

Breaking the Curse of Kareken and Wallace

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https://github.com/phantommachine/_gkwcurses

History

Late 18th to 19th century U.S.

- Emerging markets:
 - ▶ geographical separation
 - ▶ informationally partitioned
- Banks as principal capitalists:
 - ▶ Underwriters of business activity, and
 - ▶ (local) providers of medium of exchange *even if notes were not legal tender*
- Observed:
 - ▶ multiple currencies emerged and coexist as medium of exchange
 - ▶ banks grew supplies independently

History

Late 18th to 19th century U.S.

By the 1850s, with so many entities commissioning bank notes of their own design ...,

*the money supply became a great confluence of **more than ten thousand** different kinds of paper that **continually changed hands** [sic], baffled the uninitiated, and fluctuated in **value according to the whims of the market.***

*Thousands of different kinds of gold, silver, and copper coins issued by **foreign governments** and domestic merchants complicated the mix.*

Source: Mihm (2007), *A Nation of Counterfeiters*, Harvard University Press.

Theoretical Conundrum

Present-day open economies and prevailing theory

- Co-existence of multiple media of exchange.
- Absent obvious legal restrictions on currencies as media of exchange,
 - ▶ Circulating currencies must have same rate of return; and
 - ▶ A monetary equilibrium has indeterminate nominal exchange rate.

Kareken and Wallace (1981, *QJE*).

- Determinacy solved by ad hoc frictions – MIU, CIA, currency specific transactions costs.
 - ▶ Essentially assumes determinacy as opposed to it being an equilibrium outcome.

Theoretical Conundrum

Wallace's *dictum*

Dictum:

- ① Monetary economists should explain why fiat money is essential, not assume it is.
 - ▶ This means determining its value without resorting to ad hoc restrictions.
- ② A “good” model should always have a non-monetary equilibrium as a possibility.

Theoretical Conundrum

Wallace's *dictum*, and some

Corollary:

- Monetary economists should explain why the nominal exchange rate is determinate, not assume it is.
 - ▶ This means determining its value without resorting to ad hoc restrictions.
- A “good” model should always have nominal exchange rate indeterminacy as a possibility.

Questions

- 1 Why do we observe coexistence of multiple media of exchange, ...
 - ▶ even if they differ in rates of returns ...
 - ▶ and there is no legal requirement to hold certain media of exchange?
- 2 Can we explain exchange rate determinacy as equilibrium phenomenon?
- 3 If yes, what are the properties of equilibrium coexistence of monies and exchange rate behavior?

How we do it

- Integrated world economy setting with some decentralized trading.
- No restrictions on currencies used as media of exchange.
- A pinch of asymmetric information:
 - ▶ A seller faces threat that a buyer might produce counterfeit monies;
 - ▶ A buyer tries to signal his type if offer of payment is genuine.
 - ▶ Li, Rocheteau and Weill (2013, *JPE*).
- Also generalize notion “threat of counterfeiting” to environments with:
 - ▶ trade credit; fiat monies as collateral; nominal bonds; fiscal policies; and
 - ▶ explicit two-country setting.

Answers and Lessons

Breaking the Kareken and Wallace (1981, *QJE*) result

- ① Information friction equilibria — implying active liquidity constraints
 - ▶ induce coexistence of multiple media of exchange
 - ★ even if they differ in rates of returns ...
 - ★ and there is no legal requirement to exchange with certain media of exchange.
- ② Coexistence imply determinate nominal exchange rate.
- ③ Equilibria exchange rate behave similar to that implied by ad-hoc CIA models, but have deeper connections to underlying information and market frictions.

Answers and Lessons

Moreover ...

There can exist monetary equilibrium where

- a currency is dominated in rate of return; or
- has equal rate of return;
- but there is coexistence of currencies and the nominal exchange rate is determinate.

Equilibrium exchange rate determinacy depends on:

- Relative monetary policies across countries
- Fiscal policies

Model

Markets and IWE

- Discrete-time “integrated world economy” (IWE)
 - ▶ Anonymity in *decentralized market* (DM): money is essential
 - ▶ sequential submarkets: DM-then-CM
 - ▶ new money transfers at start of each *centralized market*
CM + quasilinear preferences
 - ★ no need for geographical distinctions (i.e., multi-country setup)
- Equivalent interpretation:
 - ▶ a closed economy with multiple money-issuing entities
 - ▶ e.g. 18th-19th century U.S.

Model

Some notation in $CM(t)$

- Value of a unit of m (m^f) in units of CM good: ϕ (ϕ^f)
- Nominal exchange rate (Home price of a unit of Foreign money): e
- Buyer's state:

$$\mathbf{s} := (m + x, m^f + x^f; \phi, e)$$

- Seller's state:

$$\check{\mathbf{s}} := (\check{m}, \check{m}^f; \phi, e)$$

Model

DM-buyers

$$\mathbb{E} \left\{ \sum_{t=0}^{\infty} \beta^t [u(q_t) + U(C_t) - N_t] \right\},$$

- q_t : DM (equiv. nontradable consumption)
- N_t : CM utility of work
- C_t : CM consumption index. Can introduce international trade here (not necessary)
- Assume: u , U , and D well-behaved preference representations

Model

DM-sellers

$$\mathbb{E} \left\{ \sum_{t=0}^{\infty} \beta^t \left[-c(q_t) + U(C_t) - \check{N}_t \right] \right\},$$

DM-effort/utility-cost function $c : \mathbb{R}_+ \rightarrow \mathbb{R}_+$:

- $c(0) = 0$,
- $c'(q) > 0$, and
- $c''(q) \geq 0$.

Model

Markets and Timing (Li, Rocheteau, Weill, 2013)

Start date $t \in \{0, 1, 2, \dots\}$...

- DM(t) opens:
 - ▶ DM-Sellers randomly matched with buyer w.p. σ , and vice-versa. On-the-spot production.
 - ▶ DM-Buyer makes TIOLI offer; any composition, any money; Private information on portfolio.
- DM(t) closes, CM(t) opens.
 - ▶ Money suppliers grow monies at factor Π_t and Π_t^f .
 - ▶ New monies transferred uniformly to all agents.
 - ▶ DM-buyers work and consume, and either:
 - ★ work to accumulate more monies (m, m^f) for next DM and
 - ★ decide to counterfeit m , and/or m^f ; per-period fixed costs (κ, κ^f) .
 - ★ DM-sellers rebalance portfolio and consume and/or work.

Model

Markets and Timing (Li, Rocheteau, Weill, 2013)

- 1 *Endogenous buyer type* unobservable by random seller.
 - ▶ buyer chooses “type”—asset portfolio—prior to entering $DM(t)$.
 - ▶ ex-post match with a seller:
 - ★ buyer sends message—offer $\omega := (d, d^f, q)$
 - ★ seller assigns beliefs regarding probable fraudulence and acts: accept/reject.
- 2 $DM(t)$ Bargaining Protocol: Buyer makes TIOLI bargaining offer. Seller accepts/reject.

PBE refinement ... Payoff-equivalent reverse-ordered extensive-form game: (Offer, Counterfeit/Not, Nature (σ), Accept/Reject).

Model

CM($t - 1$) to DM(t): Pure strategies

A **pure strategy of a buyer** σ^b in the counterfeiting game is a triple $\langle \omega, \eta(\omega), a(\omega) \rangle$:

- 1 Feasible offer decision rule, $s_{-1} \mapsto \omega \equiv \langle q, d, d^f \rangle(s_{-1})$;
- 2 Binary decision rules on counterfeiting,
 $\chi(\omega) := \langle \chi(\omega), \chi^f(\omega) \rangle \in \{0, 1\}^2$, for each currency; and
- 3 Feasible asset accumulation decision, $\omega \mapsto a(\omega)$, and,
 $(d, d^f) \leq a(\omega)$.

A **pure strategy of a seller** σ^s is a binary acceptance rule
 $(\omega, \check{s}_{-1}) \mapsto \alpha(\omega, \check{s}_{-1}) \in \{0, 1\}$.

Model

CM($t - 1$) to DM(t): Behavior strategies

DM-Buyer:

$$\tilde{\sigma}^b := \langle \omega, G[a(\omega)|\omega], \eta(\chi|\omega) \rangle$$

- Offer/ToT, (q, d, d^f)
- Lottery over portfolio
- $\eta(\cdot|\omega) := \langle \eta(\cdot|\omega), \eta^f(\cdot|\omega) \rangle$, fraud lottery.

DM-Seller:

- $\tilde{\sigma}^s := \pi(\omega)$ which generates a lottery over $\{0, 1\} \ni \alpha$.

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Model

DM-Buyers total payoffs given $\tilde{\sigma} = (\tilde{\sigma}^b, \tilde{\sigma}^s)$

- CM($t - 1$) flow cost: portfolio accumulation

$$U^b(\tilde{\sigma}) = -\phi_{-1}(m + e_{-1}m^f)$$

$$-\kappa(1 - \eta) - \kappa^f(1 - \eta^f)$$

$$+\beta\sigma\hat{\pi} [u(q) - \phi(\eta d + \eta^f e d^f)]$$

- CM($t - 1$) expected cost: portfolio fraud lottery
- Expected DM(t) continuation, given DM-seller strategy $\hat{\pi}$.

Model

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Model

Total payoffs: DM-Sellers

$$\begin{aligned} U^s(\tilde{\sigma}) &= \beta \sigma \pi(\omega) [-c(q) + W^s(\hat{\eta}d, \hat{\eta}^f d^f; \phi, e)] \\ &\quad + \beta [\sigma (1 - \pi(\omega)) + (1 - \sigma)] [-c(0) + W^s(0, 0; \phi, e)] \\ &= \beta \sigma \pi(\omega) [\phi (\hat{\eta}d + e\hat{\eta}^f d^f) - c(q)] , \end{aligned}$$

RI-Equilibrium

Solution concept

- Perfect Bayesian Equilibrium (PBE)
- In-Wright reordering refinement

a.k.a. Reordering-Invariant- or RI-equilibrium.

RI-Equilibrium

Definition

A PBE $\tilde{\sigma} := (\tilde{\sigma}^b, \tilde{\sigma}^s) = \langle \omega, \eta(\omega), \pi(\omega) \rangle$ of the reordered game is such that

- 1 Players' beliefs are consistent with behavior strategies;
- 2 Seller's mixed strategy over accept/reject π , given offer ω , is profit maximizing (SPC);
- 3 Buyer's mixed strategy over counterfeit/not either/both assets, (η, η^f) , following ω is incentive compatible (BIC); and
- 4 And buyer's offer ω is surplus maximizing given Items 1-3 (TIOLI).

RI-Equilibrium

Backward induction

Characterizing RI-equilibrium of game

- Backward induction on reordered extensive form
 - ▶ BW3. Sellers decision: acceptance mixed strategy π
 - ▶ BW2. Buyer's counterfeiting mixed strategy $\eta = (\eta, \eta^f)$
 - ▶ BW1. Buyer's message: optimal offer $\omega \equiv (q, d, d^f)$
- Check candidate behavior strategy profile $\tilde{\sigma}$ if PBE

RI-Equilibrium

Backward induction

BW3. Seller's Problem

$$\pi(\omega) \in \left\{ \arg \max_{\pi' \in [0,1]} \pi' [\phi(\hat{\eta}d + e\hat{\eta}^f d^f) - c(q)] \right\},$$

... given $\omega = (d, d^f, q)$.

BW2. Buyer's Counterfeiting Problem

$$\eta(\omega) \in \left\{ \arg \max_{\eta(\omega) \in [0,1]^2} \left[-\kappa(1-\eta) - \kappa^f(1-\eta^f) \right. \right. \\ \left. \left. - \left(\frac{\phi_{-1}}{\phi} - \beta \right) \phi \eta d - \left(\frac{\phi_{-1}e_{-1}}{\phi e} - \beta \right) \phi e \eta^f d^f \right. \right. \\ \left. \left. - \beta \sigma \hat{\pi} \phi (\eta d + e \eta^f d^f) \right] \right\}.$$

given offer history ω , and belief about the seller's best response, $\hat{\pi}$.

RI-Equilibrium

Signalling-Bargaining game

BW1. Buyer's Offer/Message

$$\omega \in \left\{ \arg \max_{\omega' \in \Omega(\phi, e)} \left\{ -\kappa (1 - \hat{\eta}) - \kappa^f (1 - \hat{\eta}^f) \right. \right. \\ \left. \left. - \left(\frac{\phi_{-1}}{\phi} - \beta \right) \phi \hat{\eta} \hat{d} - \left(\frac{\phi_{-1} e_{-1}}{\phi e} - \beta \right) \phi e \hat{\eta}^f \hat{d}^f \right. \right. \\ \left. \left. + \beta \sigma \hat{\pi} \left[u(q) - \phi \left(\hat{\eta} \hat{d} + \hat{\eta}^f e \hat{d}^f \right) \right] \right\} \right\}.$$

RI-Equilibrium

Signalling-Bargaining game

- 1 Each seller accepts with probability $\hat{\pi} = \pi(\omega) = 1$;
- 2 Each buyer does not counterfeit: $(\hat{\eta}, \hat{\eta}^f) = (\eta, \eta^f) = (1, 1)$; and
- 3 Each buyer's TIOLI offer ω is such that:

$$\omega \in \left\{ \arg \max_{\omega \in \Omega(\phi, e)} \left[- \left(\frac{\phi_{-1}}{\phi} - \beta \right) \phi d - \left(\frac{\phi_{-1}e_{-1}}{\phi e} - \beta \right) \phi e d^f + \beta \sigma \hat{\pi} [u(q) - \phi (d + e d^f)] \right] : \right.$$

$$(SPC, \zeta) : \phi (d + e) - c(q) = 0,$$

$$(BIC, \lambda) : \phi d \leq \frac{\kappa}{\phi_{-1}/\phi - \beta(1 - \sigma)},$$

$$(BIC^f, \lambda^f) : \phi e d^f \leq \frac{\kappa^f}{\phi_{-1}e_{-1}/\phi e - \beta(1 - \sigma)} \Big\}$$

General Monetary Equilibrium

Steady State Version

- Game's RI-equilibrium embeddable into infinite-horizon general equilibrium.
- Stationary monetary equilibrium (SME), for all t :

$$\phi_{-1}M_{-1} = \phi M \quad (\$)$$

$$e_{-1}\phi_{-1}M_{-1}^f = e\phi M^f \quad (€)$$

$$q_{-1} = q \quad (\text{☕})$$

- Steady-state equilibria money supplies grow at some constant rates Π and Π^f .
- $(\$)$ and $(€)$ imply

$$\frac{e_{t+1}}{e_t} = \frac{\Pi}{\Pi^f}$$

General Monetary Equilibrium

Steady State Version

Buyers' Euler (weak) inequalities:

$$\beta\sigma \left[\frac{u'(q)}{c'(q)} - 1 \right] = \lambda - \nu + (\Pi - \beta) = \lambda^f - \nu^f + (\Pi^f - \beta). \quad (\text{X.a})$$

DM-sellers' participation constraint binding ($\zeta > 0$):

$$c(q) = \phi d + \phi^f d^f, \quad (\text{X.b})$$

KKT conditions are:

$$\begin{aligned} \lambda \cdot [\bar{\kappa}(\Pi) - \phi d] &= 0, & \lambda &\geq 0, & \phi d &\leq \bar{\kappa}(\Pi), \\ \lambda^f \cdot [\bar{\kappa}^f(\Pi^f) - \phi^f d^f] &= 0, & \lambda^f &\geq 0, & \phi^f d^f &\leq \bar{\kappa}^f(\Pi^f), \\ -\nu \cdot d &= 0, & d &\geq 0, & \nu &\geq 0, \\ -\nu^f \cdot d^f &= 0, & d^f &\geq 0, & \nu^f &\geq 0. \end{aligned} \quad (\text{X.c})$$

General Monetary Equilibrium

Steady State Version

Cases:

- ① A. Home money dominates in rate of return: $\Pi^f > \Pi$.
- ② B. Foreign money dominates in rate of return: $\Pi^f < \Pi$.
- ③ C. Both monies have equal rate of return: $\Pi^f = \Pi$.

General Monetary Equilibrium

Proposition 7: Coexistence and the KW Curse Breaks

Case A. $\Pi > \Pi^f$

- 1 Exists equilibria s.t. $(\lambda = \lambda^f = 0)$, or $(\lambda > 0, \lambda^f = 0)$. Then a SME exists where only low inflation money circulates; or,
- 2 Exists equilibria s.t $(\lambda^f > \lambda = 0)$. Then exists unique SME with coexistence, and unique

$$e = \frac{M}{M^f} \frac{\kappa^f}{c(q) [\Pi^f - \beta(1 - \sigma)] - \kappa^f};$$

where q solves

$$\frac{\Pi - \beta}{\sigma\beta} = \frac{u'(q) - c'(q)}{c'(q)}.$$

- 3 Exists equilibria s.t. $(\lambda^f > \lambda > 0)$, then unique SME with coexistence and unique

$$e = \frac{\kappa^f M}{\kappa M^f} \frac{\Pi - \beta(1 - \sigma)}{\Pi^f - \beta(1 - \sigma)}.$$

General Monetary Equilibrium

Proposition 7: Coexistence and the KW Curse Breaks

Case C. $\Pi = \Pi^f$

- 1 neither liquidity constraints bind ($\lambda = \lambda^f = 0$), then the fiat monies coexist but the individual's currency portfolio composition and the nominal exchange rate are indeterminate (the KW equilibrium); or
- 2 both liquidity constraints bind ($\lambda = \lambda^f > 0$), then the currencies coexist. The individual's currency portfolio composition is unique, and thus there is a unique nominal exchange rate

$$e = \frac{\kappa^f M}{\kappa M^f}.$$

Case B. $\Pi < \Pi^f$. Just read Case A upside down.

General Monetary Equilibrium

Coexistence: properties

(Cases A and B): Coexistence of currencies when one currency RoR-dominates:

- Occurs because of threat of counterfeiting; LC on the currency binds.
- Hold LC'ed dominating currency up to LC limit; then top up with lower return money.
- Topping up because equilibrium DM q is inefficient.
 - ▶ By offering to pay with another currency, buyer can consume more;
 - ▶ Seller willing to accept since his participation constraints continue to hold.
- Not possible if no private information problem and no currency controls.

General Monetary Equilibrium

Coexistence equilibria: properties

In Cases A and B:

- Higher Π causes a depreciation of the domestic currency. Obvious, ... but for different reasons.
 - ▶ In Case A, the domestic-money LC is inactive, foreign-money is LC'ed. However, higher $\Pi \Rightarrow$ economize on d , reduces q , and thus increases e .
 - ▶ In Case B, the domestic money LC'ed, LC tightens with Π . Thus, the marginal liquidity value of an additional unit of domestic currency goes to zero sooner, hence it is less valuable relative to a unit of foreign currency.

General Monetary Equilibrium

Coexistence: properties

(Case C): Equal rates of return

- Possible for determinate portfolio when both LCs bind.
- When one LC binds, all must bind. Otherwise, all do not bind: indeterminacy.

General Monetary Equilibrium

Coexistence: properties

(Case C): Equal rates of return ...

- The shocking result is when $\lambda = \lambda^f > 0$ and we have identical currencies $\Pi = \Pi^f$ and $\kappa = \kappa^f$

- In this case we have

$$e = \frac{M}{M^f}$$

- This is the standard solution for the nominal exchange rate coming out of a symmetric two country CIA model.
- Is this a micro-foundation for that model?
 - ▶ NO!!! This only holds for certain parameter values – not a general result. Hence beware of the monetary economist with free parameters.

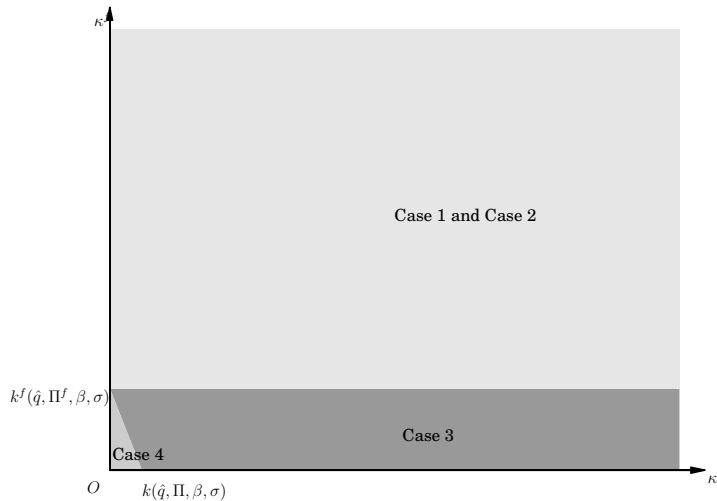
Comparative Statics

Case A: $\Pi > \Pi^f$

- Focus on this case with coexistence equilibria as example.
- What are (κ, κ^f) required to sustain coexistence in this Case?
- How do they vary with policy or fundamentals?

Comparative Statics

Case A: $\Pi > \Pi^f$... baseline



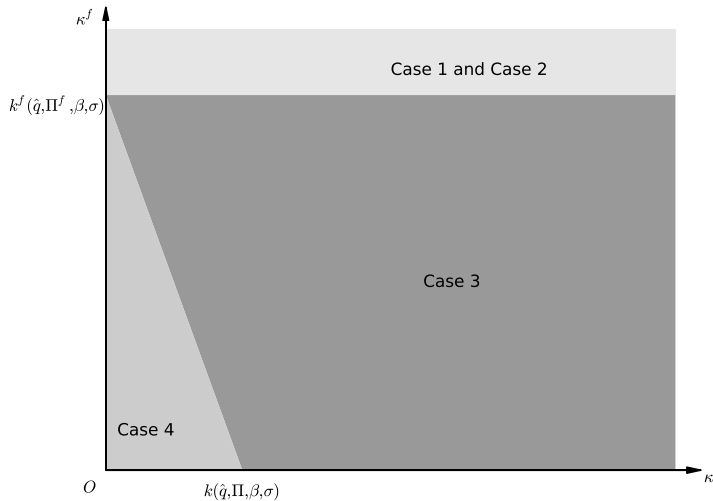
Comparative Statics

Case A: $\Pi > \Pi^f$... Higher Π^f



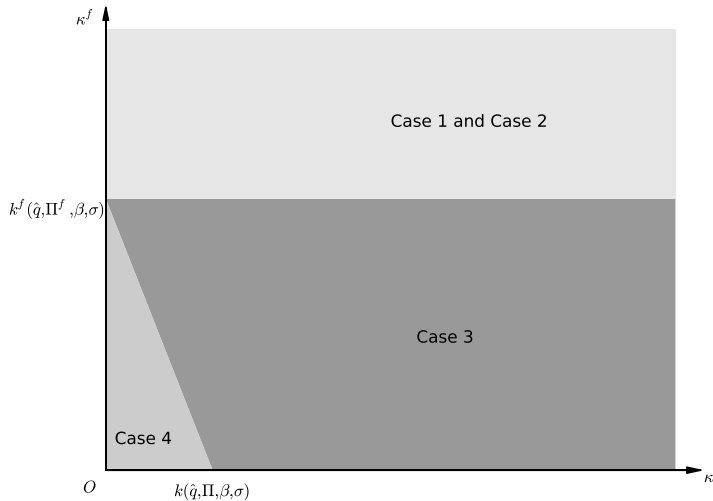
Comparative Statics

Case A: $\Pi > \Pi^f$... Higher matching probability σ



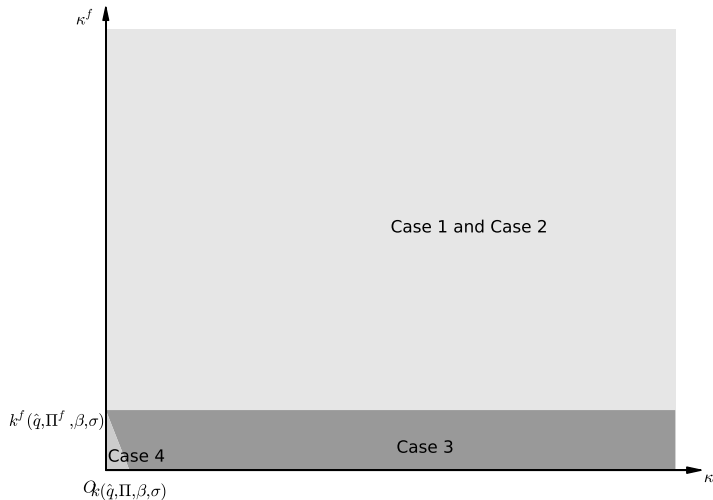
Comparative Statics

Case A: $\Pi > \Pi^f$... Lower IES $1/\theta$



Comparative Statics

Case A: $\Pi > \Pi^f$... more convex $c(q)$



Comparative Statics

Coexistence: comparative statics (Case A: $\Pi > \Pi^f$)

If a currency

- has low enough inflation relative to its foreign counterpart,
- circulates in DM with lower matching frictions,
- is demanded by agents with low intertemporal elasticity of substitution (in q), or that
- DM production cost $c(q)$ is not too convex,

then to sustain coexistence (determinate e) equilibria, the costs of counterfeiting must be relatively higher.

More in the Paper

Extension 1: Fiscal Policies

- Income tax on CM output, results in:

$$\phi m \leq \frac{\kappa(1 - \tau)}{\phi_{-1}/\phi - \beta(1 - \sigma)},$$

and

$$e\phi m^f \leq \frac{\kappa^f(1 - \tau)}{\phi_{-1}e_{-1}/\phi e - \beta(1 - \sigma)}$$

- Proposition:** Assume income taxation in CM and lump-sum transfers of fiscal revenue to all agents. There exists income tax rates τ and τ^f such that there still exists positive demand for both monies and e is made determinate.

More in the Paper

More Extensions

Main coexistence and determinacy result survives environments with:

- Trade Credit in DM
- Fiat monies as collateral
- Nominal bonds (and fraud in assets)

More in the Paper

Timing of government transfers

Consider alternative:

- Seigniorage revenue transferred to DM-buyers after CM closes
- Vital who gets which new money
- Implies explicit modelling of country-specific DMs
- Two-country model suffices

Main coexistence and determinacy result survives, but now 3×16 cases of equilibrium configurations to consider.

Conclusion

- Standard international monetary economics presume “currency-in-advance” to pin down nominal exchange rates, e .
- Kareken-Wallace (QJE 81): Absent this assumption, e is everywhere indeterminate.
- This paper: Shows connection between threat of counterfeiting (private info) and
 - ▶ phenomena of partial and complete dollarization; and
 - ▶ equilibrium e determinacy,

without ad-hoc restrictions on payment instruments.