International Monetary Theory:
Trade, Exchange Rates and Spillovers

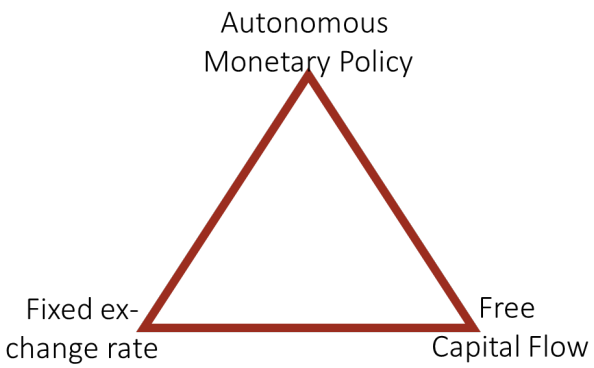
by

Markus K. Brunnermeier and Yuliy Sannikov
Princeton and Stanford University

Motivation

- Global currency spillovers
  - "Flight to safety" – dollar appreciation when risk rises
  - How large country monetary policy affects capital flows/ exchange rates
  - Local currency: good store of value/hedge for idiosyncratic risk
  - Global currency: good hedge for international competitiveness risk

- Monetary policy space: "Nuanced Mundell-Fleming Trilemma"
  - Local and global money have different risk profile (imperfect substitutes)
    increases policy space
  - Too high inflation:
    local citizens substitute local currency
    for global currency
    limits policy space



- Reserve currency management – irrelevance theorem

Modeling Framework

	Closed economy	Open Economy
Static	Hick's IS-LM	Mundell-Fleming
Dynamic Impulse response	New Keynesian	Obstfeld-Rogoff
Risk & Dynamic financial frictions	Bewley (Samuelson) I Theory of Money	X
		+ money has risk profile

Frictions

- Incomplete markets
  - Within country
    - only with respect to idiosyncratic risk
    - other risk can be shared within national economy
  - Across countries
    - only currencies can be traded

- Money is a bubble
  - Like in Samuelson, Bewley

- Prices are fully flexible

International setting

- Small Economy

- Large Economy*

- Local currency
  - Store of value to insure against <u>idiosyncratic</u> risk

Exchange rate

- Global currency* $
  - Store of value, hedge idiosyncratic risk

cross-holdings to hedge "trade risk"

- Shocks to productivities of tradables
  - **export good 1, productivity b_t**
  - **import good 2**

Good 1 productivity b_t^*
Good 2 productivity …

International setting

- Small Economy

- Large Economy*

- Local currency
  - Store of value to insure against <u>idiosyncratic</u> risk

Exchange rate

- Global currency* $
  - Store of value, hedge idiosyncratic risk

cross-holdings to hedge "trade risk"

- Shocks to productivities of tradables
  - **export good 1, productivity b_t**

Good 1 productivity b_t^*

$ demand depends on b_t^*/b_t risk (optimal hedge level)
total (local currency + $) depends on friction / idiosyncratic risk
currencies are imperfect substitutes

Intuition

- Small country: trades global goods
- Hold global money as Net Foreign Asset Position to hedge trade risk

- Value of money
  - Total money demand depends on frictions inside country (idiosyncratic risk)
  - Global money portion depends on optimal hedging of trade risk

  - 2 money can coexist (even though both are "bubbles")
    - Different return-risk profile

Large country

logarithmic utility

$$E\left[\int_0^\infty e^{-\rho t}\log c_t^* \, dt\right]$$

where c_t^* is the consumption of the tradable good

- Capital produces a^* units of the (non-tradable) investment good or b_t^* of the tradable consumption good
- Agents choose fraction α_t^* of capital to produce the consumption good

$$\frac{dk_t^*}{k_t^*} = (\Phi(\iota_t^*) - \delta^*)dt + \tilde{\sigma}^* d\tilde{Z}_t, \qquad \iota_t^* = (1-\alpha_t^*)a^*$$

- value of all goods produced is $a^* K_t^*$
- value of all consumption $(a^* - \iota^*) K_t^*$
- - " - physical capital $q_t^* K_t^*$
- - " - large country's money $p_t^* K_t^*$

in investment good as numeraire

- Assume parameters s.t. optimal portfolio weight on small country's money is 0

Optimality & Market clearing

- Consumption= ρ × net worth, so

$$\underbrace{\rho}_{\substack{\text{net worth}\\ \text{dividend yield}}} = \underbrace{1-\theta^*}_{\substack{\text{capital}\\ \text{portfolio}\\ \text{share}}} \underbrace{\frac{a^* - \iota^*}{q^*}}_{\substack{\text{dividend}\\ \text{yield}}} + \theta^* \cdot 0, \quad \text{where } \Phi'(\iota^*) = \frac{1}{q^*}$$

… money portfolio share, θ^*, determines q^* and ι^*

- Portfolio Choice: diff in returns = Cov(diff in risk, wealth risk)
- capital gain on money/capital = $\Phi(\iota^*) - \delta^*$

$$\frac{\rho}{1-\theta^*} = \underbrace{\frac{a^* - \iota^*}{q^*}}_{\substack{\text{difference in}\\ \text{dividend yield}\\ \text{capital vs. money}}} = \underbrace{\tilde{\sigma}^*}_{\substack{\text{difference}\\ \text{in risk}}} \cdot \underbrace{(1-\theta^*)\tilde{\sigma}^*}_{\substack{\text{net worth}\\ \text{risk}}}$$

- $\Rightarrow \theta^* = 1 - \frac{\sqrt{\rho}}{\tilde{\sigma}^*}$ money demand increases in $\tilde{\sigma}^*$

Return on global money ($)

- a^* is constant $\Rightarrow$ money has risk-free return in the investment good

$$r^* = \Phi(\iota^*) - \delta = \text{growth of large country's capital}$$

- Return in terms of the tradable good is

$$dr_t^G = r^* dt + db_t^* / b_t^*$$

tradable good productivity

Small country

- Same preferences preferences:

$$E\left[\int_0^\infty e^{-\rho t}\log C_t\ dt\right]$$

- $\hat{\alpha}_t K_t$ devoted to produce tradable consumption good

  … then traded for tradable basket / global money

- $C_t = \xi_t b_t K_t$ consumption
- $(\hat{\alpha}_t - \xi_t) b_t K_t$ trade imbalance (net export)
- $G_t > 0$, net foreign asset position (only global money)

(measured in tradable basket)

$$\frac{dG_t}{G_t} = \underbrace{r^* dt + \frac{db_t^*}{b_t^*}}_{dr_t^G} + \frac{(\hat{\alpha}_t - \xi_t) b_t K_t}{G_t} dt$$

State variable

- Net foreign asset position to tradable production potential

$$v_t = G_t/(b_t K_t)$$

- Assume

$$\frac{d(b_t / b_t^*)}{b_t / b_t^*} = \mu^{PT} dt + \sigma^{PT} dZ_t$$

$$\frac{dG_t}{G_t} = \underbrace{r^* dt + \frac{db_t^*}{b_t^*}}_{dr_t^G} + \frac{\hat{\alpha}_t - \xi_{tt}}{v_t} dt \Rightarrow$$

$$\frac{dv_t}{v_t} = \underbrace{(r^* - \Phi(\iota_t) + \delta - \mu^{PT} + (\sigma^{PT})^2)}_{M(v)} dt + \frac{\hat{\alpha}_t - \xi_t}{v_t} dt - \sigma^{PT} dZ_t .$$

Equilibrium in the small country

- Equilibrium in the small country is a map

history of shocks $\longrightarrow$ prices q_t, p_t, allocations

$\{Z_s, Z_s^*, 0 \le s \le t\}$ $\hat{\alpha}_t, \iota_t, \xi_t$ & portfolio weigths $(1\text{-}\theta_t - \zeta_t, \theta_t, \zeta_t)$

- such that
  - all agents maximize utility (choose portfolio, consumption, technology)
  - all markets clear (capital, local and global money)

State variable

- Equilibrium in the small country is a map

history of shocks

$\{Z_s, Z_s^*, 0 \le s \le t\}$

prices q_t, p_t, allocations

$\hat{\alpha}_t, \iota_t, \xi_t$ & portfolio weigths $(1\text{-}\theta_t - \zeta_t, \theta_t, \zeta_t)$

$v_t = G_t/(b_t K_t)$

Portfolio choice & asset pricing (dynamic)

- Portfolio share (processes)
- Local money $$\frac{d\theta_t}{\theta_t} = \mu_t^{\theta} dt + \sigma_t^{\theta} dZ_t$$
- Global money $$\frac{d\zeta_t}{\zeta_t} = \mu_t^{\xi} dt + \sigma_t^{\xi} dZ_t$$
- Returns expressed with country net worth N_t, as numeraire
- Return on individual net worth $$dr_t^n = \rho\ dt + (1\text{-}\theta_t - \zeta_t)\tilde{\sigma}\ d\tilde{Z}_t$$
- Return on local money $$dr_t^{ML} = \frac{d\theta_t}{\theta_t}$$
- Return on global money ($) $$dr_t^{MG} = \frac{\xi_t - \hat{\alpha}_t}{\nu_t} dt + \frac{d\zeta_t}{\zeta_t}$$
- Asset pricing equation (with log utility)

$$E[dr_t^n - dr_t^{MG}] = Cov[dr_t^n - dr_t^{MG}, dr_t^n] \Rightarrow \rho - \frac{\xi_t - \hat{\alpha}_t}{\nu_t} - \mu_t^{\xi} = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$$

$$E[dr_t^n - dr_t^{ML}] = Cov[dr_t^n - dr_t^{ML}, dr_t^n] \Rightarrow \rho - \mu_t^{\theta} = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$$

Money valuation

$$\rho - \mu_t^\theta = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2 \Rightarrow \theta_0 = E\left[\int_0^\infty e^{-\rho t}(1-\theta_t-\zeta_t)^2 \tilde{\sigma}^2 \theta_t \, dt\right]$$

- Constant environment (fixed ζ): fixed point where

$$\frac{(1-\theta-\zeta)^2 \tilde{\sigma}^2}{\rho} = 1$$

  - θ = 0 also a fixed point…

- Global money valuation equation a bit harder to interpret

$$\rho - \frac{\xi_t - \hat{\alpha}_t}{\nu_t} - \mu_t^\xi = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$$

but a back-of-the-envelope calculation gives

$$\zeta = \frac{\overbrace{r^* - (\Phi(\iota) - \delta) - \mu^{PT} + (\sigma^{PT})^2}^{M}}{(\sigma^{PT})^2}$$

Consumption & Investment (static equations)

- Wealth (in tradable) G_t / ζ_t
- Value of all capital (in tradable) $(1-\zeta_t-\theta_t)G_t / \zeta_t$

- Consumption market clearing $\rho \underbrace{\frac{G_t}{\zeta_t}}_{\text{wealth in tradable basket}} = \xi_t b_t K_t$

- Optimal investment

$$\Phi'((1-\hat{\alpha}_t)a)a\frac{(1-\zeta_t-\theta_t)G_t}{\zeta_t K_t}\begin{cases} = b_t & \text{if } \hat{\alpha}_t \in (0,1) \\ \leq b_t & \text{if } \hat{\alpha}_t = 1 \\ \geq b_t & \text{if } \hat{\alpha}_t = 0 \end{cases}$$

Computation

"Time step"
θ(v,t - ε), ζ(v,t - ε)

portfolio weights
θ(v,t), ζ(v,t)

law of motion of v,
asset-pricing equations

$$\rho - \frac{\xi_t - \hat{\alpha}_t}{\nu_t} - \mu_t^{\xi} = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$$

$$\rho - \mu_t^{\theta} = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$$

"Static step":
find $\xi_t, \hat{\alpha}_t, q_t, \iota_t$
from static equations

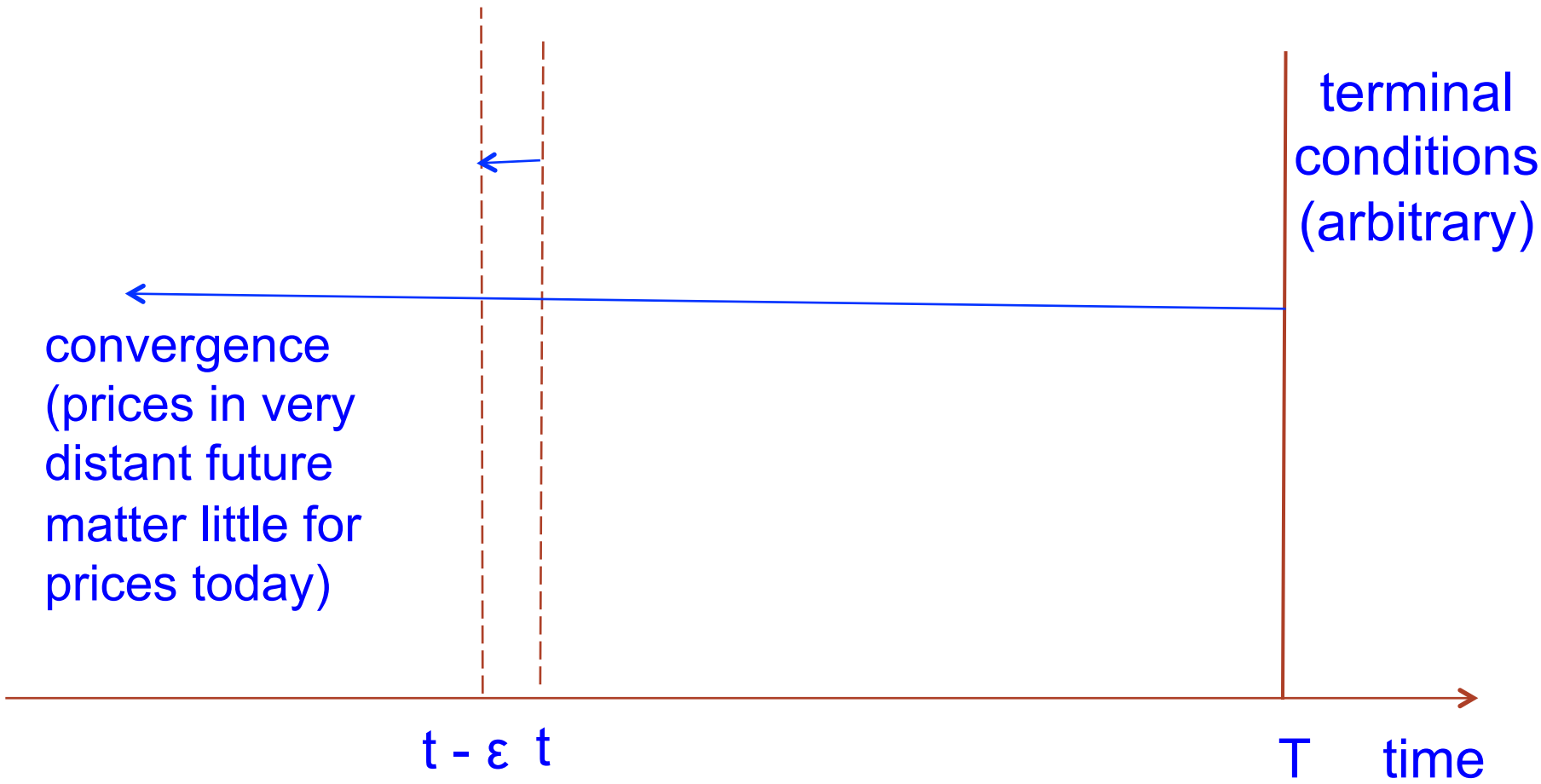
t - ε

t

time

- For details of this method, see survey "Money, Macro and Finance: A Continuous-Time Approach" with Markus Brunnermeier

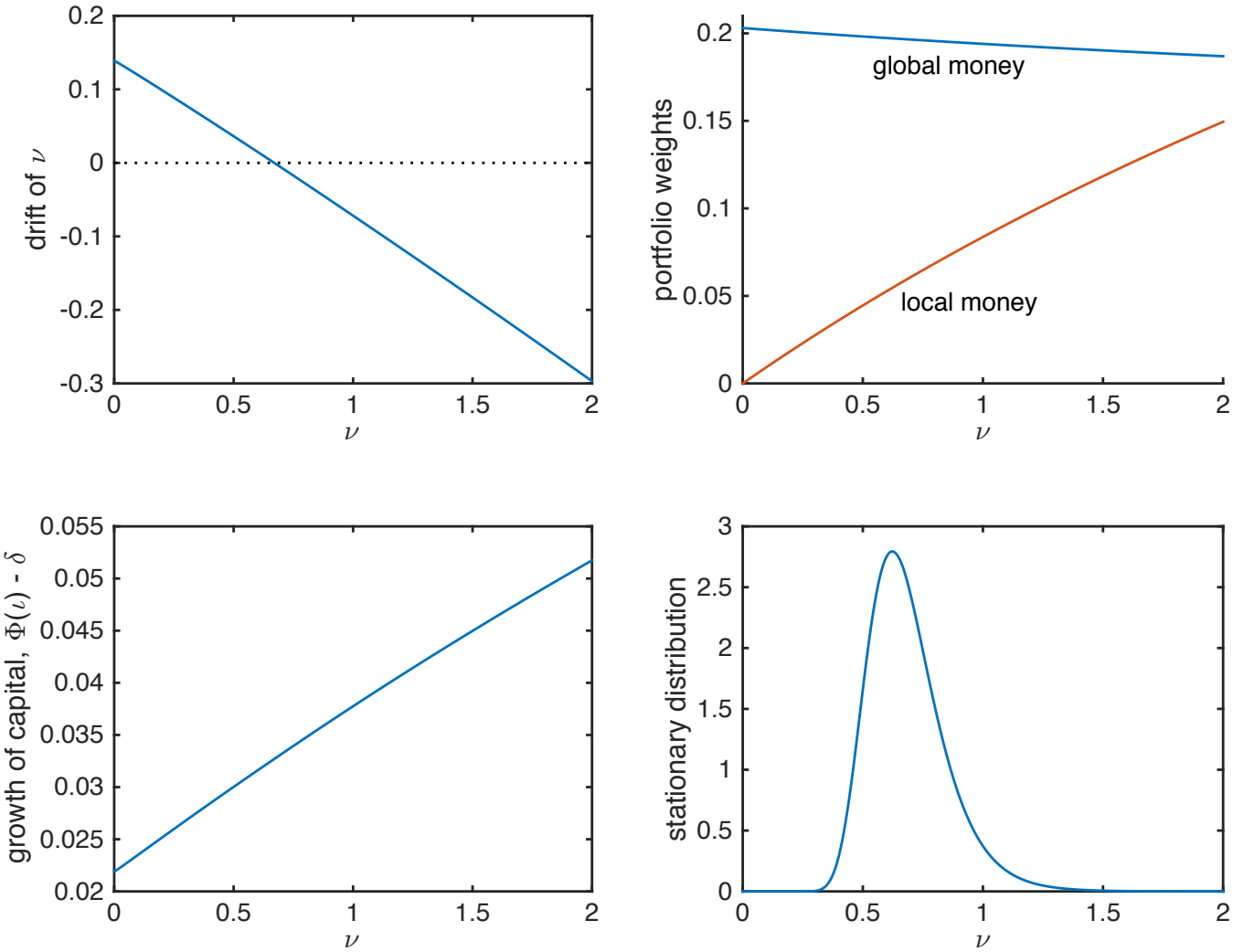
Computation



Numerical Example

$$\rho = 5\%,\ \tilde{\sigma} = 0.3,\ \mu^{PT} = 1\%,\ \sigma^{PT} = 0.15,$$

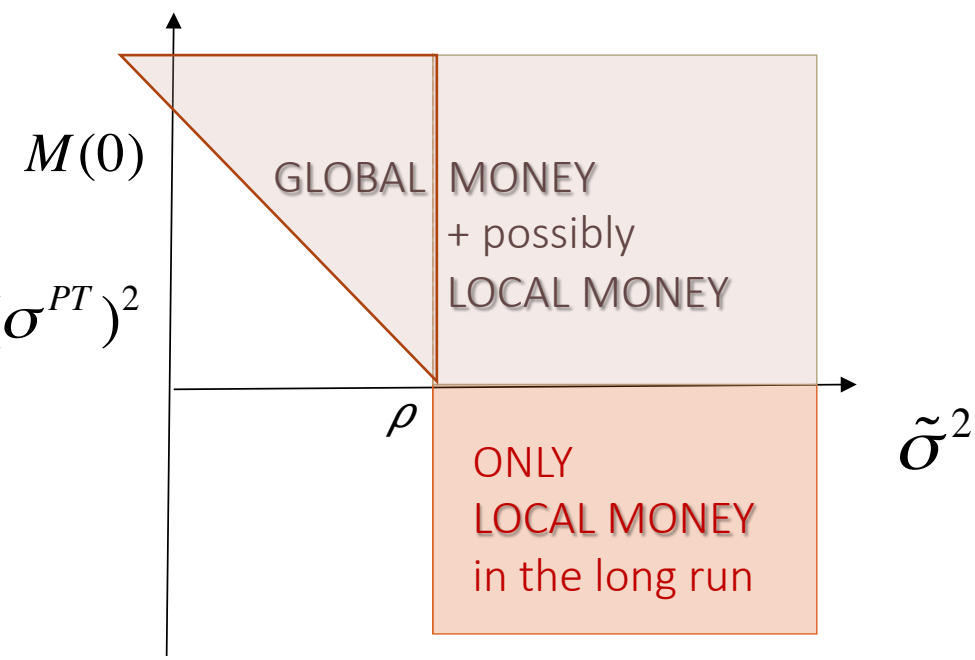
$$a = 0.13,\ \delta = 0.02,\ \Phi(\iota) = \log(\kappa\iota + 1)/\kappa,\ \kappa = 2,\ r^* = 2.2\%$$



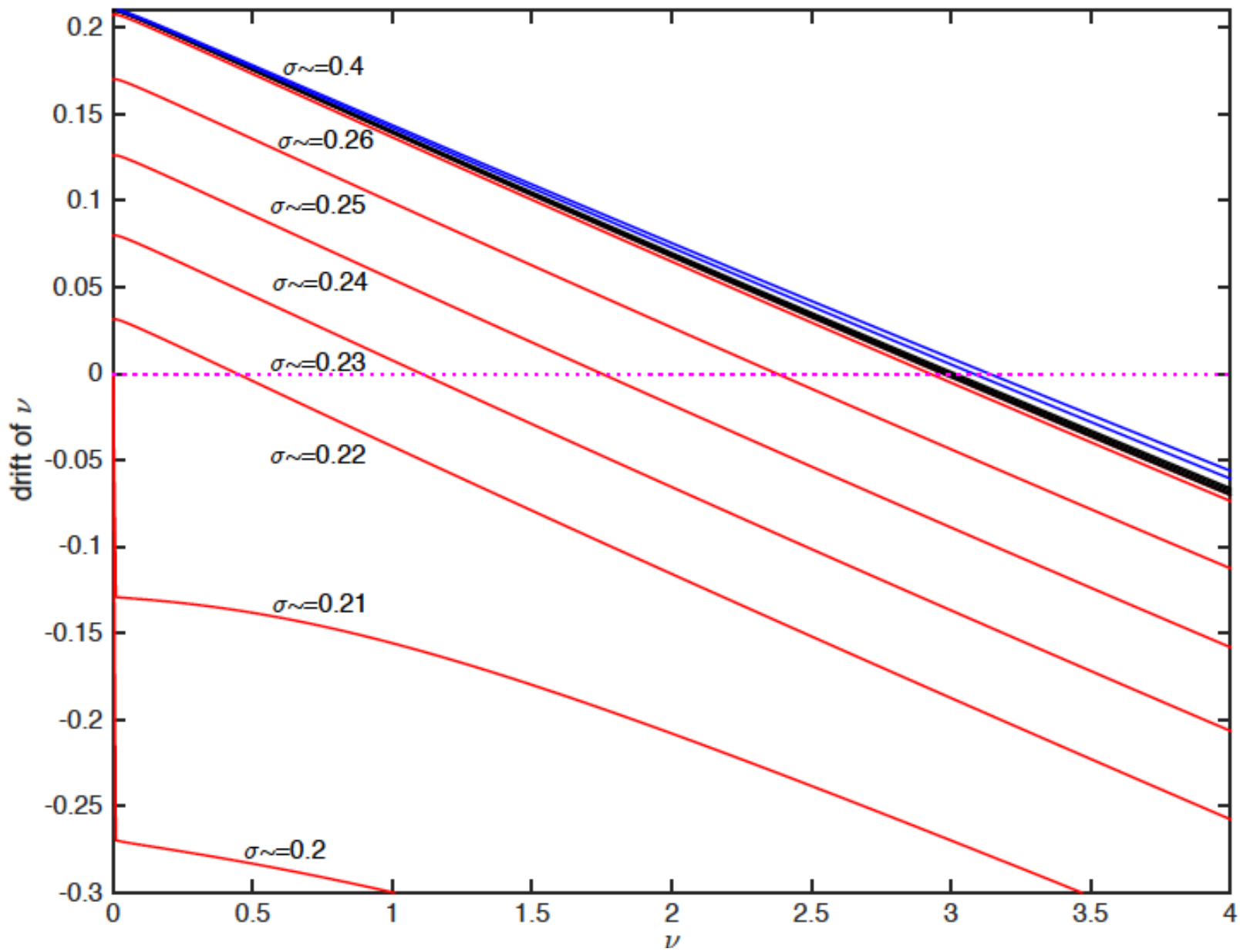
(Co-)Existence of Money

- Proposition 1:
- If $\tilde{\sigma}^2 > \rho$ and M(0) ≤ 0, then local money has value and ν = 0 (no NFAP) is absorbing state
- Otherwise, if $\tilde{\sigma}^2 - \rho + M(0) > 0$ then positive amount of global money is held in the small country (and local money may or man not have value)

$$M(\nu_t) = r^* - (\Phi(\iota_t) - \delta) - \mu^{PT} + (\sigma^{PT})^2$$



Local and global money demand



Brunnermeier & Sannikov

Flight to safety (into dollar)

- Unanticipated increase in σ^{PT}
  - terms of trade or productivity becomes more volatile

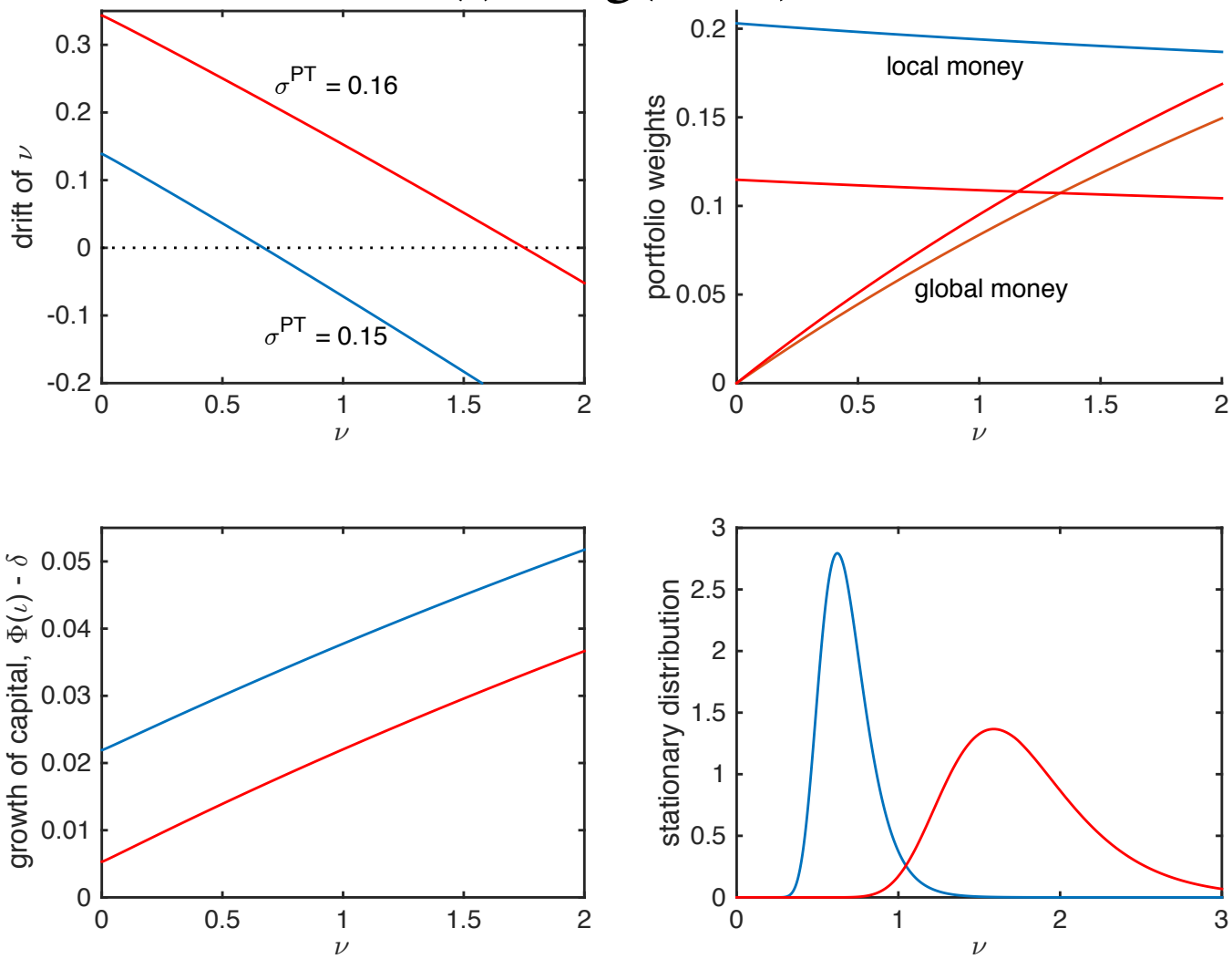
- Portfolio share held in dollars increases
  - ➡ Dollar valuation is higher

- Transition
  - $\nu_t = G_t/(b_t K_t)$ remains unchanged upon shock, then drifts up

Numerical Example, σ^{PT} up from .15 to .16

$$\rho = 5\%,\ \tilde{\sigma} = 0.3,\ \mu^{PT} = 1\%,$$

$$a = 0.13,\ \delta = 0.02,\ \Phi(\iota) = \log(\kappa\iota + 1)/\kappa,\ \kappa = 2,\ r^* = 2.2\%$$



Brunnermeier & Sannikov

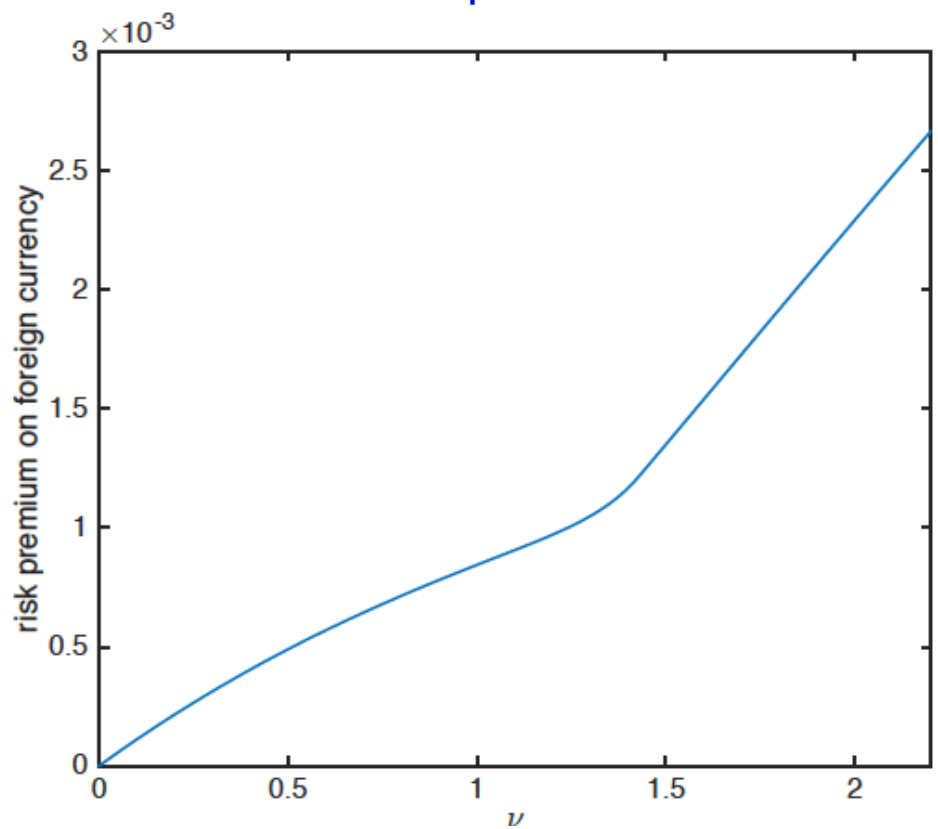
Exchange rate dynamics - UIP

- For $i_t = i_t^*$ (= 0)
  - foreign currency is expected to appreciate relative to local (if held in positive quantity)
- Exchange rate and ν:
  - high ν: dollar falls in value relative to local currency (and expected to appreciate faster as ν moves back to the steady state)
  - locals overhedge trade risk, so demand for dollar falls

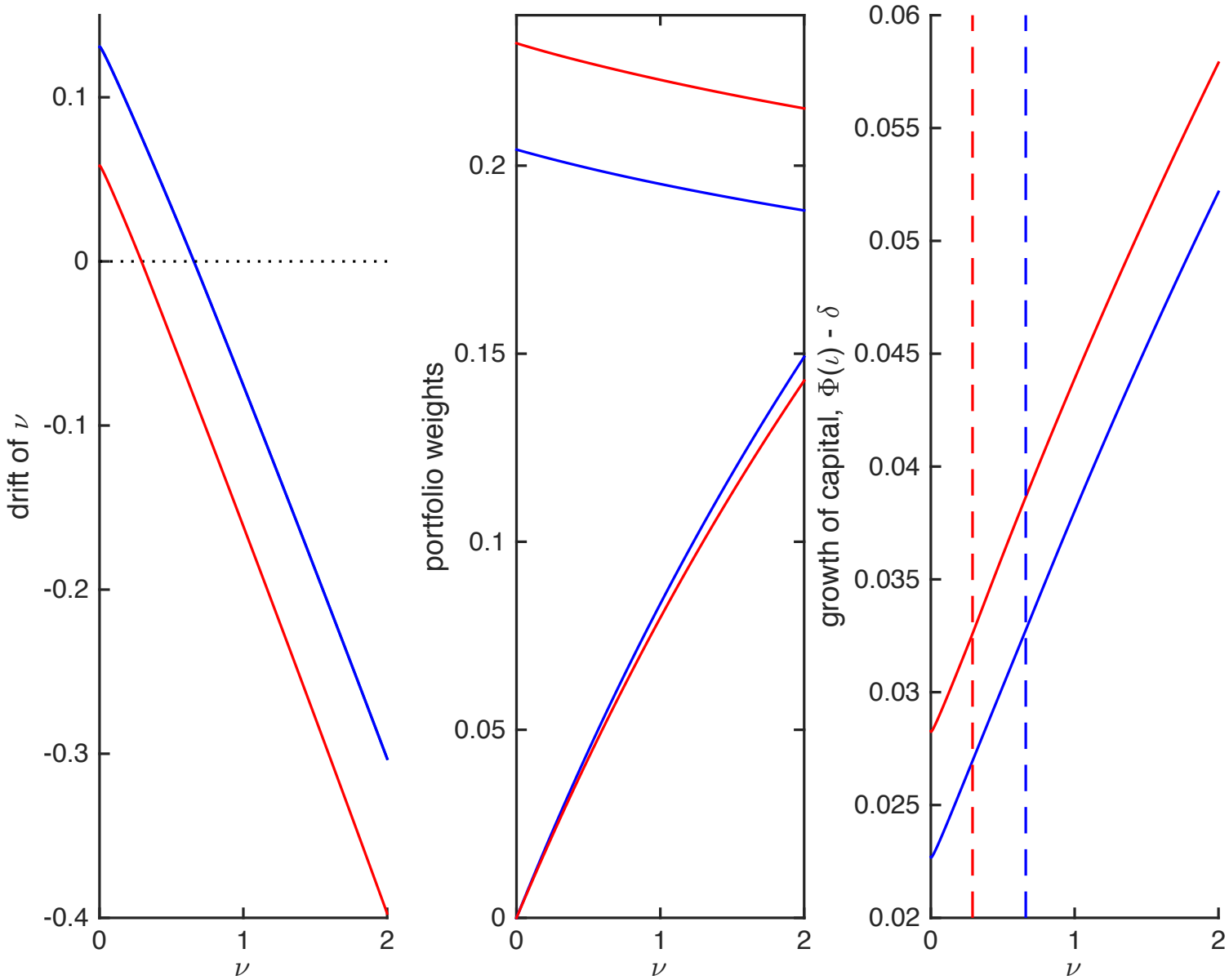
$$i_t^* - i_t = E_t[\Delta E] + \psi_t$$

$$\psi_t = \underbrace{-\sigma^\theta}_{>0} \underbrace{(\sigma^\xi - \sigma^\theta)}_{>0}$$

from asset pricing equations



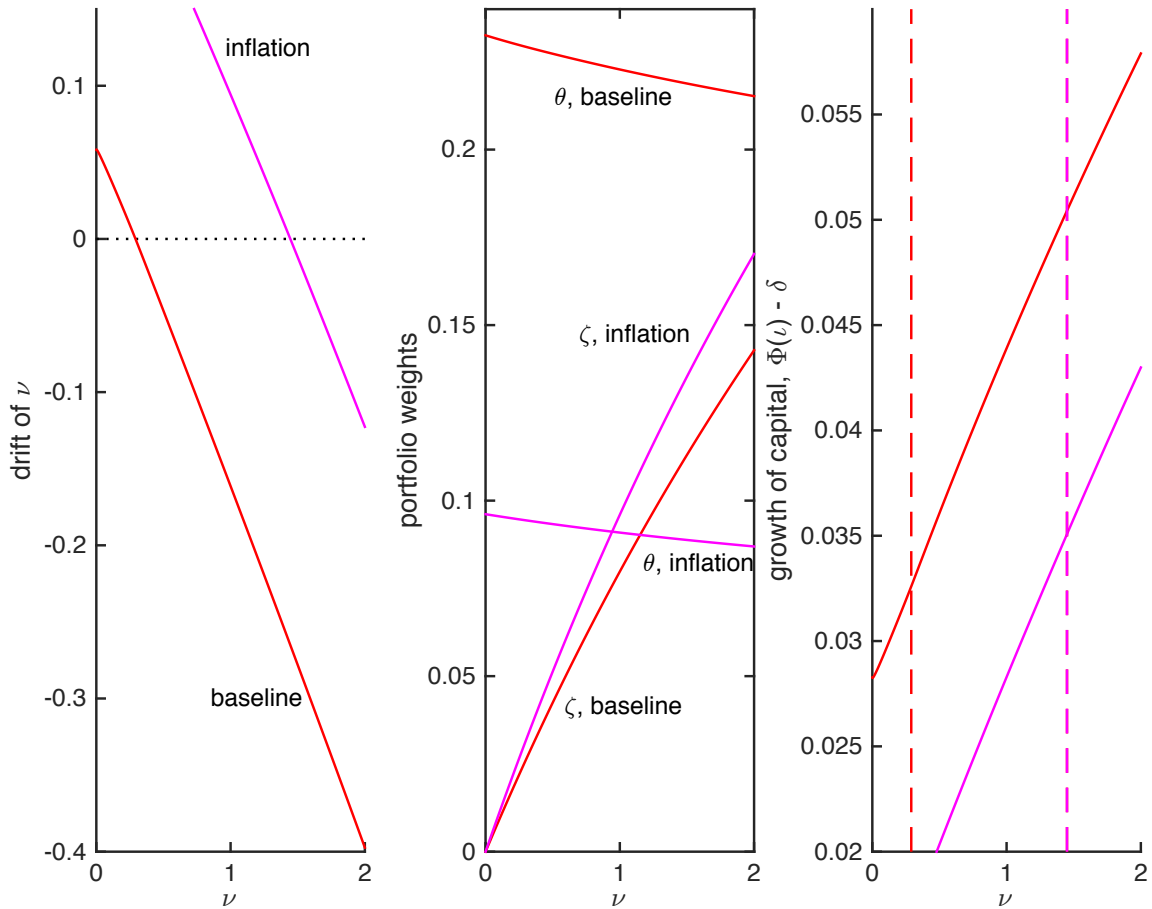
Spillover from lowering r^*



Brunnermeier & Sannikov

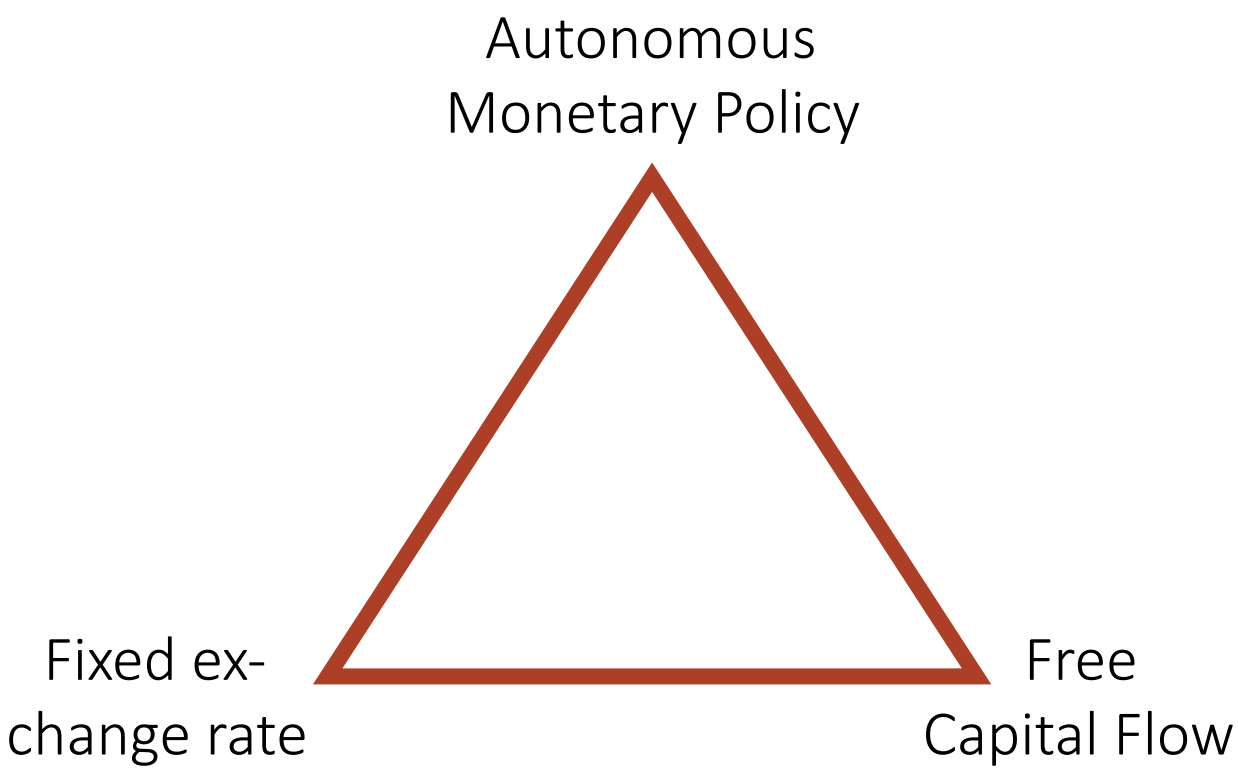
Higher inflation π_t

- seigniorage subsidizes capital
- local money is less attractive $\rho + \pi_t - \mu_t^\theta = (1\text{-}\theta_t - \zeta_t)^2 \tilde{\sigma}^2$
- short run: investment drops, long run: investment rises (slightly)



Mundell-Fleming Trilemma

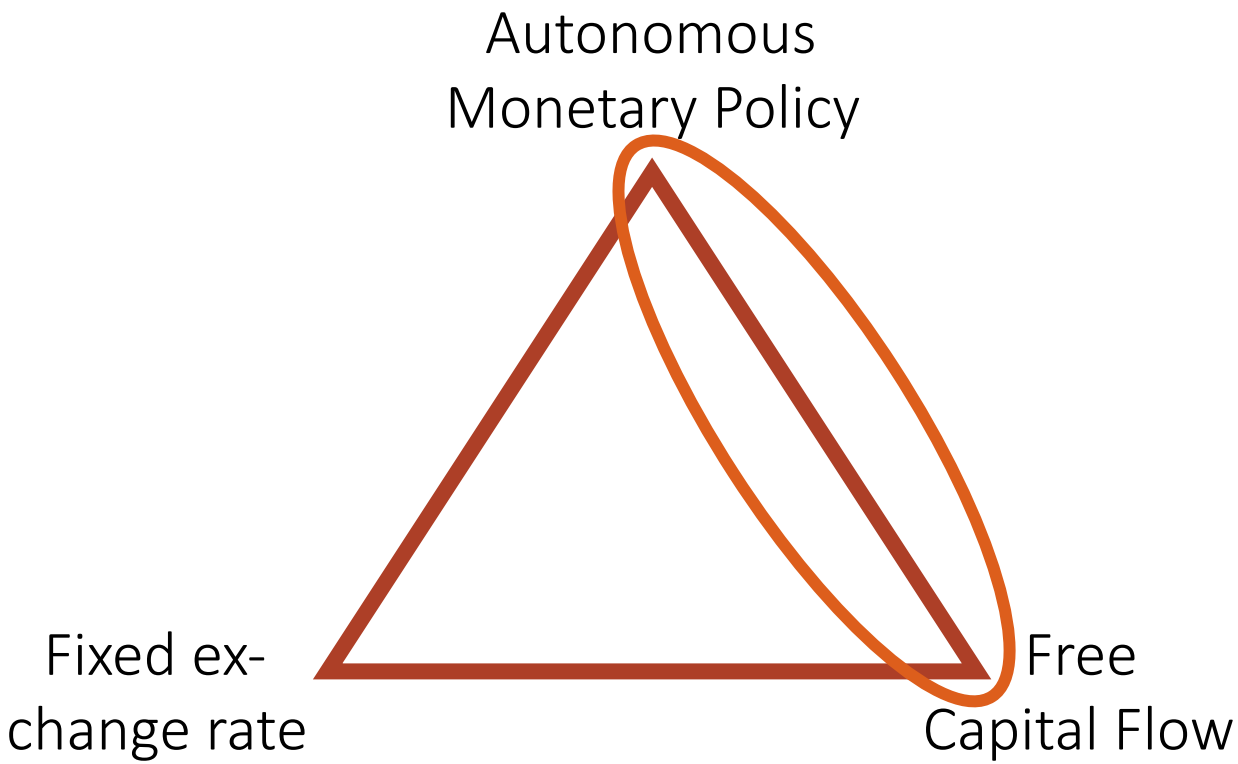
- Trilemma: Can only pick a 2 desiderata out of 3 –1 side



- "Dilemma": Pick only 1

Mundell-Fleming Trilemma

- Trilemma: Can only pick a 2 desiderata out of 3 –1 side



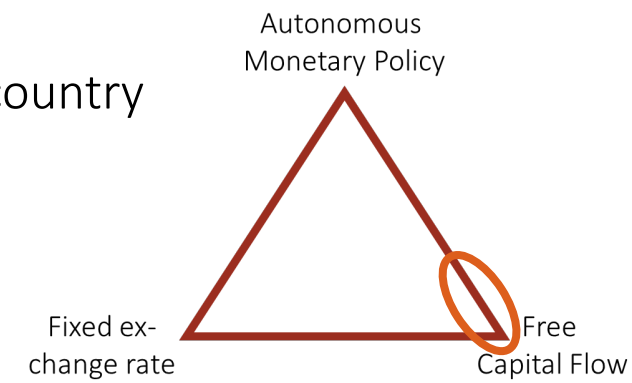
- "Dilemma": Pick only 1

Floating Exchange Rate

- With floating exchange rate & open capital account

Still range of monetary policy (local & global money imperfect substitutes)

- Inflation boosts growth, but only possible up to limit $\bar{\pi}(r^*)$
- Beyond limit, monetary policy has no bite
  - Citizens of small country hold only global money
- Range is higher with higher inflation in the large country
  - Large country's monetary policy determines range for small country



- Policy range is larger

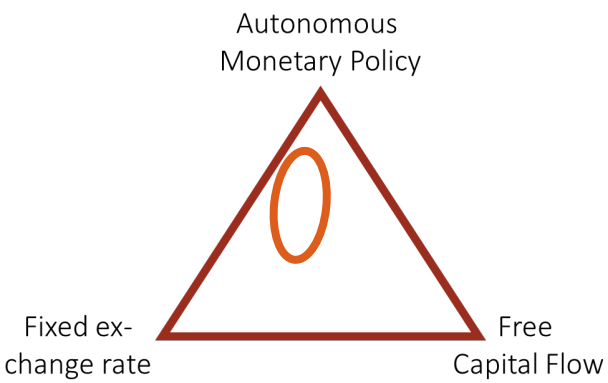
if local money is backed by taxes

Closed capital account

- Range of monetary policy is much larger

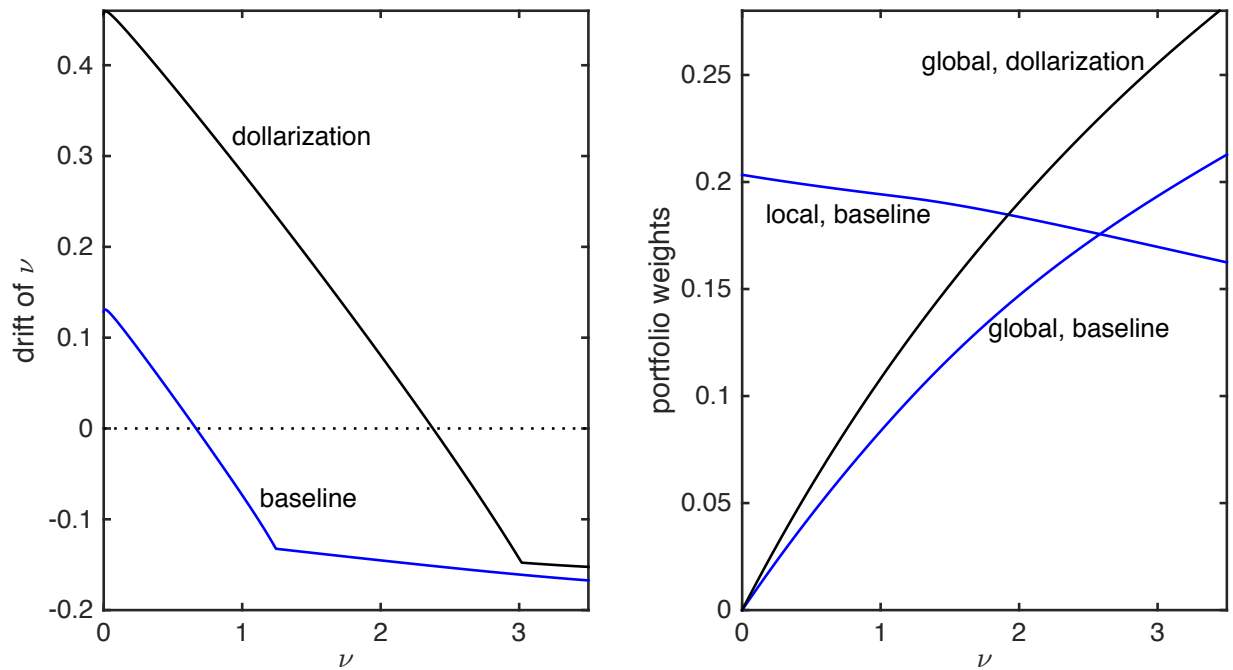
up to $\overline{\overline{\pi}} = \tilde{\sigma}^2 - \rho$

(physical capital is risky store of value)



Fixed exchange rate regimes & no MoPo

- Dollarization = (fully backed) Currency Board



- Exchange rate peg
  - Requires strong fiscal backing (since no backing by holding global reserves)
    - After a string of adverse shocks, government must tax and use to proceeds to remove some of the local currency in circulation

Foreign Currency Reserves

- Irrelevance Theorem: If central bank holds global money (reserves) citizens in small country will hold accordingly less

- Remarks:
  - If central banks holds more $-reserves than citizens would like to hold, then agents borrow foreign currency from abroad
  - If local money is worthless (without foreign reserves), then the value of local money derives only from the reserves
  - If government borrows $, small country citizens will hold accordingly more $
  - With fiscal backing of the local money, there are more nuances

Conclusion

- Endogenous value of money in 2 countries
  - Local currency: better hedge for idiosyncratic risk (non-tradeable consumption)
  - Global currency: hedge against ToT + export productivity shocks
  - Exchange rate endogenous
- Spillover effects from foreign monetary policy
- Nuanced Mundell-Fleming Trilemma
  - Local and global money have different risk profile (imperfect substitutes)
    ⇒ increases MoPo space
  - Too high inflation:
    local citizens substitute local currency for global currency
    ⇒ limits MoPo space
- Central Bank's foreign reserves holding: Irrelevance Result
- Optimal Monetary Policy
  - Idiosyncratic risk – correct pecuniary externality (real interest rate)
  - International savings

Thank you!