Inflation as a Long-run Optimal Policy in an Open Economy

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Inflation $\rightarrow$ Production $\rightarrow$ Terms of trade

- Fact 1: Trend inflation (in many countries)
- Fact 2: Price rigidity: X-country, X-good diffs

Inflation → Production → Terms of trade

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- Question: Long-run implications w/ trade
- Model: Trend Calvo + Ricardo (-Viner) trade
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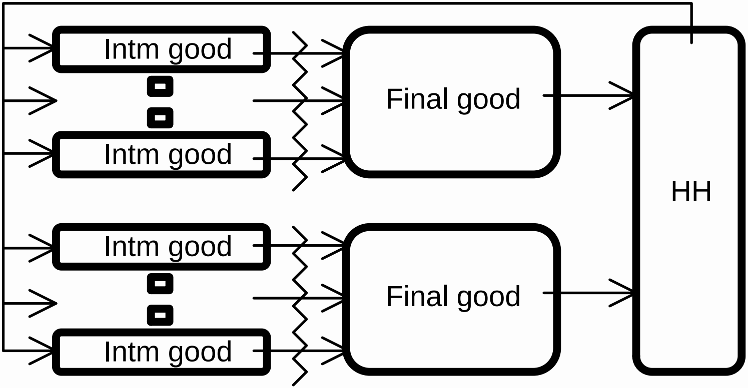
★ Inflation affects trade pattern
  - Breaking the dichotomy

★ Welfare enhancing inflation
  - Contrast to closed or small-open models
  - Effect of the terms of trade

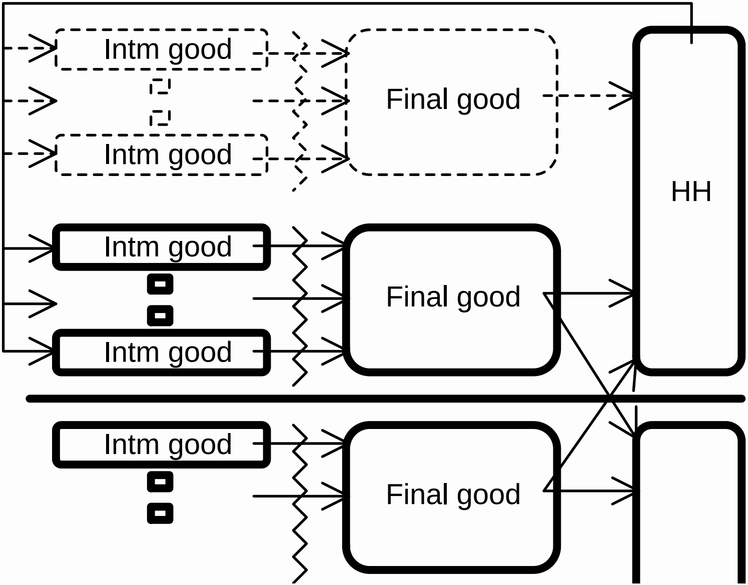
Model environment

- $t = 0, 1, ..., \infty$, analyze stationary state
- Home & foreign (w/ * if necessary)
- Stand-in HH in each country
- Final goods i, costless-tradeable
- Continuum $\upsilon \in (0, 1)$ of non-tradeable intermediate goods for each i
- No intl asset trade & balanced trade
- Money-less economy

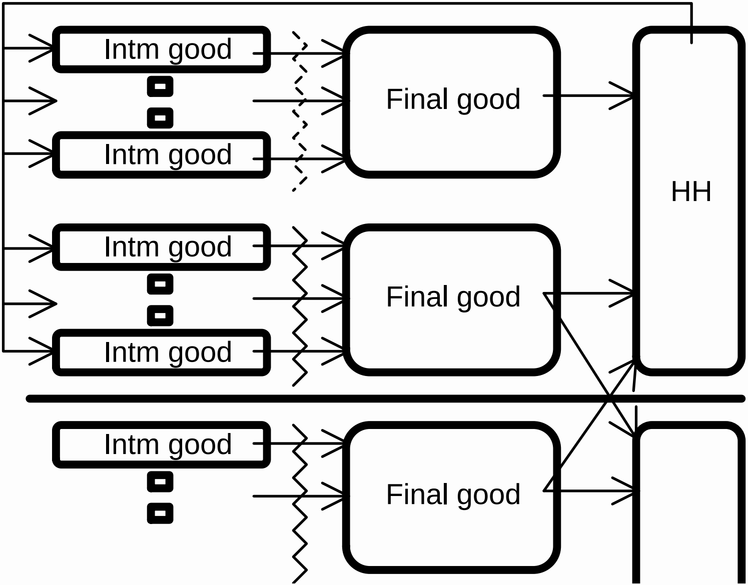
Model environment: Closed-economy



Model environment: CRS (Ricardian trade)



Model environment: DRS (Ricardo-Viner trade)



Home & the rest of the world

- foreign: the rest of the world
- Symmetry except for
  - Size: N, N^*
  - Exog. tech of int. good: θ_{it}, θ_{it}^*
  - Prob. of price change: ω_i, ω_i^*
  - Tax/subsidy rates: $\tau_{Lt}, \tau_{Lt}^*, \tau_{it}, \tau_{it}^*$
  - Inflation rate: Π, Π^*
- Not consider strategic situation
  - Π: treated as a policy parameter
  - Π^*: exogenously fixed

Households

$$\max \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t u\left(\left(\sum_i \alpha_i c_{it}^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}}, l_t\right),$$

$$\text{s.t. } \frac{\sum_i P_{it} c_{it}}{P_t} + b_t + \tau_{Lt} = \frac{1+i_{t-1}}{\Pi_t} b_{t-1} + w_t l_t + f_t,$$

where $u(c, l) = c^{\psi}(1-l)^{1-\psi}$.

- b_t: intra-country nominal bond
- τ_{Lt}: lump-sum tax
- i_t: nominal int. rate
- $\Pi_t = P_t / P_{t-1}$: gross inf. rate
- f_t: firms' real prfts

Final goods firms

$$\max P_{it}y_{it} - \int_0^1 P_{it}(v)y_{it}(v)\mathrm{d}v,$$

$$\text{s.t. } y_{it} = \left(\int_0^1 y_{it}(v)^{\frac{\eta-1}{\eta}}\mathrm{d}v\right)^{\frac{\eta}{\eta-1}}.$$

Intermediate good firms

- Each int. firm produces differentiated product
  - Index υ
- Facing the demand curve
- Using labor
  - RTS: $\gamma \in (0, 1]$
- Input subsidy $\tau_{it} \in [0, 1)$
- θ_{it}: productivity, common w/i industry
- Can update price w/ prob. $1 - \omega_i$
- Intertemporal problem of prfts max
  - discounting: $\Lambda_{tt+j} \equiv \beta^j \frac{u_{ct+j}}{u_{ct}}$

Intermediate good firms

$$\max_{P_{it}(v),\{l_{it+j}(v),y_{it+j}(v)\}_{j=0}^{\infty}} \mathrm{E}_t \sum_{j=0}^{\infty} \Lambda_{tt+j}\omega_i{}^j$$

$$\times \left[\frac{P_{it}(v)}{P_{t+j}} y_{it+j}(v) - (1-\tau_{it+j})w_{t+j}l_{it+j}(v)\right],$$

s.t.

$$y_{it+j}(v) = \theta_{it+j} l_{it+j}(v)^{\gamma},$$

$$y_{it+j}(v) = \left(\frac{P_{it+j}}{P_{it}(v)}\right)^{\eta} y_{it+j}.$$

Industry-price

- Those who adjust price: pick $\tilde{P}_{it}$

$$\left(\frac{\tilde{P}_{it}}{P_t}\right)^{1-\eta+\frac{\eta}{\gamma}} = \frac{\eta}{\eta-1}$$

$$\times \frac{E_t \sum_{j=0}^{\infty} \Lambda_{tt+j} \omega_i^j \left(\frac{P_{it+j}}{P_{it}}\right)^{\frac{\eta}{\gamma}} (1-\tau_{it+j}) \frac{w_{t+j}}{\gamma} \left(\frac{y_{it+j}}{\theta_{it+j}}\right)^{\frac{1}{\gamma}}}{E_t \sum_{j=0}^{\infty} \Lambda_{tt+j} \omega_i^j \frac{P_{it+j}}{P_{t+j}} \left(\frac{P_{it+j}}{P_{it}}\right)^{\eta-1} y_{it+j}}$$

Industry-price

- Industry-price, law of motion
$$P_{it} = \left(\omega_i P_{it-1}^{1-\eta} + (1-\omega_i)\tilde{P}_{it}^{1-\eta}\right)^{\frac{1}{1-\eta}}$$

- LoM of $p_{it} \equiv P_{it}/P_t$ determined

Price dispersion leads to resource costs

$$y_{it}\left(\frac{P_{it}}{P_{it}(\upsilon)}\right)^{\eta} = y_{it}(\upsilon) = \theta_{it} l_{it}(\upsilon)^{\gamma}$$

Integration over υ

$$y_{it}\underbrace{\left(\int_0^1 \left(\frac{P_{it}}{\tilde{P}_{it}}\right)^{\frac{\eta}{\gamma}} \mathrm{d}\upsilon\right)^{\gamma}}_{\equiv s_{it}^{\gamma}} = \theta_{it}\underbrace{\left(\int_0^1 l_{it}(\upsilon)\mathrm{d}\upsilon\right)}_{=l_{it}}^{\gamma},$$

i.e.,

$$y_{it} = \frac{\theta_{it}}{s_{it}^{\gamma}} l_{it}^{\gamma}.$$

Stationary state

Consider $\theta_{it} = \theta_i$, $\Pi_t = \Pi$

- Agg. & industry-level variables: constant

$$y_i = \frac{\theta_i}{s_i^\gamma} l_i^\gamma, \quad p_i = (1-\tau_i) v_i \frac{s_i^\gamma}{\theta_i} \frac{w}{\gamma} l_i^{1-\gamma}$$

where

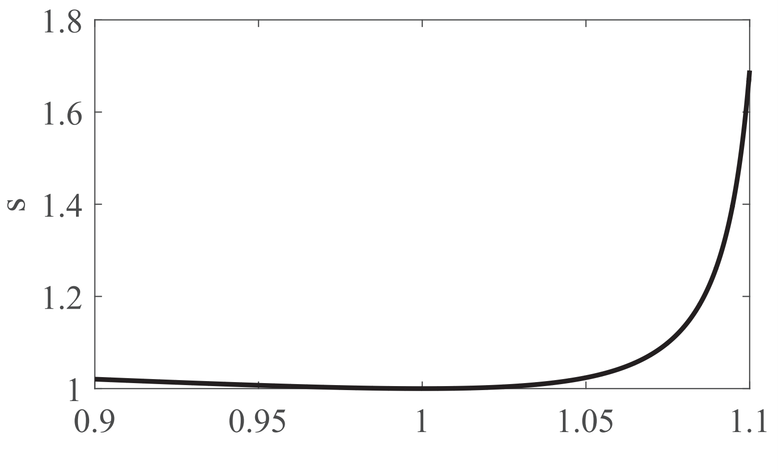
$$s_i = \frac{1-\omega_i}{1-\omega_i \Pi^{\frac{\eta}{\gamma}}} \left(\frac{1-\omega_i \Pi^{\eta-1}}{1-\omega_i} \right)^{\frac{\eta}{\eta-1}\frac{1}{\gamma}},$$

$$v_i = \frac{\eta}{\eta-1} \frac{1-\beta\omega_i \Pi^{\eta-1}}{1-\beta\omega_i \Pi^{\frac{\eta}{\gamma}}} \frac{1-\omega_i \Pi^{\frac{\eta}{\gamma}}}{1-\omega_i \Pi^{\eta-1}}.$$

Markup deterioration & resource costs

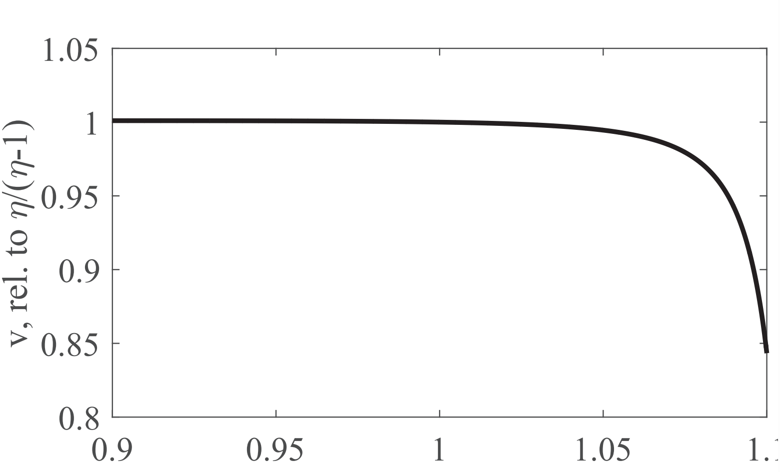
- $\Pi > 1$, $\omega > 0 \rightarrow$ markup gradually $\downarrow$
- Price re-setter picks larger markup
- Avg markup (v_i), gradually $\downarrow$
- Given price dispersion, output dispersion
- Ex ante symmetric, ex post not
- Allocation inefficiency, s_i

Dispersion costs (against annual Π)



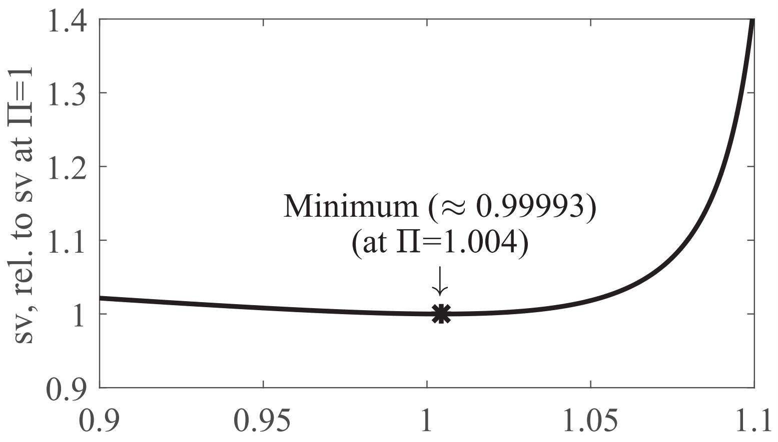
- min: $s = 1$ (when $\Pi = 1$ or $\omega = 0$)
- Asymmetrically increasing as Π deviates

Markup (against annual Π)



- Decreasing in Π around $\Pi = 1$
- Often abstracted (thru tax adjustment)

Relative price (against annual Π)



- Min: slightly larger than $\Pi = 1$
- Small impact of v → Assume $(1 - \tau_i)v_i = 1$

CRS, single-good autarky

- CRS ($\gamma = 1$), single-good, autarky
- Welfare

$$u \propto \left(\frac{\theta}{s}\right)^{\psi}$$

  - $s = 1$ (by $\Pi = 1$) achieves max
- Result not much affected by cost of hitting zero-lower bound (Schmitt-Grohé & Uribe 11, Coibion et al. 12)

CRS, two-good autarky

- CRS, two-good autarky
- Welfare
  - Max at $\Pi = 1$
- Relative price

$$\frac{p_A}{p_B} = \frac{\frac{s_A}{\theta_A}}{\frac{s_B}{\theta_B}}$$

  - Relative price depends on Π, ω_i, ... thru s (& v)

CRS, two-good costless trade eqm

Labor market

$$\sum_i l_i = l$$

Bond market

$$b_i = 0$$

Costless trade goods market for $i = A, B$

$$Nc_i + N^* c_i^* = Ny_i + N^* y_i^*$$

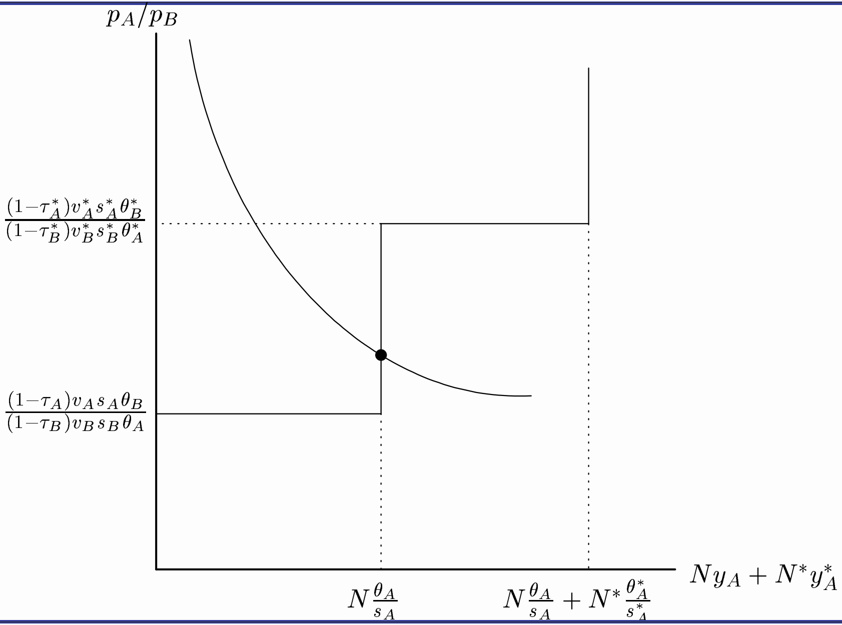
Two-good model, trade pattern (Prop. 1)

- CRS → Ricardian trade
- Home exports good A if

$$\frac{\frac{s_A}{\theta_A}}{\frac{s_B}{\theta_B}} = \frac{p_A}{p_B} < \frac{p_A^*}{p_B^*} = \frac{\frac{s_A^*}{\theta_A^*}}{\frac{s_B^*}{\theta_B^*}}$$

- Inf. rate affects trade pattern
  - thru s (& v)
- Eqm rel. price = home's terms of trade (TOT)

Prop 2: TOT $\uparrow$ by Π's deviation from 1



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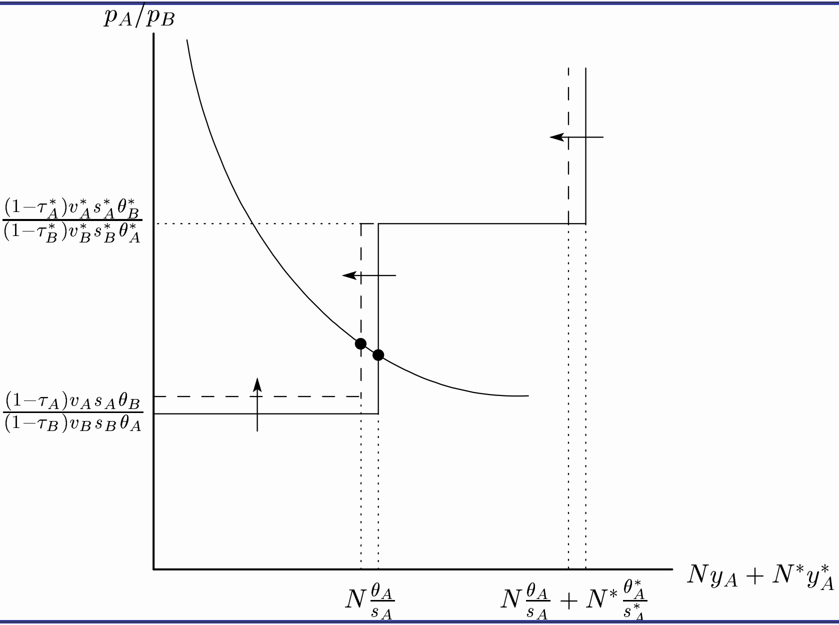


Welfare under trade

- Home's welfare

$$u = \left(\frac{\psi}{1-\psi}\right)^{\psi-1} \left(\frac{\theta_A}{s_A}\right)^{\psi}$$
$$\times \left(\alpha_A^{\rho} + \alpha_B \alpha_A^{\rho-1} \left(\frac{\theta_B^*}{\theta_A}\frac{s_A}{s_B^*}\frac{N^*}{N}\right)^{\frac{\rho-1}{\rho}}\right)^{\frac{\psi}{\rho-1}}$$

Prop 3: Welfare enhancing inflation

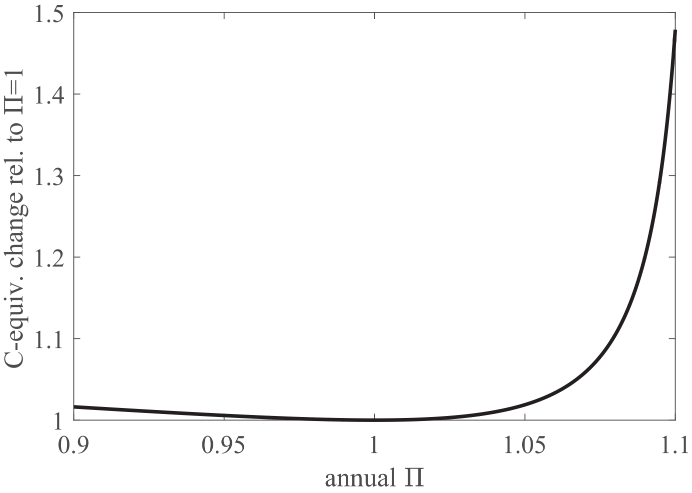
$$\frac{\partial u}{\partial \Pi} = -\Phi_0 \Phi_1 \frac{1}{s_A} \frac{\partial s_A}{\partial \Pi}$$

where $\Phi_0 > 0$ (constant) and

$$\Phi_1 = 1 - \frac{1-\rho}{\rho} \frac{\alpha_B}{\alpha_A} \left(\frac{\theta_B^*}{\theta_A} \frac{s_A}{s_B^*} \frac{N^*}{N} \right)^{\frac{\rho-1}{\rho}}$$

- If $\Phi_1 > 0$, $\Pi = 1$: maximizer
- If $\Phi_1 < 0$, $\Pi = 1$: (local) minimizer

Welfare enhancing inflation



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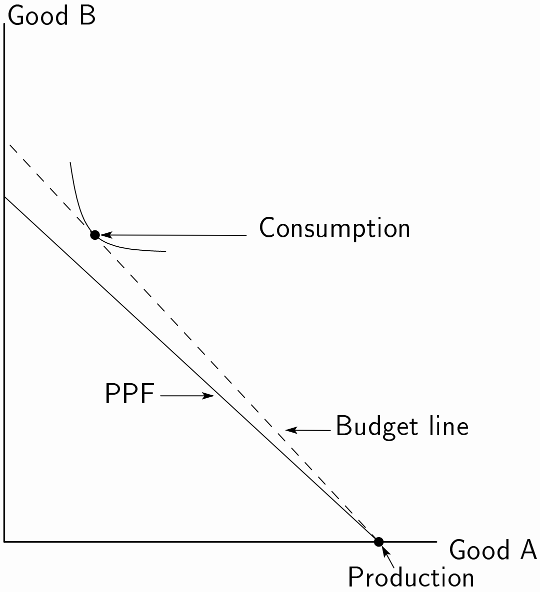

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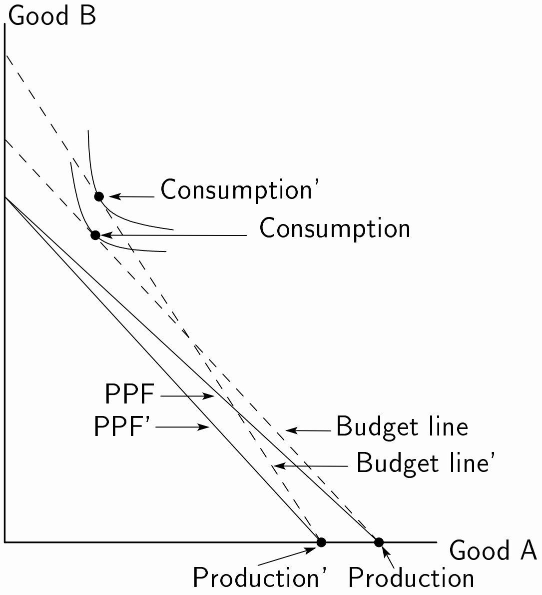
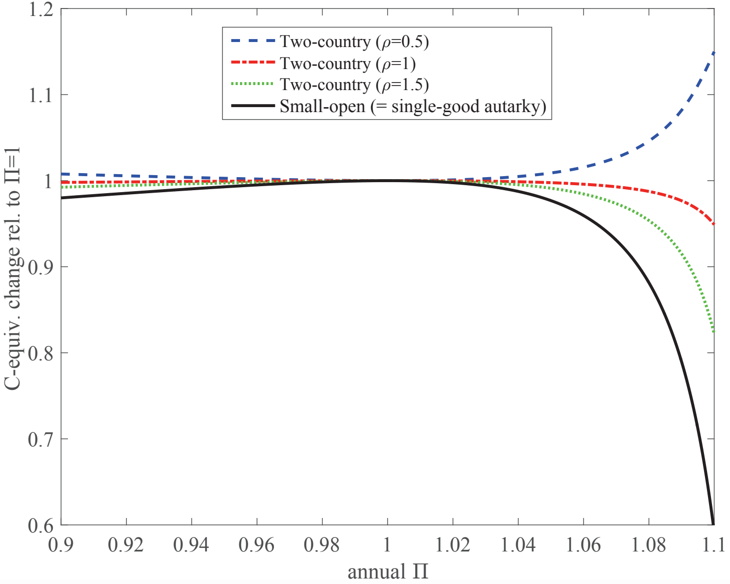


Mechanism known as immiserizing growth

- Deviation of Π from 1: effective TFP $\downarrow$
  (a) Production capacity $\downarrow$
  (b) Exports $\downarrow \rightarrow$ Export price $\uparrow \rightarrow$ TOT $\uparrow$
- (Reverse version) known as "immiserizing growth" (Johnson 55; Bhagwati, 58)
- Closed & Small-open: only (a)
- Condition on Φ_1: making (b) stronger
  - A key parameter: ρ (subst. b/w A & B)

Comparison: small-open vs. two-country



DRS case: Ricardo-Viner trade model

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  - Both countries produce both goods
  - Ricardo-Viner (also known as specific factors) trade model
  - Consider home exports A, imports B

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  - Consider home exports A, imports B
- Prop 4: Unique eqm exists under costless trade
- Prop 5: TOT $\uparrow$ when Π's deviation from 1 if

$$\left|\frac{\partial s_A^\gamma}{\partial \Pi}\frac{\Pi}{s_A^\gamma}\right| \geq \left|\frac{\partial s_B^\gamma}{\partial \Pi}\frac{\Pi}{s_B^\gamma}\right|$$

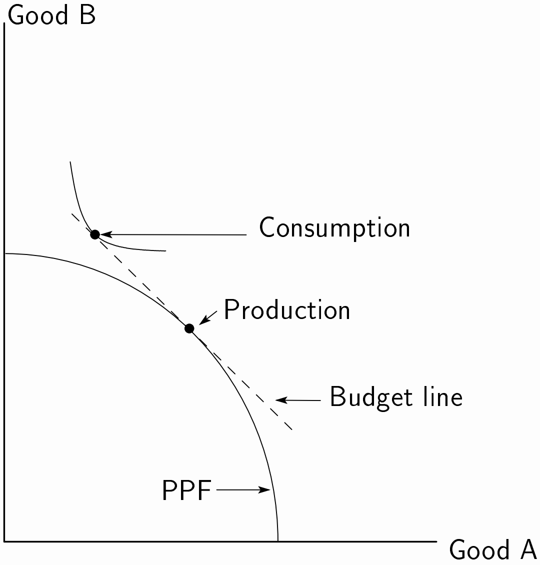
  - Exporting industry responds more to Π (i.e., more sticky)

Prop 6: Welfare formula

$$\frac{\mathrm{d}u}{\mathrm{d}\Pi}\frac{\Pi}{u} \propto \underbrace{\frac{p_B(y_B - c_B)}{c}}_{\text{import share}} \frac{\mathrm{d}p}{\mathrm{d}\Pi}\frac{\Pi}{p} - \sum_{i=A,B} \frac{l_i}{l}\frac{\partial s_i^\gamma}{\partial \Pi}\frac{\Pi}{s_i^\gamma}$$

- $\mathrm{d}u/\mathrm{d}\Pi \gtrless 0$
- $\mathrm{d}p/\mathrm{d}\Pi$ depends on various parameters
- Closed or small-open: only 2nd term
  - $\Pi = 1$ always optimal

Welfare enhancing inflation



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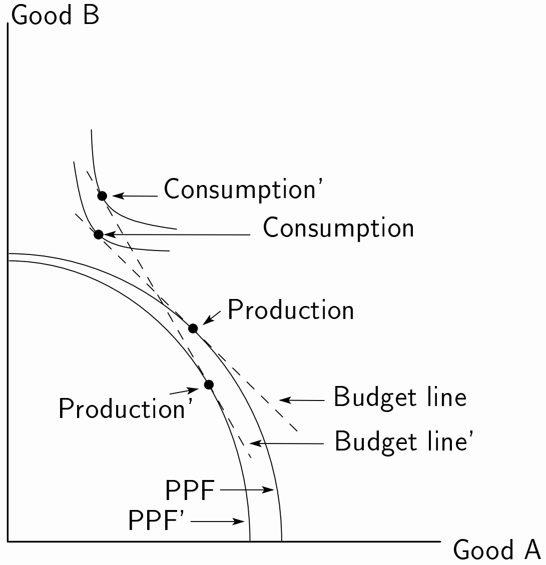

Back of the envelope calculation

Assume $s_A = s_B$

$$\frac{\mathrm{d}u}{\mathrm{d}\Pi}\frac{\Pi}{u} \propto \frac{\text{IM}}{\text{GDP}} \times \frac{\mathrm{d}p}{\mathrm{d}\Pi}\frac{\Pi}{p} - \frac{\partial s^\gamma}{\partial \Pi}\frac{\Pi}{s^\gamma}$$
$$= 0.11 \times 0.63 - 0.57$$

- $\frac{\text{IM}}{\text{GDP}} = 0.11$ US data
- $\frac{\mathrm{d}p}{\mathrm{d}\Pi}\frac{\Pi}{p} = 0.63$ regression using US time series
- $\frac{\mathrm{d}s^\gamma}{\mathrm{d}\Pi}\frac{\Pi}{s^\gamma} = 0.57$ calculated by setting $\gamma = 0.95$, $\eta = 10$, $\omega = 0.753$, $\Pi^{1/12} = 1.03$

Why important?: positive optimal inf.

- Long-run optimality of zero-inf. in closed economy
  - Eliminating price dispersion cost (King & Wolman 99, Schmitt-Grohé & Uribe 11, Coibion et al. 12)

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  - Short-run: nominal exchange rate, terms of trade (e.g., Benigno 04, Corsetti et al. 11, Bergin & Corsetti, 16)

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⋆ Provide long-run optimal in open-economy thru the terms of trade change

Why important?: digging up TFP

- Ricardian models: empirically good
    - Trade pattern & X-country prosperity (Eaton & Kortum 02, Alvarez & Lucas 07, Waugh 10, Costinot et al. 12)
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  - Trade context (Matsuyama 05, Ishise 16)
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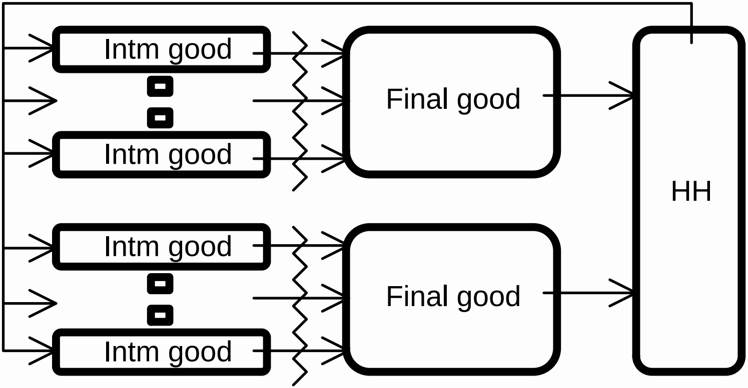
⋆ Provide a story of sector-level TFP

⋆ Breaking the classical dichotomy

Summary & future works

- Trend-Calvo & Ricardo (-Viner) trade
- Inf. rate affects trade pattern
- TOT attenuates the welfare loss
- Optimal inflation rate
  - $\Pi = 1$ may not be optimal under some parameters
- More empirical assesment
  - Π's role of determining trade pattern
  - TOT on the long-run welfare

Model structure (c.f., Obstfeld-Rogoff)



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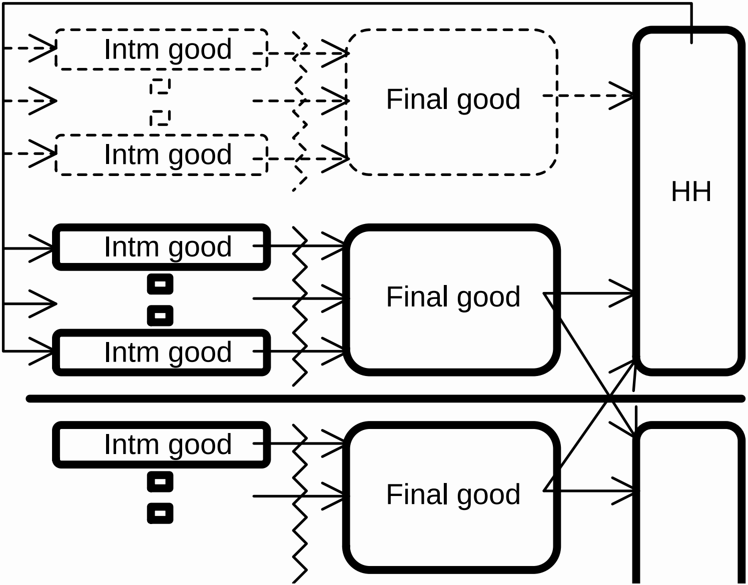

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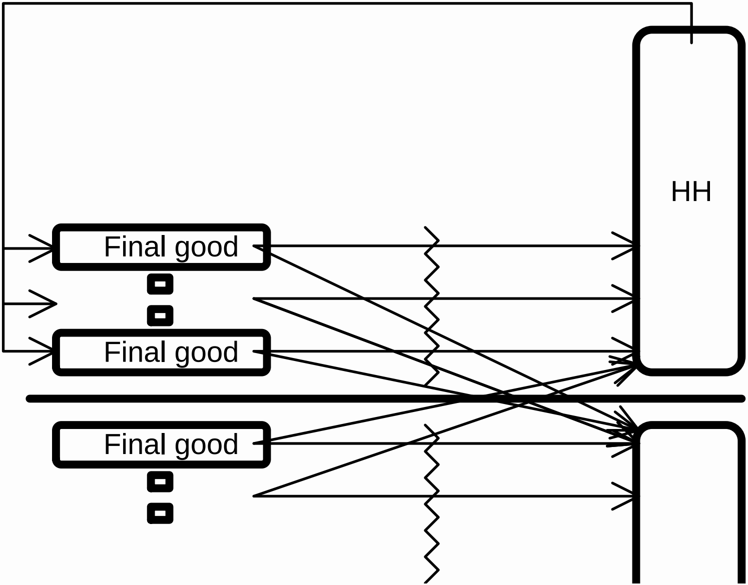

Law of motion of the price dispersion

$$
\begin{aligned}
s_{it} =& (\omega_i)^0 (1-\omega_i) \left(\frac{P_{it}}{\tilde{P}_{it}}\right)^{\eta} \\
&+ (\omega_i)^1 (1-\omega_i) \left(\frac{P_{it}}{\tilde{P}_{it-1}}\right)^{\eta} \\
&+ (\omega_i)^2 (1-\omega_i) \left(\frac{P_{it}}{\tilde{P}_{it-2}}\right)^{\eta} + \ldots \\
=& (1-\omega_i) \left(\frac{P_{it}}{\tilde{P}_{it}}\right)^{\eta} + \omega_i \left(\frac{P_{it}}{P_{it-1}}\right)^{\eta} s_{it-1}
\end{aligned}
$$