d}\geq 0$$

$$-w\left(q\right)+\beta\times\boldsymbol{\phi}_{t+1}\cdot\mathbf{d}\geq 0$$

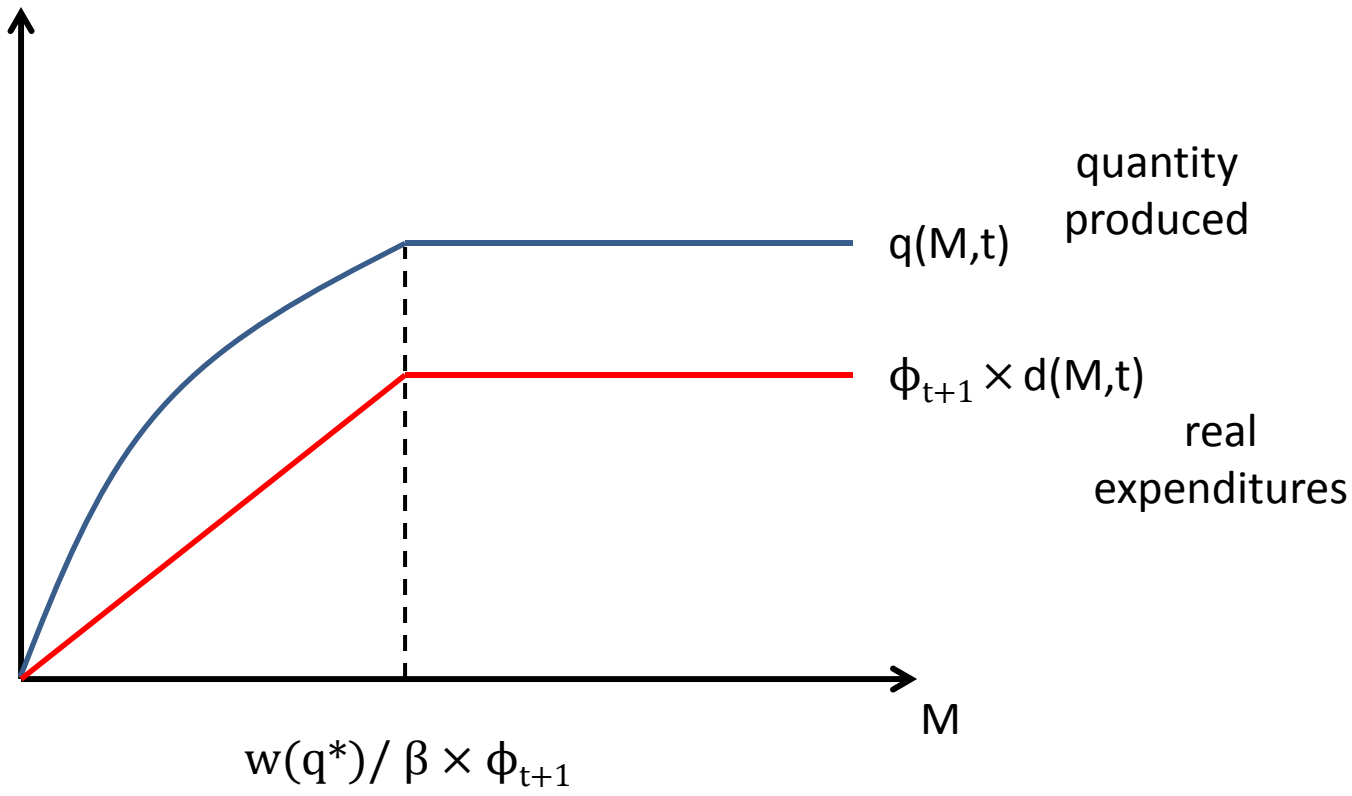
$$\mathbf{d}\leq\mathbf{M}_{t}^{b}$$

Surplus in the Decentralized Market



$u'(q^*) = w'(q^*)$

Terms of Trade in the Decentralized Market



Portfolio Problem

- First-order conditions are

$$\phi_t^i = \beta \phi_{t+1}^i L_\theta \left(\boldsymbol{\phi}_{t+1} \cdot \mathbf{M}_t^b \right)$$

$$\lim_{t \to \infty} \beta^t \times \boldsymbol{\phi}_t \cdot \mathbf{M}_t^b = 0$$

- $L_\theta : \mathbb{R}_+ \to \mathbb{R}_+$ is given by

$$L_\theta(A) = \begin{cases} \sigma \frac{u'\left(m^{-1}(\beta A)\right)}{m'\left(m^{-1}(\beta A)\right)} + 1 - \sigma \text{ if } A < \beta^{-1} \left[\theta w(q^*) + (1-\theta) u(q^*)\right] \\ 1 \text{ if } A \geq \beta^{-1} \left[\theta w(q^*) + (1-\theta) u(q^*)\right] \end{cases}$$

- Kareken and Wallace (1981): In the absence of portfolio restrictions and barriers to trade, the exchange rate between two currencies is indeterminate

Entrepreneur's Problem

- Solve entrepreneur's problem to derive *money supply* function
- Law of motion for currency $i \in \{1, ..., N\}$ is

$$M_t^i = \Delta_t^i + M_{t-1}^i$$

- Budget constraint is given by

$$x_t^i + \sum_{j \neq i} \phi_t^j M_t^{ij} = \phi_t^i \Delta_t^i + \sum_{j \neq i} \phi_t^j M_{t-1}^{ij}$$

- Entrepreneur does not hold other currencies in portfolio:

$$x_t^i = \phi_t^i \Delta_t^i$$

Entrepreneur's Problem

- Entrepreneur takes prices as given

- Solve profit-maximization problem

$$\Delta_t^{*,i} \in \arg \max_{\Delta \in \mathbb{R}_+} \left[\phi_t^i \Delta - c(\Delta) \right]$$

- Existence and uniqueness depends on the properties of $c : \mathbb{R}_+ \longrightarrow \mathbb{R}_+$

Equilibrium

- A perfect-foresight monetary equilibrium is an array $\left\{\mathbf{M}_t, \mathbf{M}_t^b, \boldsymbol{\Delta}_t^*, \boldsymbol{\phi}_t\right\}_{t=0}^{\infty}$ satisfying

$$\phi_t^i = \beta \phi_{t+1}^i L_\theta \left(\boldsymbol{\phi}_{t+1} \cdot \mathbf{M}_t^b\right)$$

$$\lim_{t \to \infty} \beta^t \times \boldsymbol{\phi}_t \cdot \mathbf{M}_t^b = 0$$

$$\boldsymbol{\Delta}_t^{*,i} \in \arg \max_{\boldsymbol{\Delta} \in \mathbb{R}_+} \left[\phi_t^i \boldsymbol{\Delta} - c\left(\boldsymbol{\Delta}\right)\right]$$

$$\mathbf{M}_t = \mathbf{M}_t^b$$

$$M_t^i = \boldsymbol{\Delta}_t^{*,i} + M_{t-1}^i$$

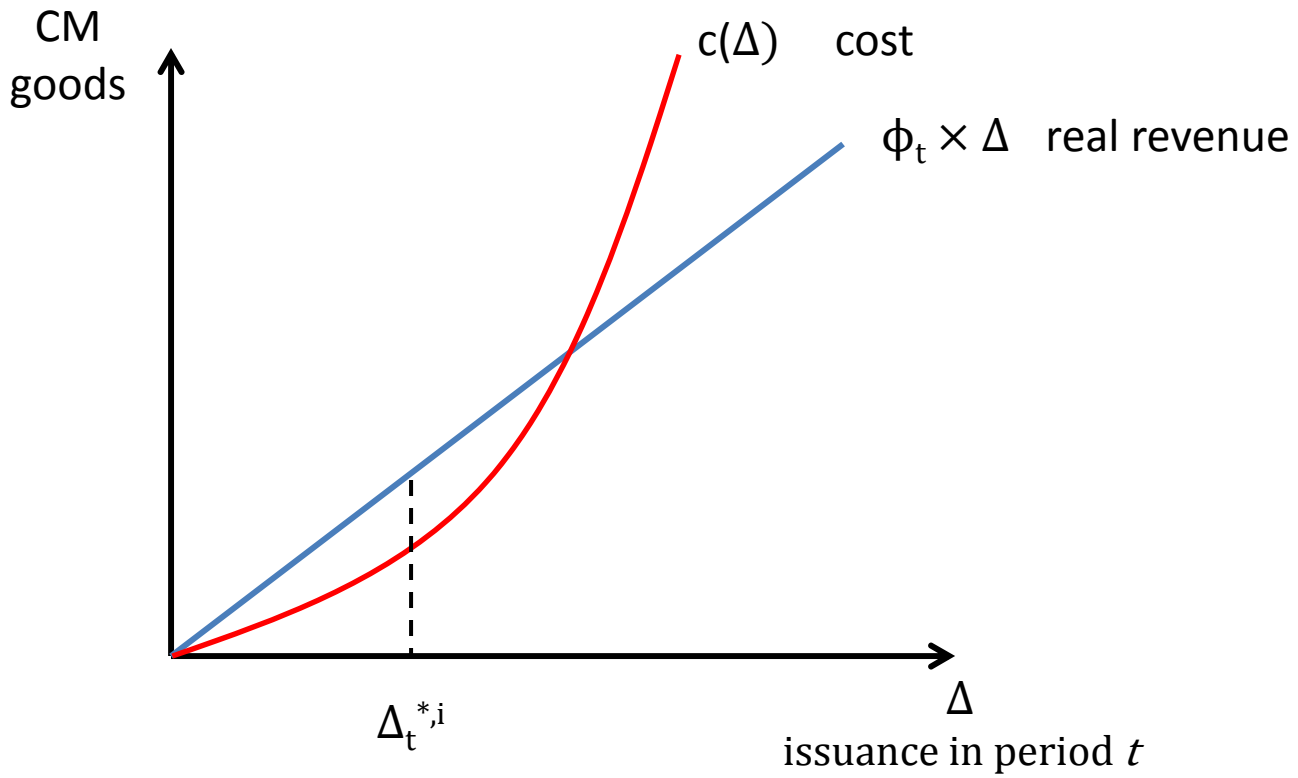
Positive Analysis

- Make assumptions on preferences such that money demand function is strictly decreasing in the inflation rate

- **PROPOSITION:** Suppose that $c : \mathbb{R}_+ \longrightarrow \mathbb{R}_+$ is strictly convex. Then, there is no monetary equilibrium consistent with price stability.

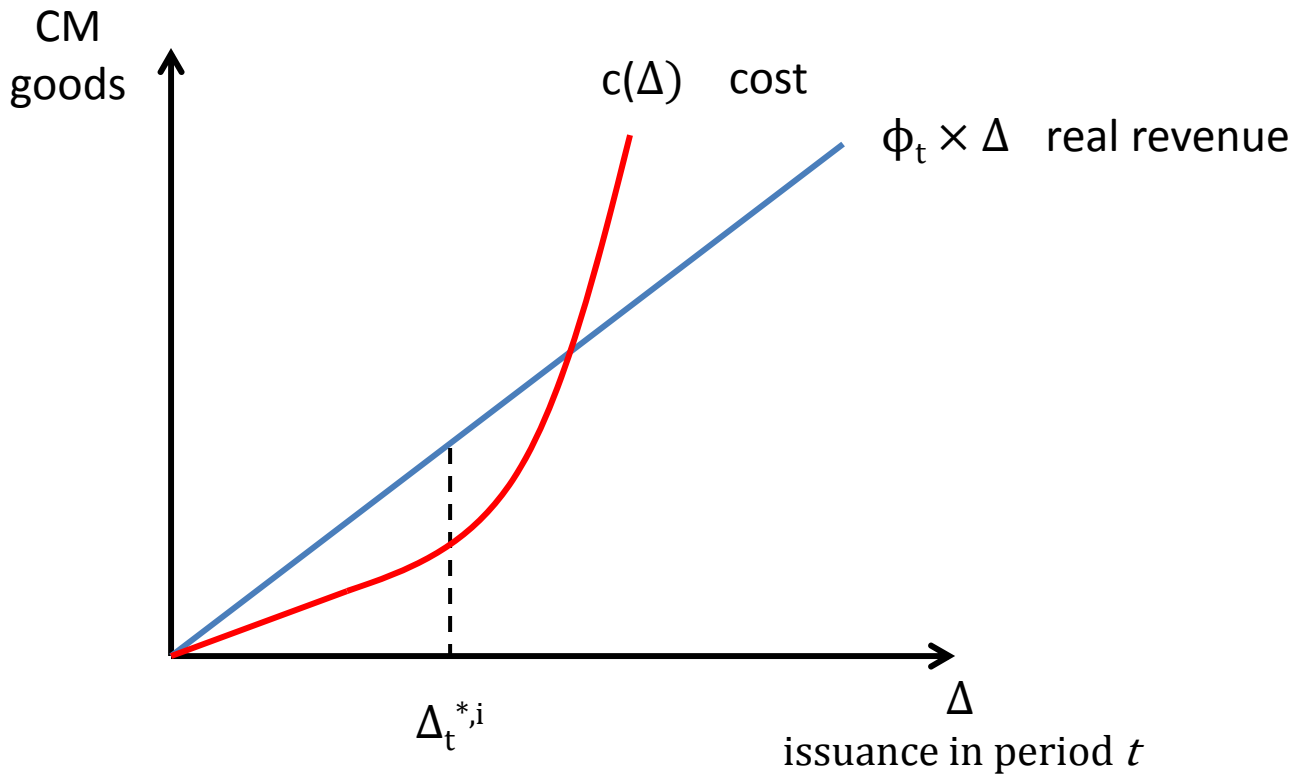
- "*A fiduciary currency would thus probably tend through increased issue to degenerate into a commodity currency – into literal paper standard – there being no stable equilibrium price level short of that at which the money value of currency is no greater than that of the paper it contains*." Friedman (1959)

Entrepreneur's Profit Maximization Problem



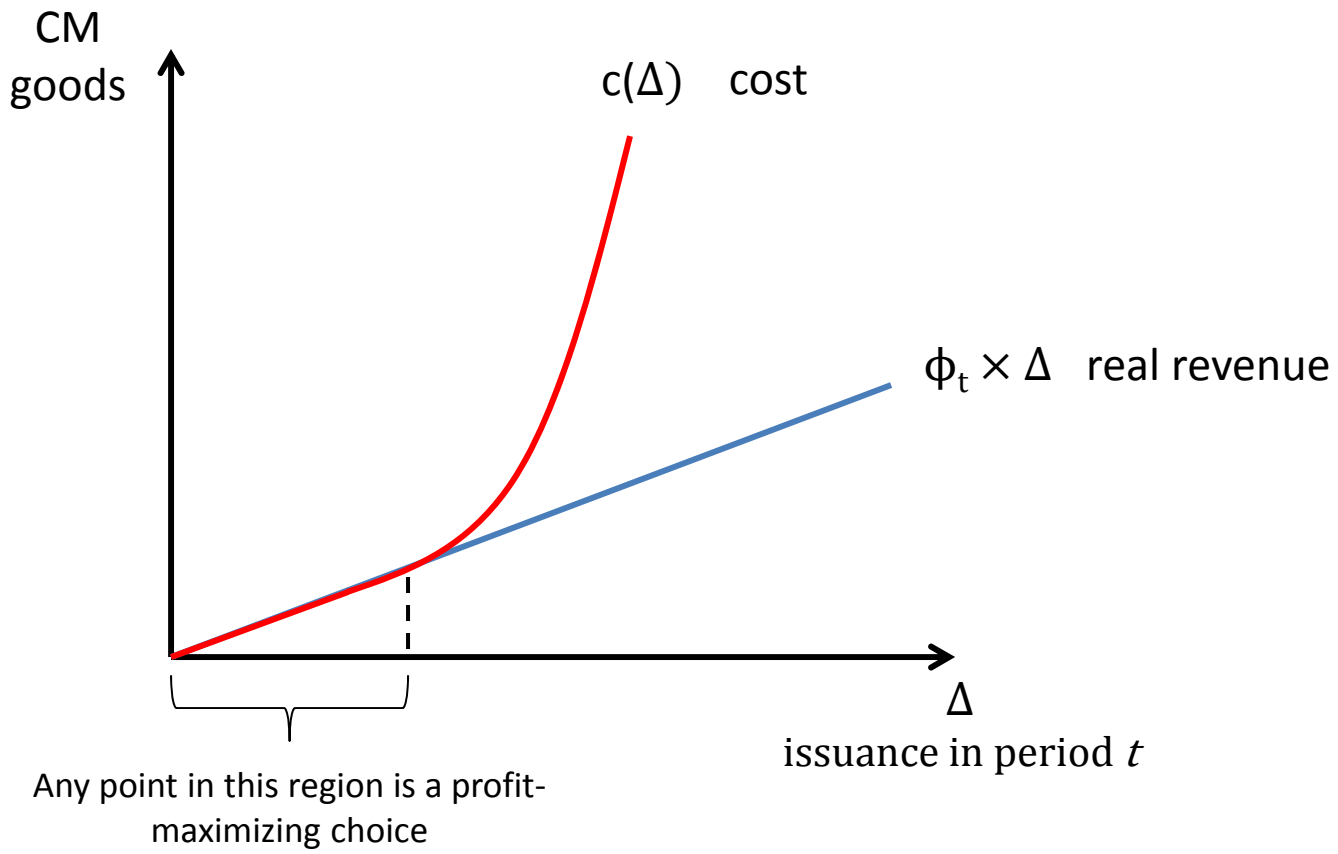
Strictly convex cost function

Entrepreneur's Profit Maximization Problem



Weakly convex cost function

Entrepreneur's Profit Maximization Problem



Weakly convex cost function

Positive Analysis

- **PROPOSITION:** Suppose that $c : \mathbb{R}_+ \to \mathbb{R}_+$ is locally linear in a neighborhood $[0, \Delta'] \subset \mathbb{R}_+$. Then, there is a monetary equilibrium consistent with strong price stability.

- Cryptocurrency protocol that holds the marginal cost of mining initially constant

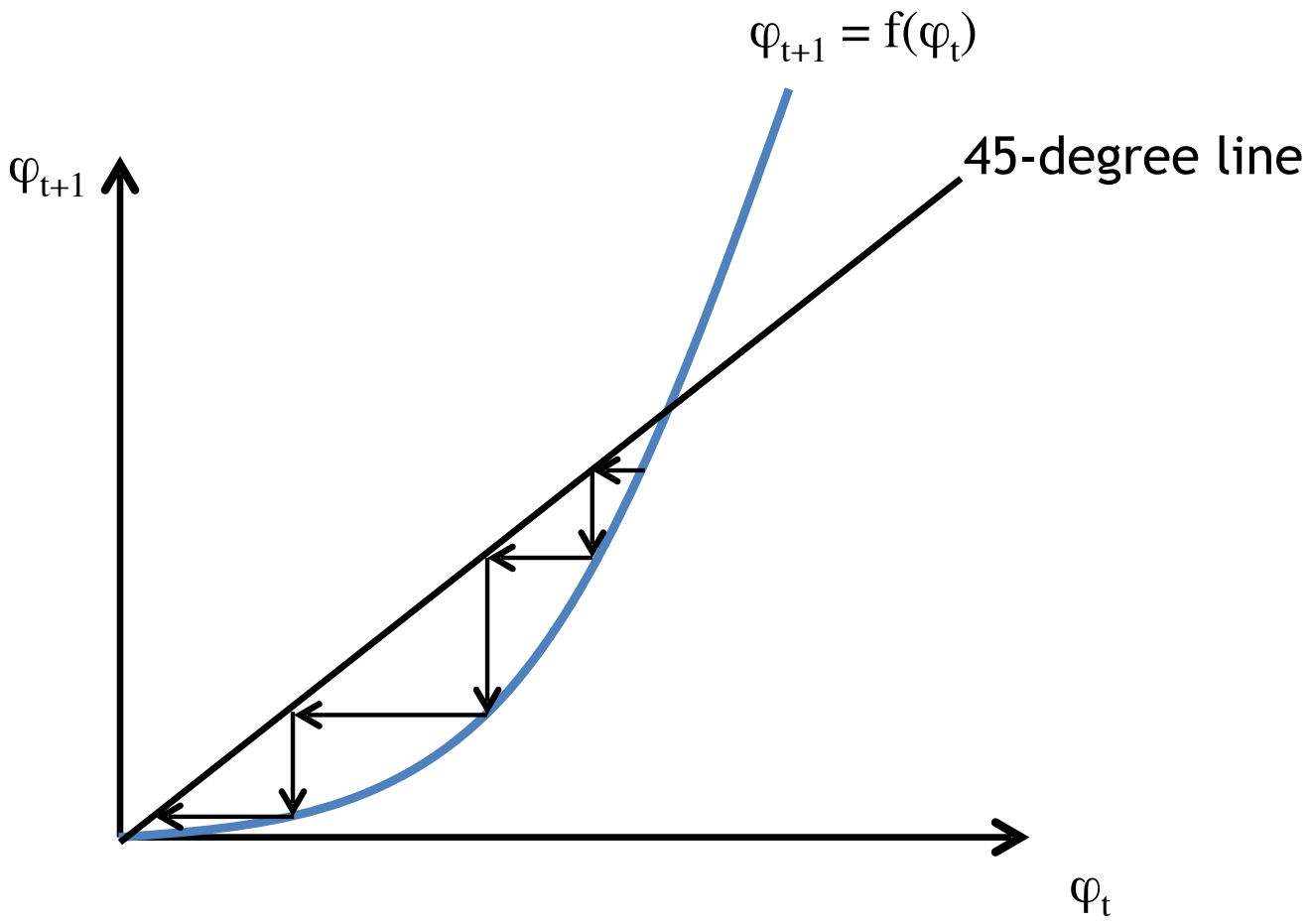
- Partial vindication of Hayek

Positive Analysis

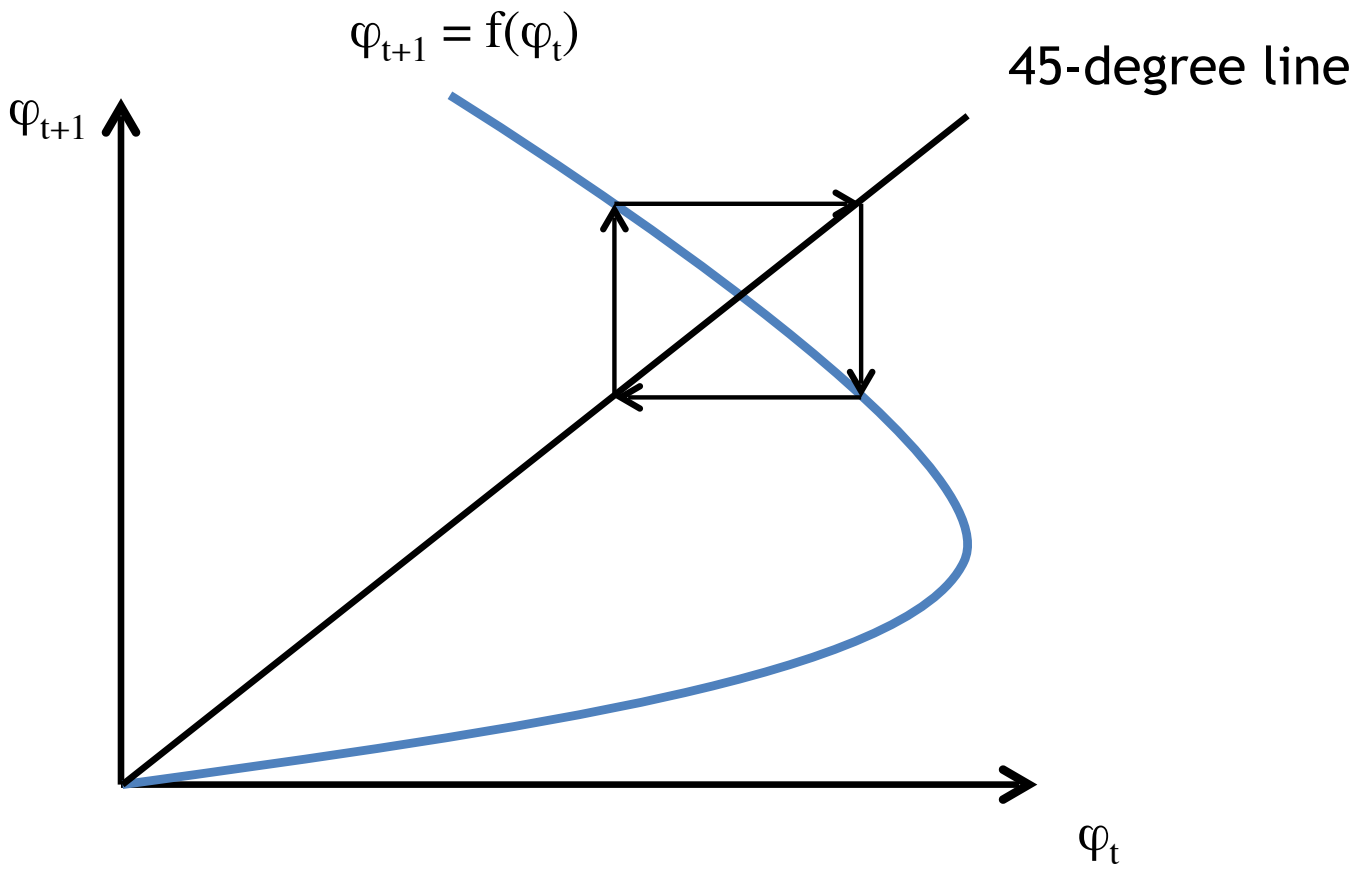
- There exists a continuum of equilibria in which the sequence $\left\{\phi_t^i\right\}_{t=0}^{\infty}$ converges monotonically to zero.
  - Self-fulfilling inflations

- There exist asymmetric equilibria with the property that a unique private currency circulates in the economy
  - This occurs because the market share across different types of money is indeterminate

Dynamic System: One Fiat Currency in Fixed Supply

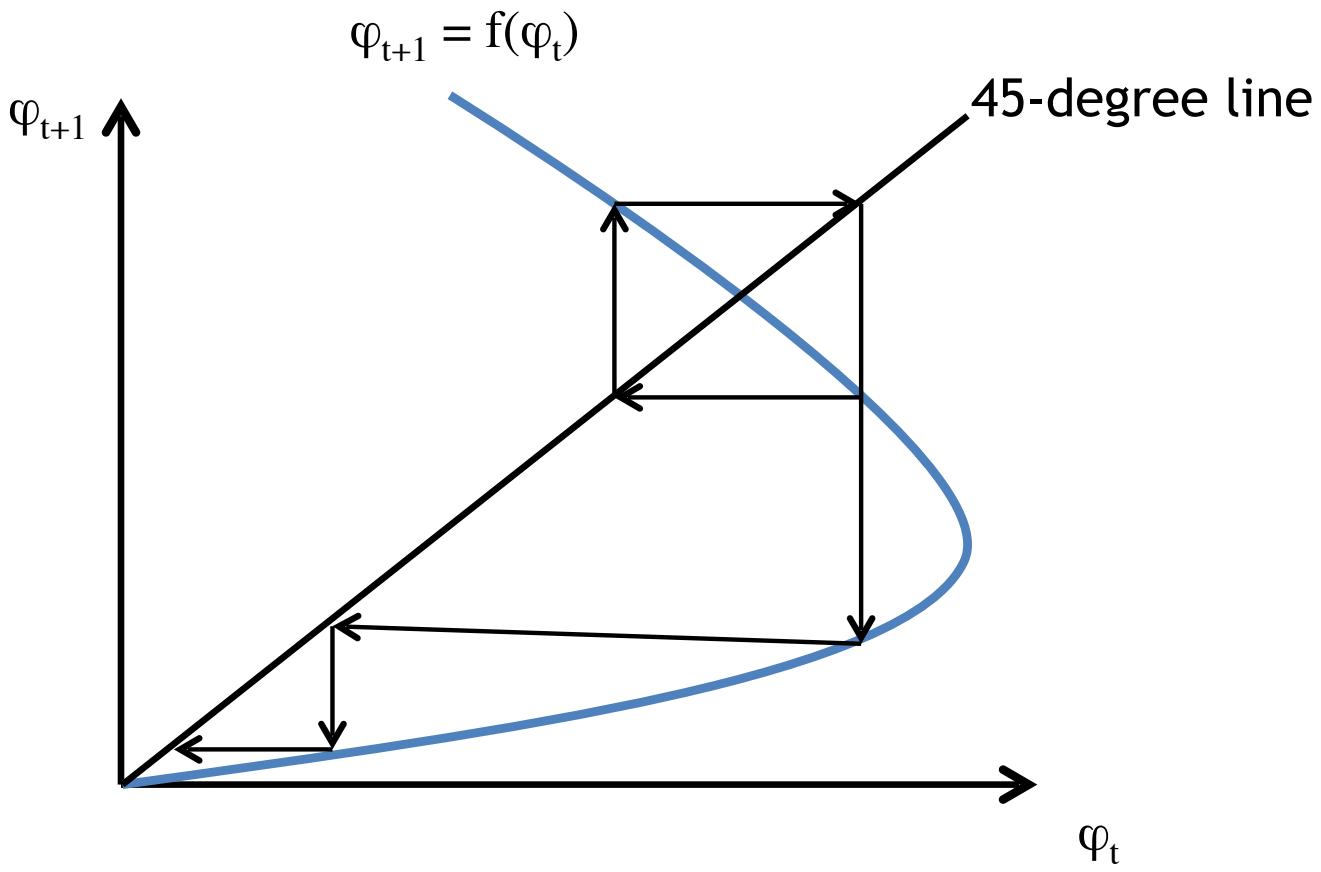


Dynamic System: One Fiat Currency in Fixed Supply



Perfect Cycles

Dynamic System: One Fiat Currency in Fixed Supply



Cycles and Crash

Normative Analysis

- **PROPOSITION:** There is no stationary monetary equilibrium with a strictly positive real return on money.

- Positive real return on money requires either deflation or interest payments on currency
  - Private agents have no incentives to pursue these goals

- Purely private arrangement is inconsistent with an efficient allocation
  - Pecuniary externality in the creation of tokens

Government and Private Monies

- Government enters the currency-issuing business, referred to as $N+1$
- Government budget constraint:

$$\phi_t^{N+1}\Delta_t^{N+1} + \tau_t = c\left(\Delta_t^{N+1}\right)$$

- Follows money-growth rule:

$$M_t^{N+1} = (1+\omega)\, M_{t-1}^{N+1}$$

Government and Private Monies

- **PROPOSITION:** There is no stationary equilibrium in which **(i)** at least one private currency is valued and **(ii)** the real return on money is strictly positive

- Implementation of monetary policy through a money-growth rule is significantly impaired by competing currencies

- Profit-maximizing entrepreneurs frustrate the government's attempt to implement a positive real return on money through deflation

Government and Private Monies

- Pegging the real value of government money

- Assume the government issues currency to satisfy

$$\phi_t^{N+1} \bar{M}_t^{N+1} = m$$

- **PROPOSITION:** There exists a unique stationary equilibrium with a constant positive real return on money provided m is sufficiently large. In this equilibrium, government money drives private money out of the economy

- Unique implementation requires the provision of "good" government money

Productive Capital

- Is it possible to implement an efficient allocation in the absence of government intervention if we introduce productive capital in the economy?

- Lucas tree that yields a constant stream of dividends $\kappa > 0$ in terms of the CM good

- Suppose that there exist J automata, each programmed to follow a predetermined plan
  - Each automaton has an equal claim on the real asset
  - Yields a predetermined dividend plan $\left\{f_t^j\right\}_{t=0}^{\infty}$

Productive Capital

- Budget constraint is

$$\phi_t^j \Delta_t^j + \frac{\kappa}{J} = f_t^j$$

- Law of motion for currency j is

$$H_t^j = \Delta_t^j + H_{t-1}^j$$

- Suppose $f_t^j = \frac{f}{J}$ for all $j \in \{1, ..., J\}$, with $0 \leq f \leq \kappa$

Productive Capital

- Obtain the dynamic system:

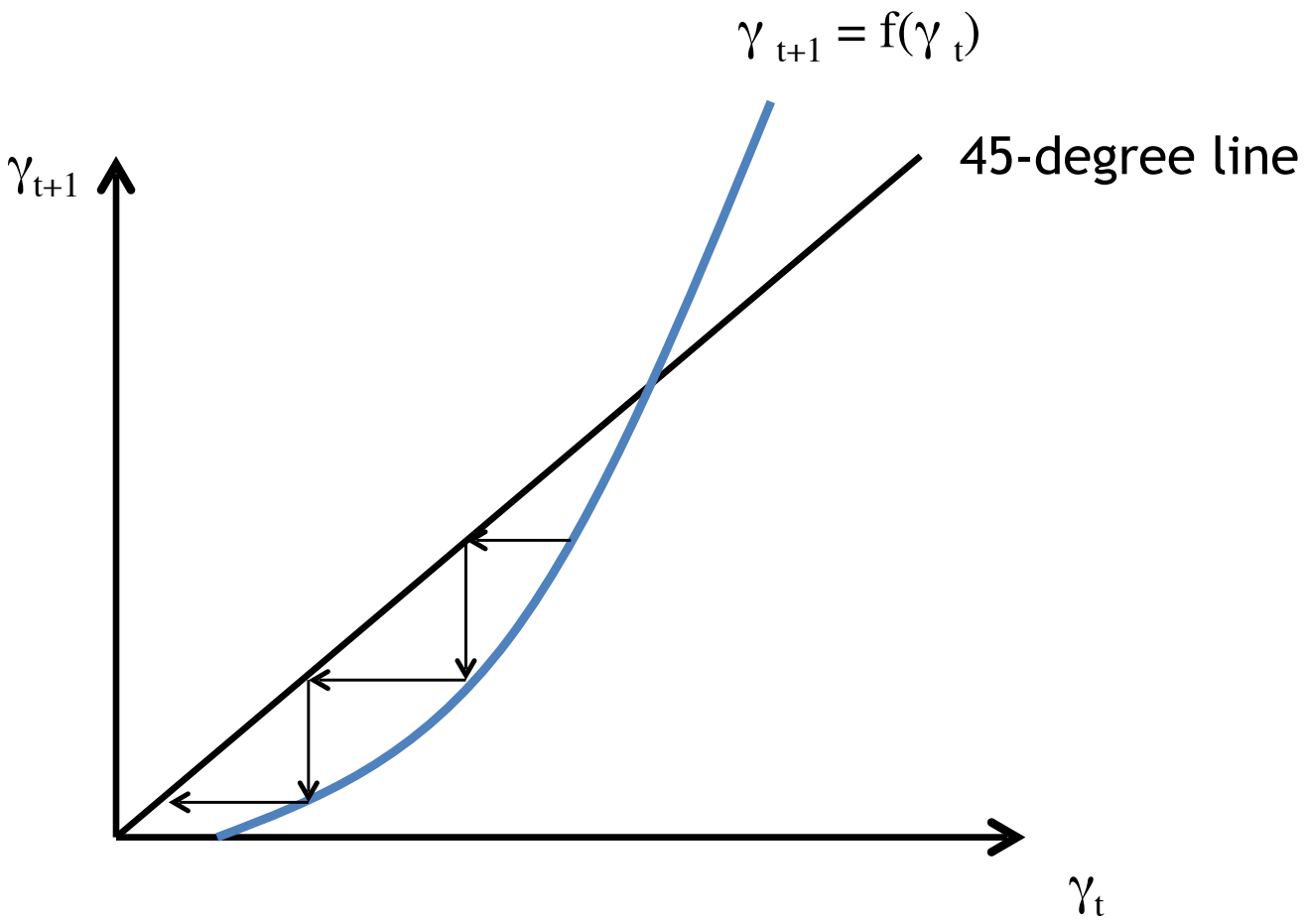
$$z\left(\gamma_{t+1}\right) - \gamma_t z\left(\gamma_t\right) + \kappa - f = 0$$

$$z\left(\gamma_t\right) \geq 0$$

$$\beta\gamma_t z\left(\gamma_t\right) \leq w\left(q^*\right)$$

- **PROPOSITION:** There exists a unique equilibrium allocation with $\gamma_t = \gamma^s$ for all $t \geq 0$ and $1 < \gamma^s \leq \beta^{-1}$.

Dynamic System: Productive Capital



Conclusions

- A system of private competing currencies can work
- Discussed price stability and efficiency of private money arrangement in a competitive environment
- Just scratched the surface
  - Study different transaction costs among currencies
  - Structure of settlement and clearing systems
  - Entry and exit in the industry