Ramsey-optimal Tax Reforms and Real Exchange Rate Dynamics

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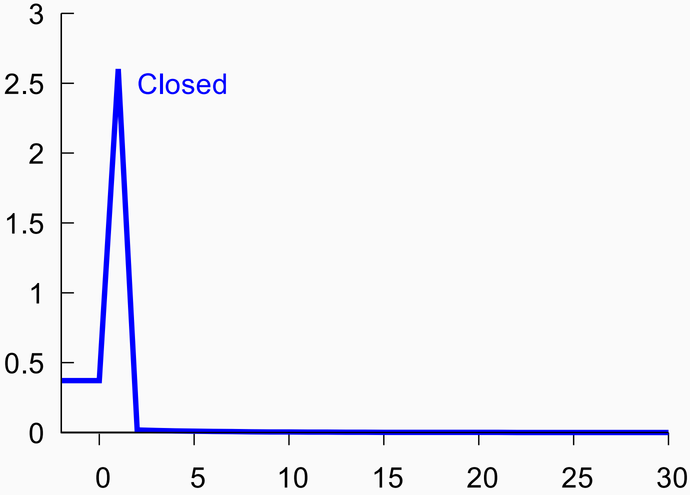
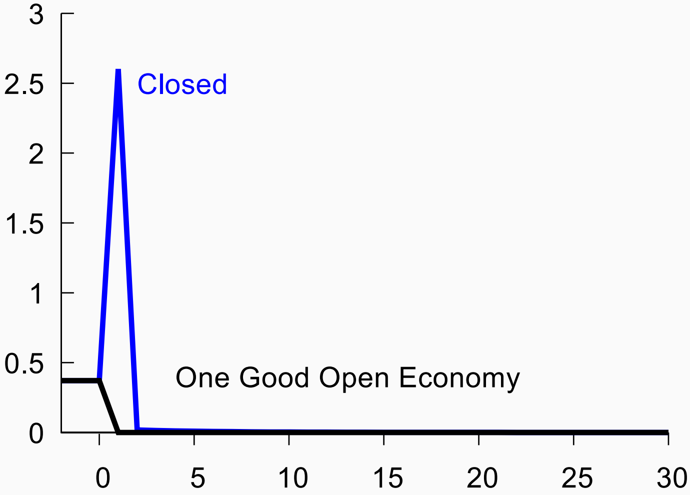
Ramsey policies: what we know

Ramsey: Capital Income Tax Rate



Ramsey: Capital Income Tax Rate



What We Do

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$$R^k_{t+1} \equiv (1 - \tau^k_{t+1}) r_{t+1} + 1 - \delta = R^d_t$$

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What We Do

- Two good small open economy
- Two goods: real exchange rate
- Why it matters:

$$R^k_{t+1} \equiv (1 - \tau^k_{t+1}) r_{t+1} + 1 - \delta = R^d_t = R^b \frac{e_{t+1}}{e_t}$$

Closed Economy

Closed: Households

$$\max_{\{c_t,h_t,k_t,d_t\}_{t=0}^{\infty}} \mathcal{L} = \sum_{t=0}^{\infty} \Bigg\{ \beta^t U(c_t, g_t, h_t)$$

$$+ \lambda_t \left[\left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + \tau - c_t - k_t - \frac{d_t}{R_t^d} \right] \Bigg\}$$

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$$\beta^t U_c(c_t, g_t, h_t) - \lambda_t = 0$$

$$\beta^t U_h(c_t, g_t, h_t) + \lambda_t (1 - \tau_t^h) w_t = 0$$

$$-\lambda_t + \lambda_{t+1} R_{t+1}^k = 0$$

$$-\frac{\lambda_t}{R_t^d} + \lambda_{t+1} = 0$$

Closed: Implementability Condition

$$\beta^t U_c(c_t, g_t, h_t) - \lambda_t = 0$$
$$\beta^t U_h(c_t, g_t, h_t) + \lambda_t(1 - \tau_t^h) w_t = 0$$
$$-\lambda_t + \lambda_{t+1} R_{t+1}^k = 0$$
$$-\frac{\lambda_t}{R_t^d} + \lambda_{t+1} = 0$$

$$\sum_{t=0}^{\infty} \beta^t \lambda_t \left[\left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + \tau - c_t - k_t - \frac{d_t}{R_t^d} \right]$$
$$= - \sum_{t=0}^{\infty} \beta^t \left[U_c(c_t, g_t, h_t)(c_t - \tau) + U_h(c_t, g_t, h_t) h_t \right]$$
$$+ U_c(c_0, g_0, h_0) \left\{ \left[(1 - \tau_0^k) r_0 + 1 - \delta \right] k_{-1} + d_{-1} \right\} = 0$$

Closed: Ramsey

$$\mathcal{L} = \sum_{t=0}^{\infty} \Big\{ \beta^t U(c_t, g_t, h_t)$$

$$+ \phi_t \left[F(k_t, h_t) + (1-\delta) k_{t-1} - c_t - k_t - g_t \right] \Big\}$$

$$+ \lambda \Big\{ \sum_{t=0}^{\infty} \beta^t \left[U_c(c_t, g_t, h_t)(c_t - \tau) + U_h(c_t, g_t, h_t) h_t \right]$$

$$- U_c(c_0, g_0, h_0) \left\{ \left[(1 - \tau_0^k) F_1(k_{-1}, h_0) + 1 - \delta \right] k_{-1} + d_{-1} \right\} \Big\}$$

One Good Small Open Economy

One Good: Households

$$\max_{\{c_t,h_t,k_t,d_t,b_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to

$$c_t + k_t + \frac{d_t}{R_t^d} + \frac{b_t}{R^b} = \left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + b_{t-1} + \tau$$

One Good: Households

$$\max_{\{c_t, h_t, k_t, d_t, b_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

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Euler equation: International bonds:

$$\frac{U_c(c_t, g_t, h_t)}{R^b} = U_c(c_{t+1}, g_{t+1}, h_{t+1})$$

One Good: Households

$$\max_{\{c_t,h_t,k_t,d_t,b_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to

$$c_t + k_t + \frac{d_t}{R_t^d} + \frac{b_t}{R^b} = \left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + b_{t-1} + \tau$$

Euler equation: International bonds:

$$\frac{U_c(c_t, g_t, h_t)}{R^b} = U_c(c_{t+1}, g_{t+1}, h_{t+1})$$

International risk-sharing:

$$U_c(c_t, g_t, h_t) = \text{Constant}$$

One Good: Ramsey I

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to competitive equilibrium and

$$g_t + \tau + d_{t-1} = \tau_t^h w_t h_t + \tau_t^k r_t k_{t-1} + \frac{d_t}{R_t^d}$$

$$nx_t + b_{t-1} - \frac{b_t}{R^b} = 0$$

One Good: Ramsey II

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to:

$$\sum_{t=0}^{\infty} \beta^t \left[U_c(c_t, g_t, h_t)(c_t - \tau) + U_h(c_t, g_t, h_t) h_t \right]$$
$$- U_c(c_0, g_0, h_0) \left\{ \left[(1 - \tau_0^k) F_1(k_{-1}, h_0) + 1 - \delta \right] k_{-1} + d_{-1} \right\} = 0$$

$$c_t + k_t + g_t + nx_t = F(k_{t-1}, h_t) + (1 - \delta) k_{t-1}$$
$$nx_t + b_{t-1} - \frac{b_t}{R^b} = 0$$

One Good: Balance of Payments

$$nx_t + b_{t-1} - \frac{b_t}{R^b} = 0$$

One Good: Balance of Payments

$$nx_t + b_{t-1} - \frac{b_t}{R^b} = 0$$

Iterate forward:

$$b_{-1} + \sum_{t=0}^{\infty} \frac{nx_t}{(R^b)^t} = 0$$

$\beta R^b = 1$:

$$b_{-1} + \sum_{t=0}^{\infty} \beta^t nx_t = 0$$

One Good: Ramsey III

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to:

$$\sum_{t=0}^{\infty} \beta^t \left[U_c(c_t, g_t, h_t)(c_t - \tau) + U_h(c_t, g_t, h_t) h_t \right]$$
$$- U_c(c_0, g_0, h_0) \left\{ \left[(1 - \tau_0^k) F_1(k_{-1}, h_0) + 1 - \delta \right] k_{-1} + d_{-1} \right\} = 0$$

$$c_t + k_t + g_t + nx_t = F(k_{t-1}, h_t) + (1 - \delta) k_{t-1}$$
$$b_{-1} + \sum_{t=0} \beta^t nx_t = 0$$

Two Good Small Open Economy

Two Goods: Households

$$\max_{\{c_t,h_t,k_t,d_t,b_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

$$p_t c_t + k_t + \frac{d_t}{R_t^d} + e_t \frac{b_t}{R^b} \leq \left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + e_t b_{t-1} + \tau$$

Two Goods: Households

$$\max_{\{c_t,h_t,k_t,d_t,b_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

$$p_t c_t + k_t + \frac{d_t}{R_t^d} + e_t \frac{b_t}{R^b} \leq \left(1 - \tau_t^h\right) w_t h_t + R_t^k k_{t-1} + d_{t-1} + e_t b_{t-1} + \tau$$

$$c_t = \left[\varphi^{\frac{1}{\mu}} c_{ht}^{\frac{\mu-1}{\mu}} + (1-\varphi)^{\frac{1}{\mu}} c_{ft}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}$$

$$p_t = \left[\varphi + (1-\varphi) e_t^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

$$\varphi = 1 - (1-n)\gamma$$

Two Goods: Ramsey I

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t)$$

subject to:

1. Implementability condition
2. Feasibility
3. International risk-sharing
4. International solvency

Two Goods: Ramsey II

$$\max \sum_{t=0}^{\infty} \beta^t U(c_t, g_t, h_t) \quad \text{subject to:}$$

$$\sum_{t=0}^{\infty} \beta^t \left[U_c(c_t, g_t, h_t)(c_t - \tau) + U_h(c_t, g_t, h_t)h_t\right]$$

$$- \frac{U_c(c_0, g_0, h_0)}{p_t} \left\{R_0^k k_{-1} + d_{-1} + e_0 d_{-1}\right\} = 0$$

$$(1-\gamma)p_t^{\mu} c_t + \gamma e_t^{\mu} c^* + k_t + g_t = F(k_{t-1}, h_t) + (1-\delta)k_{t-1}$$

$$\frac{e_t U_c(c_t, g_t, h_t)}{p_t} = \text{Constant}$$

$$b_{-1} + \sum_{t=0}^{\infty} \beta^t \left\{\gamma e_t^{\mu-1} c^* - \gamma[(1-\gamma)e_t^{\mu-1} + \gamma]^{\mu/(1-\mu)} c_t\right\} = 0$$

$$p_t = \left[\varphi + (1-\varphi)e_t^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

Calibration

Parameterization

$$U(c, g, h) = \frac{(C(c, g)(1-h)^{\chi})^{1-\sigma}}{1-\sigma}$$

$$C(c, g) = \left[(1-\kappa)c^{\frac{\psi-1}{\psi}} + \kappa g^{\frac{\psi-1}{\psi}}\right]^{\frac{\psi}{\psi-1}}$$

$$y = F(k, h) = k^{\alpha} h^{1-\alpha}$$

Exogenously Set Paramters

Model period	1 year
Steady state	$e = 1$, $p = 1$
Log utility	$\sigma = 1$
Cobb-Douglas aggregator	$\psi = 1$
Trade openness	$\gamma = 0.3$
Home-foreign substitutability	$\mu = 1.5$
Net foreign assets	$b = 0$

Calibrated Parameters

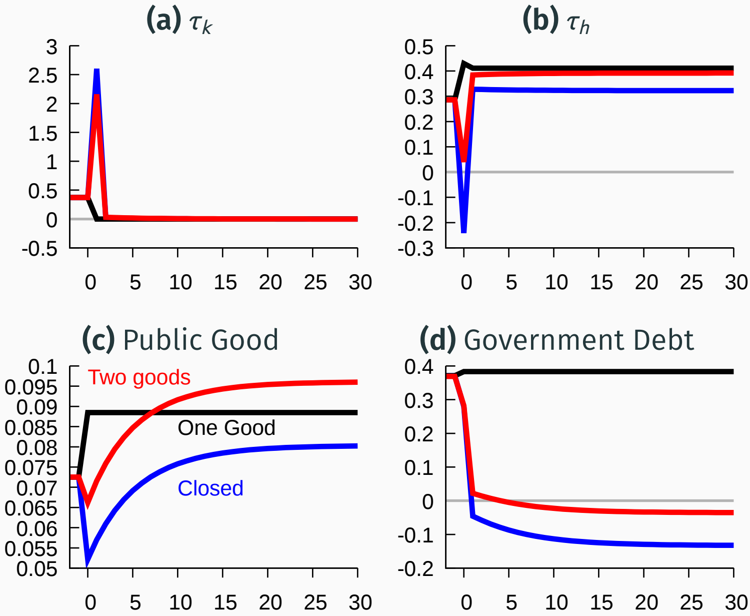
Parameter		Value
κ	weight on public goods	0.2223
χ	weight on leisure	1.33
β	discount factor	0.9615
α	capital share	0.3
δ	depreciation rate	0.075
τ^h	labor income tax	0.2859
τ^k	capital income tax	0.3710
τ	lump-sum transfer	0.0287

Calibration Targets

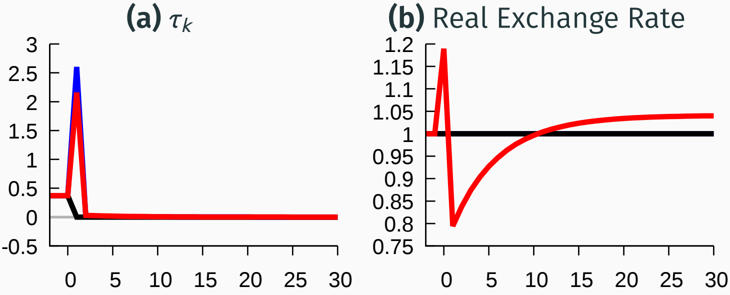
Target	(%)
Average hours	30
Real interest rate	4
Capital share	30
Depreciation	7.5
Government share	19.55
Government debt-output	100
Average effective tax rates:	
labor income	28.59
capital income	37.10

Results

Government Policy

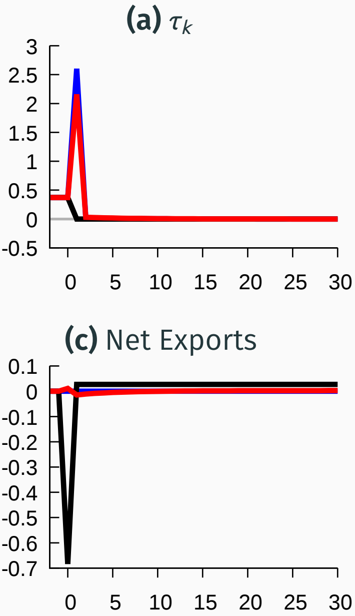


Return Arbitrage

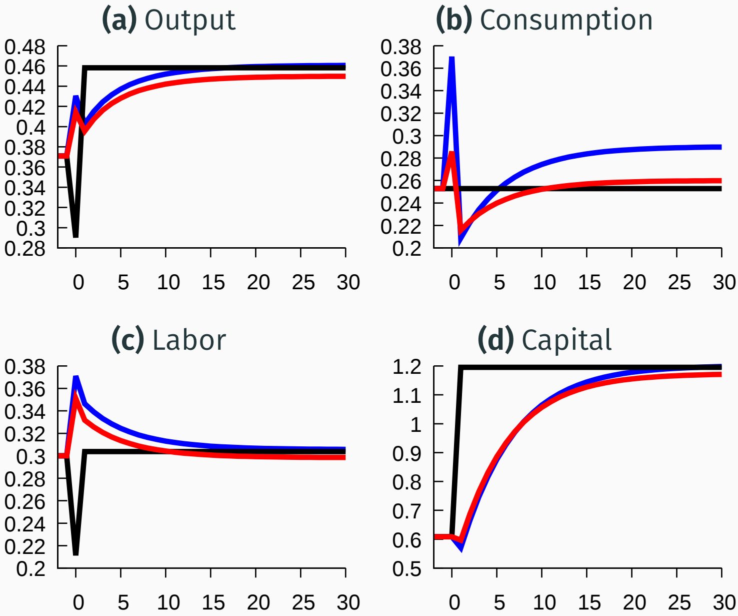


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1} R^b}{e_t}$$

Balance of Payments

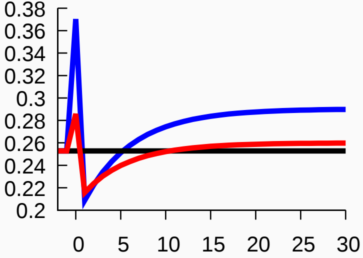


Macro Variables

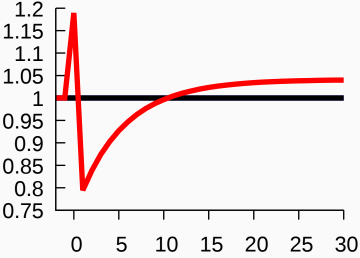


Consumption Dynamics

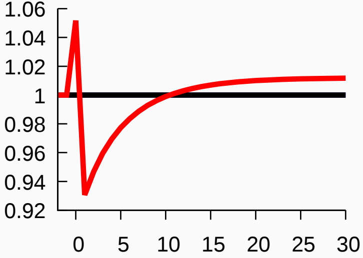
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption



(d) Risk Sharing

$$\frac{e_t U_c(t)}{p_t} = \textsc{Constant}$$

Is It Worth It?

Welfare benefit: ω satisfying

$$\sum_{t=0}^{\infty} \beta^t U((1-\omega)c_t, g_t, h_t) = \frac{U(c_0, g_0, h_t)}{1-\beta}.$$

Steady States and Welfare Benefit

	Initial	Closed	One Good	Two Good
τ^h	0.2859	0.3224	0.4114	0.3920
τ^k	0.3710	0.0000	0.0000	0.0000
y	0.3709	0.4608	0.4582	0.4500
c/y	0.6814	0.6300	0.5516	0.5778
k/y	1.6409	2.6087	2.6087	2.6087
h	0.3000	0.3055	0.3038	0.2984
g/y	0.1955	0.1744	0.1931	0.2136
d/y	1.0000	−0.2884	0.8366	−0.0788
b/y	0.0000		−1.5511	−0.1504
nx/y	0.0000		0.0597	0.0058
e	1.0000		1.0000	1.0410
ω		5.5320	5.2334	4.3614

Lessons

1. International solvency

Lessons

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2. Real exchange rate dynamics

Lessons

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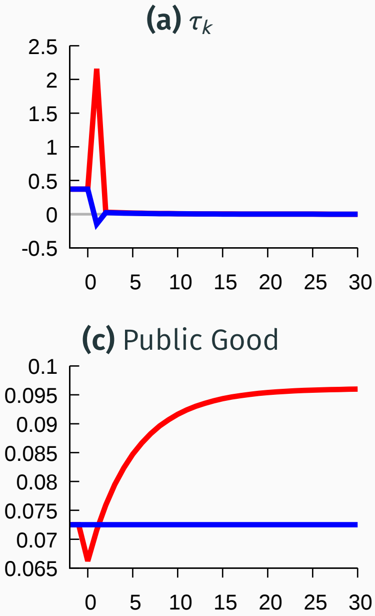
3. Capital income tax rate dynamics

Lessons

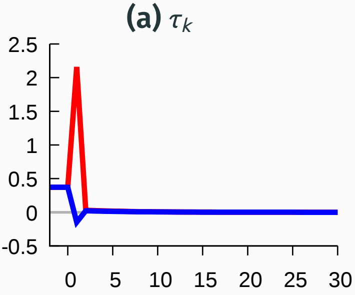
1. International solvency
2. Real exchange rate dynamics
3. Capital income tax rate dynamics
4. Welfare benefit

Useless Public Spending

Useless Public Spending: Government Policy

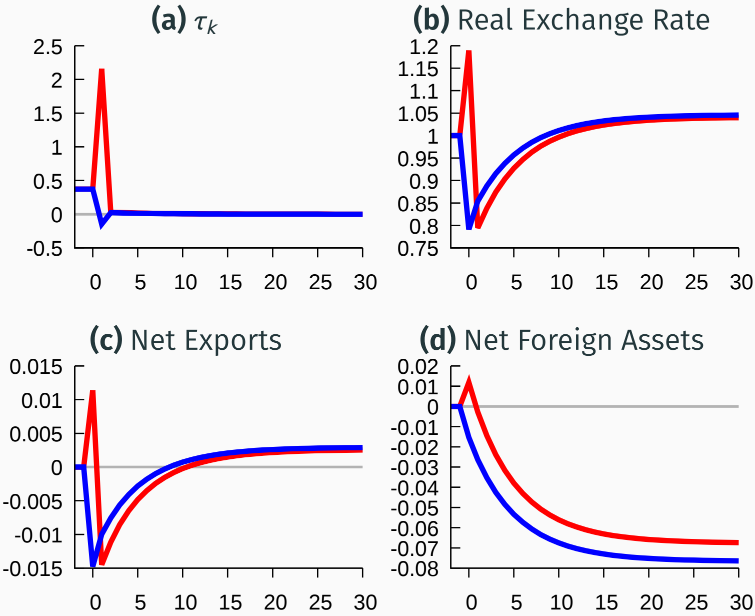


Useless Public Spending: Return Arbitrage

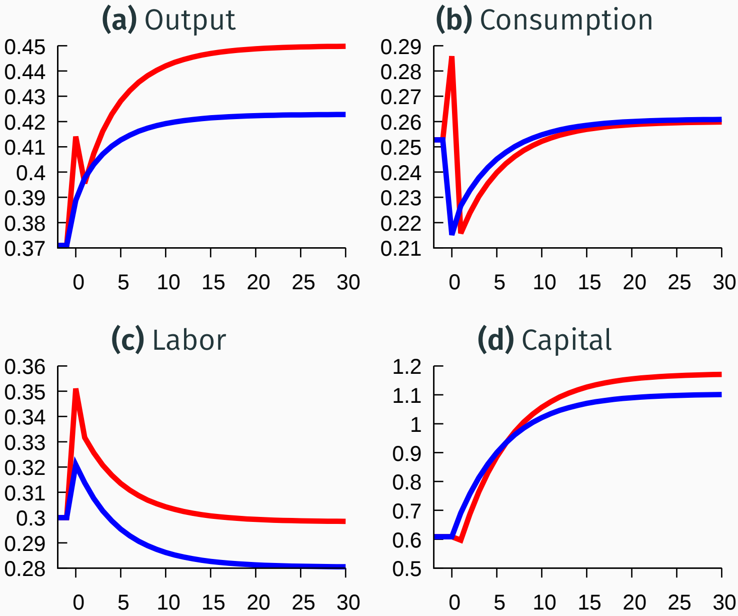


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1} R^b}{e_t}$$

Useless Public Spending: Balance of Payments

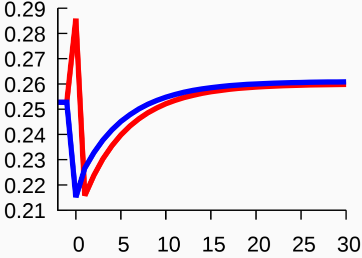


Useless Public Spending: Macro Variables

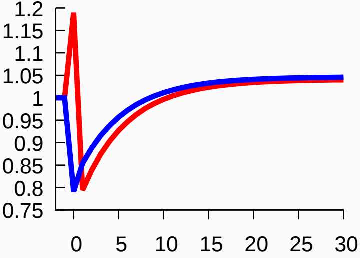


Useless Public Spending: Consumption Dynamics

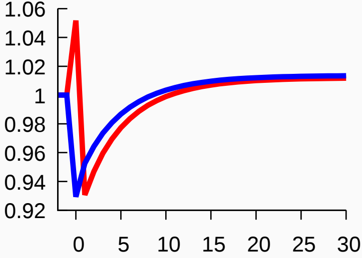
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

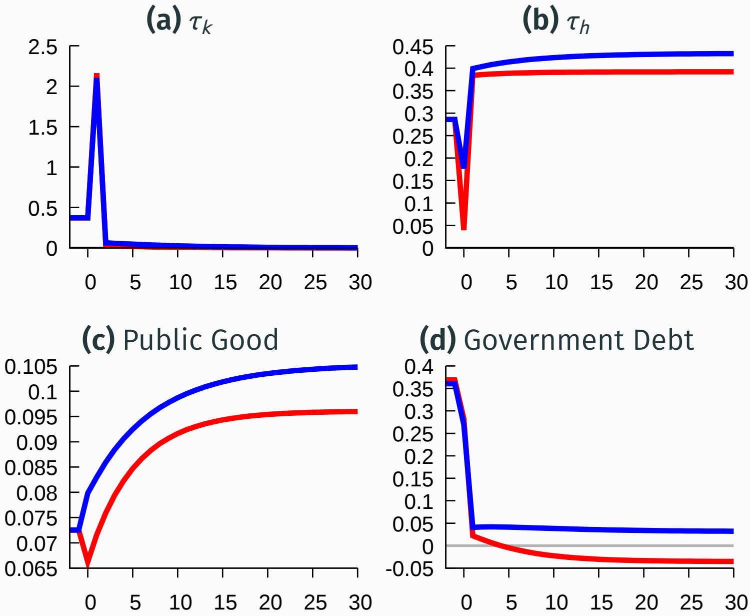


(d) Risk Sharing

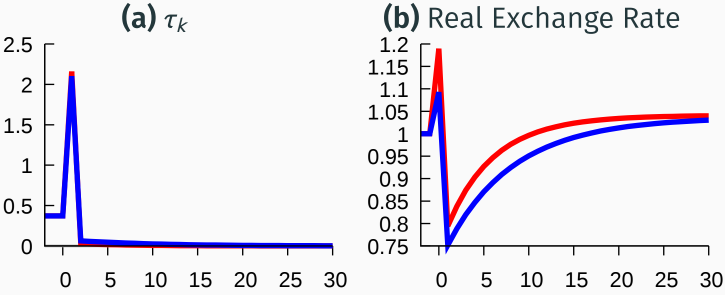
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$\sigma = 2$

$\sigma = 2$: Government Policy

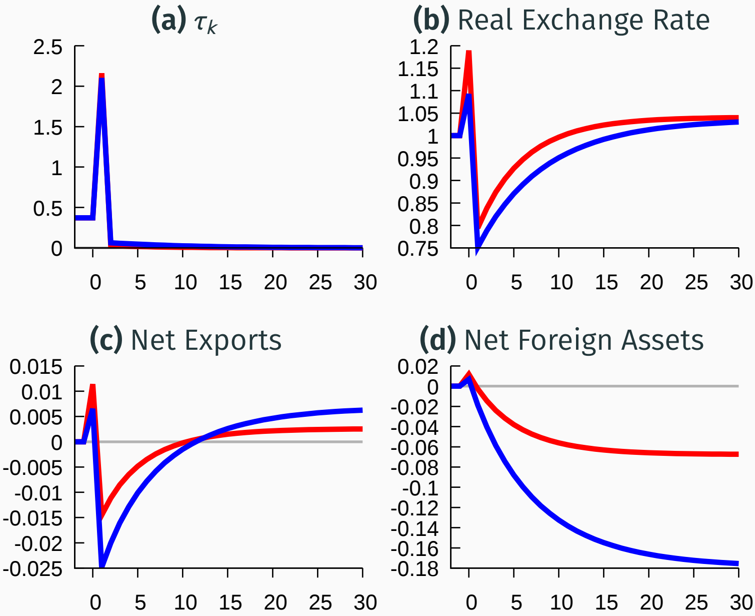


$\sigma = 2$: Return Arbitrage

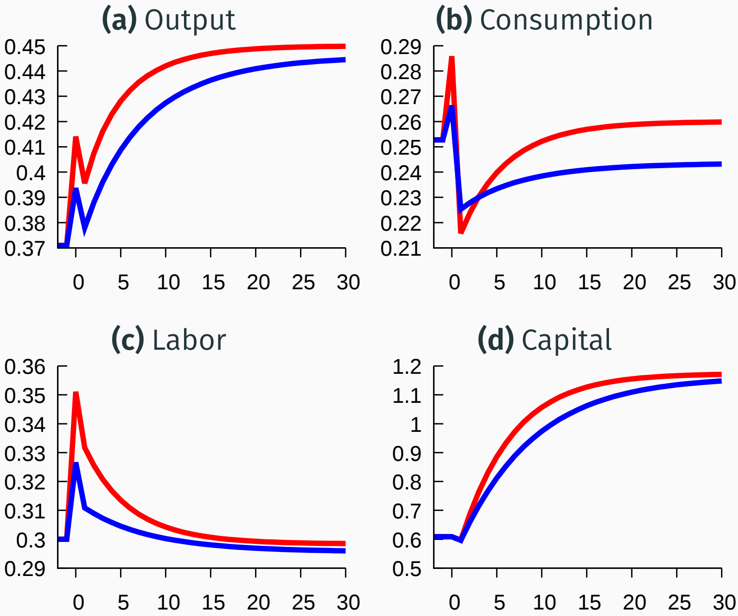


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1} R^b}{e_t}$$

$\sigma = 2$: Balance of Payments

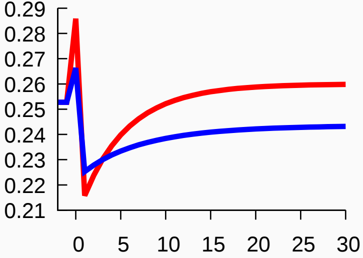


$\sigma = 2$: Macro Variables

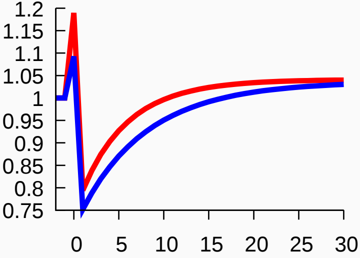


$\sigma = 2$: Consumption Dynamics

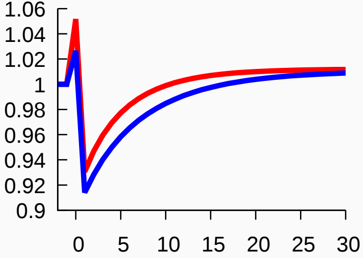
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

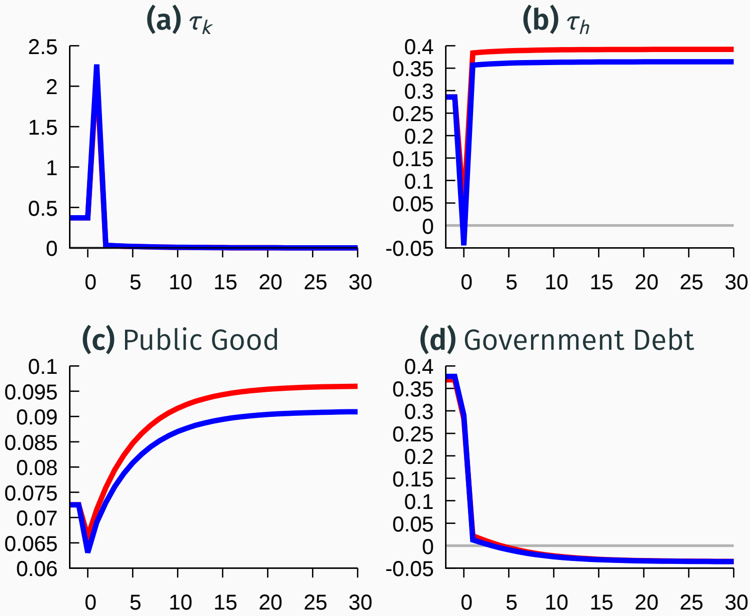


(d) Risk Sharing

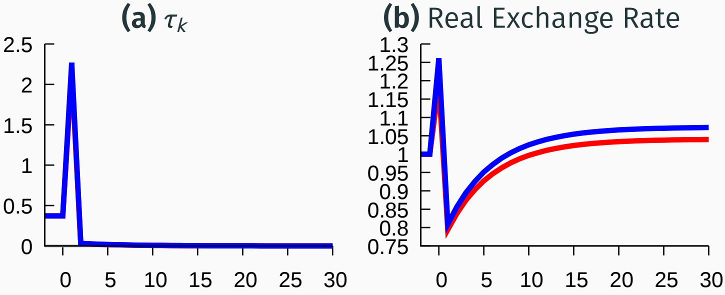
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$\psi = 1/2$

$\psi = 1/2$: Government Policy

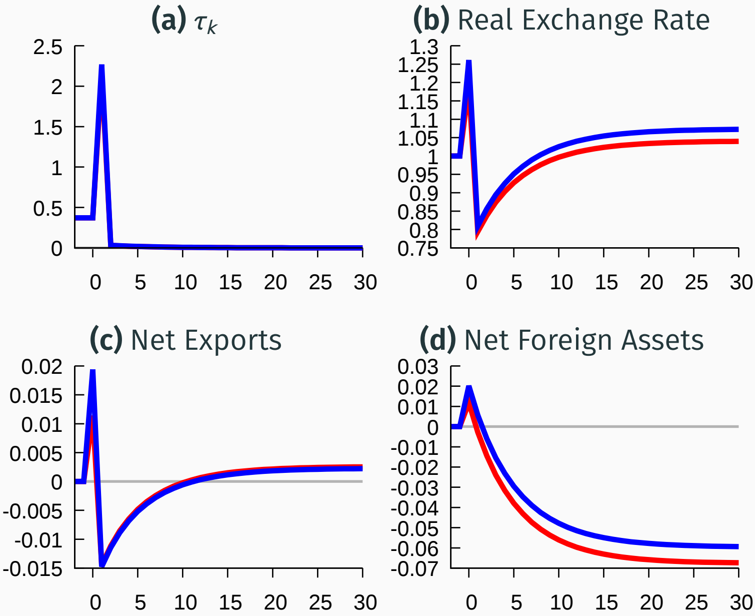


$\psi = 1/2$: Return Arbitrage

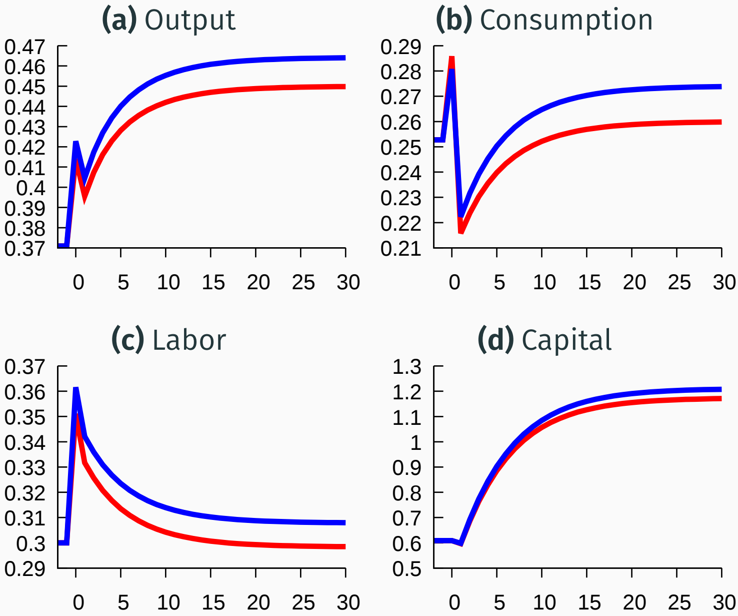


$$R_{t+1}^{k} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1}R^b}{e_t}$$

$\psi = 1/2$: Balance of Payments

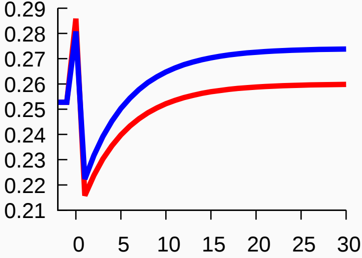


$\psi = 1/2$: Macro Variables

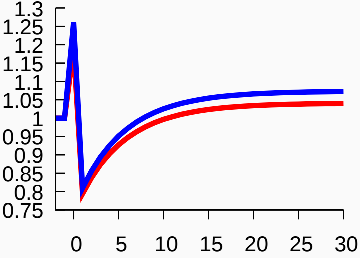


$\psi = 1/2$: Consumption Dynamics

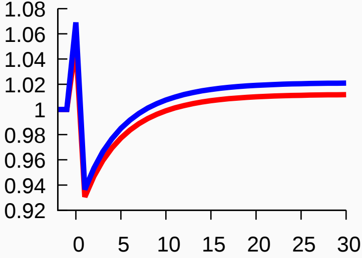
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

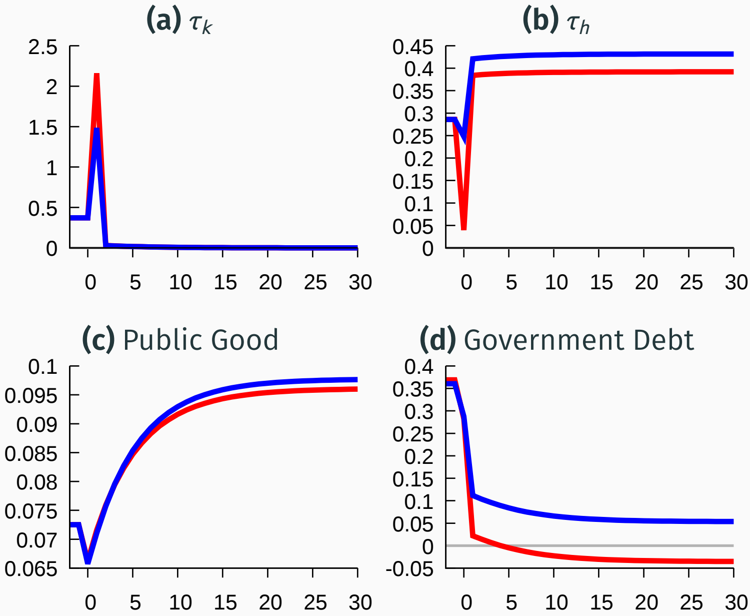


(d) Risk Sharing

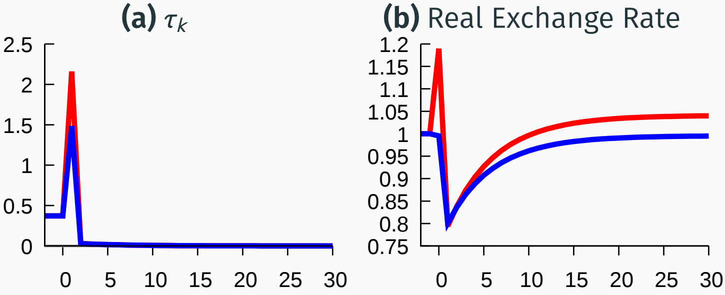
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$$\psi = 2$$

$\psi = 2$: Government Policy

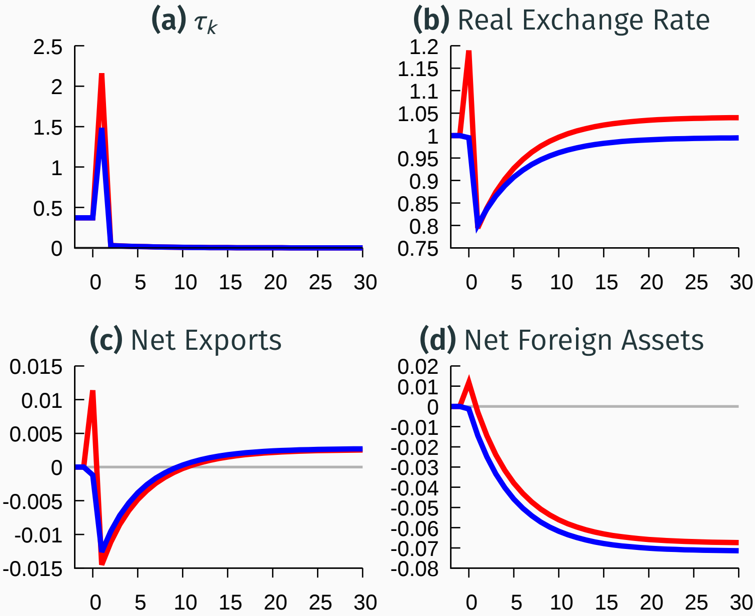


$\psi = 2$: Return Arbitrage

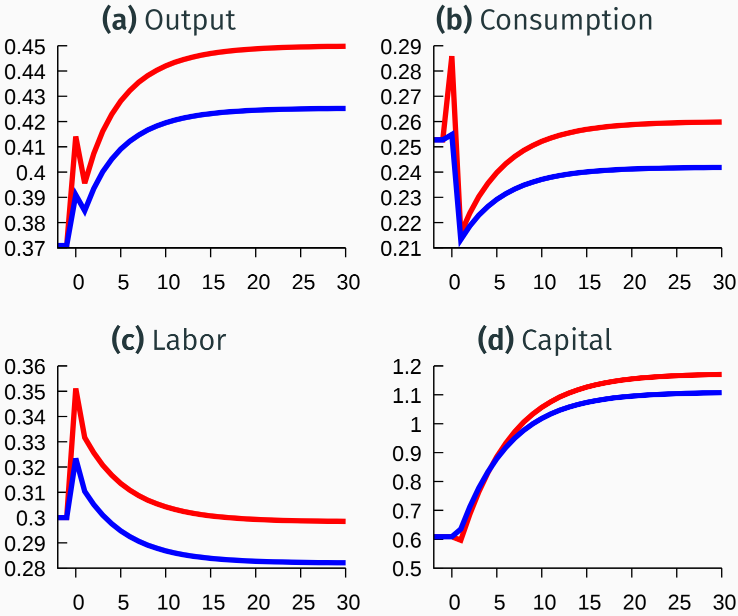


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1}R^b}{e_t}$$

$\psi = 2$: Balance of Payments

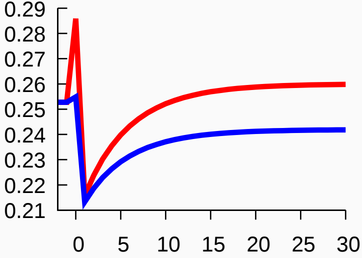


$\psi = 2$: Macro Variables

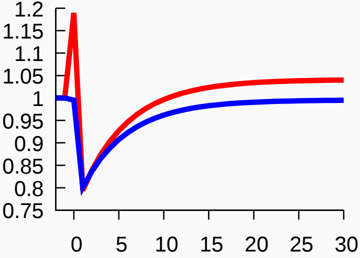


$\psi = 2$: Consumption Dynamics

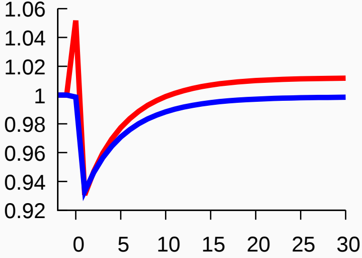
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

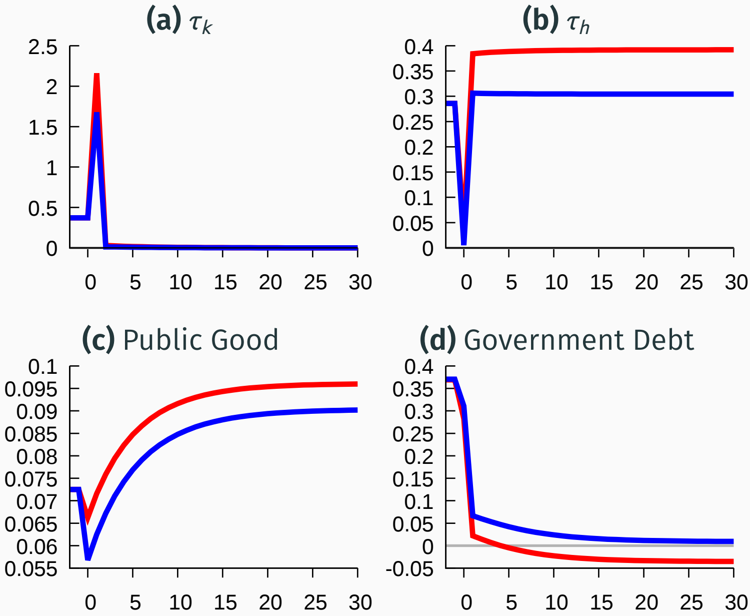


(d) Risk Sharing

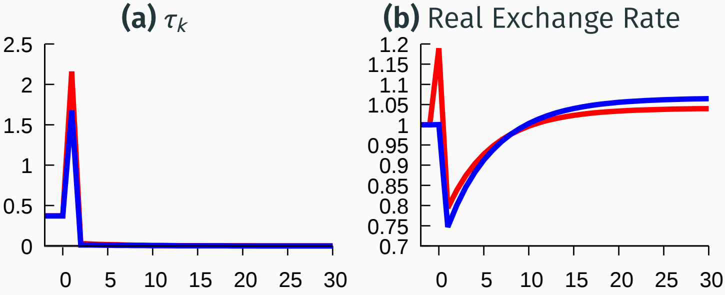
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$\gamma = 0.05$

$\gamma = 0.05$: Government Policy

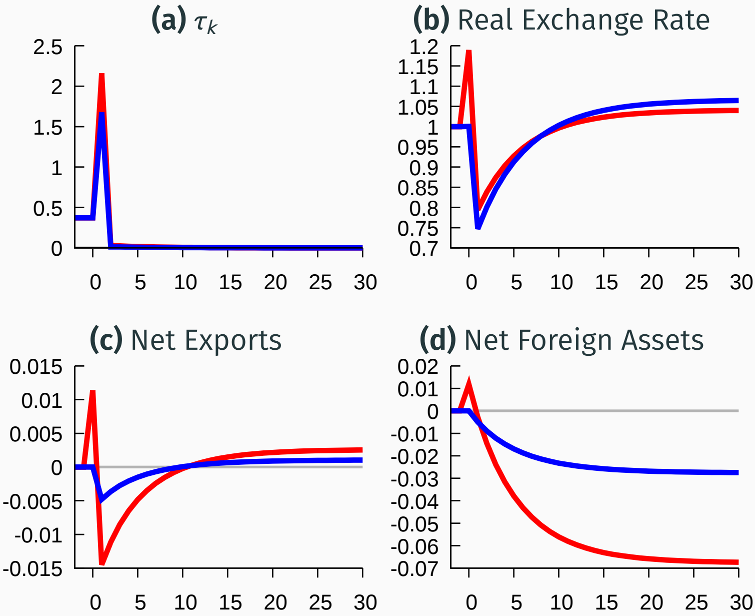


$\gamma = 0.05$: Return Arbitrage

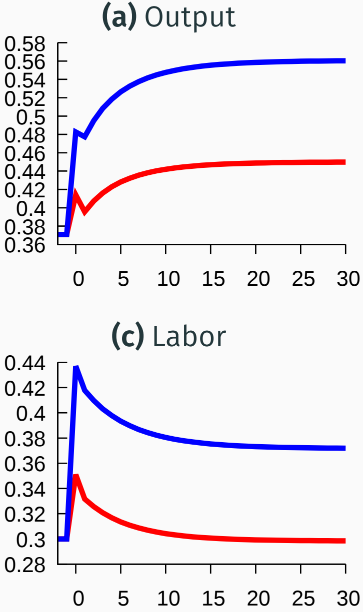


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1}R^b}{e_t}$$

$\gamma = 0.05$: Balance of Payments

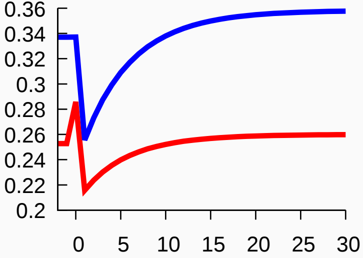


$\gamma = 0.05$: Macro Variables

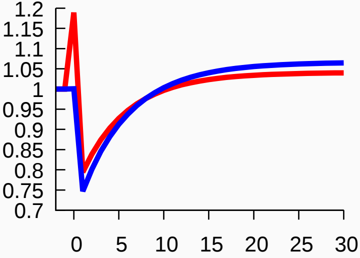


$\gamma = 0.05$: Consumption Dynamics

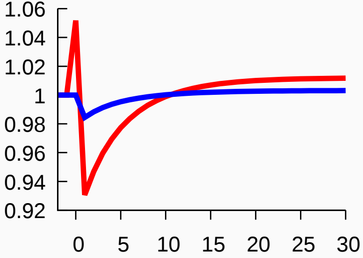
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

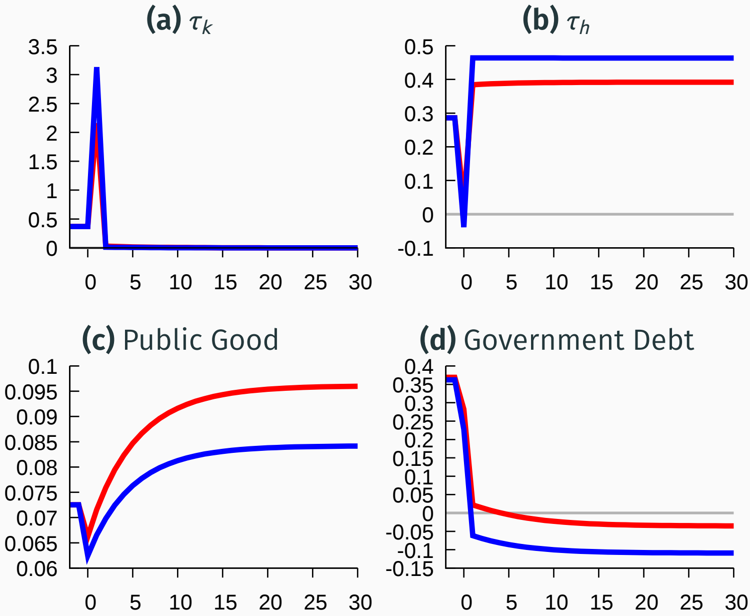


(d) Risk Sharing

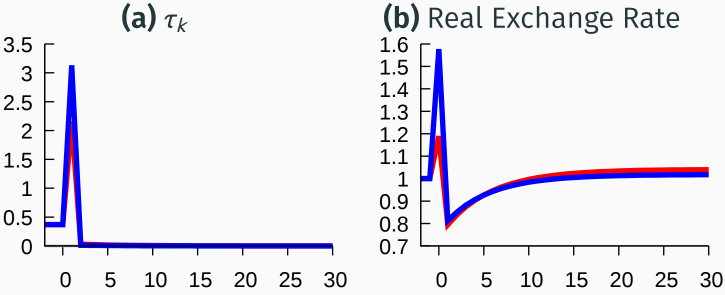
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$\gamma = 0.7$

$\gamma = 0.7$: Government Policy

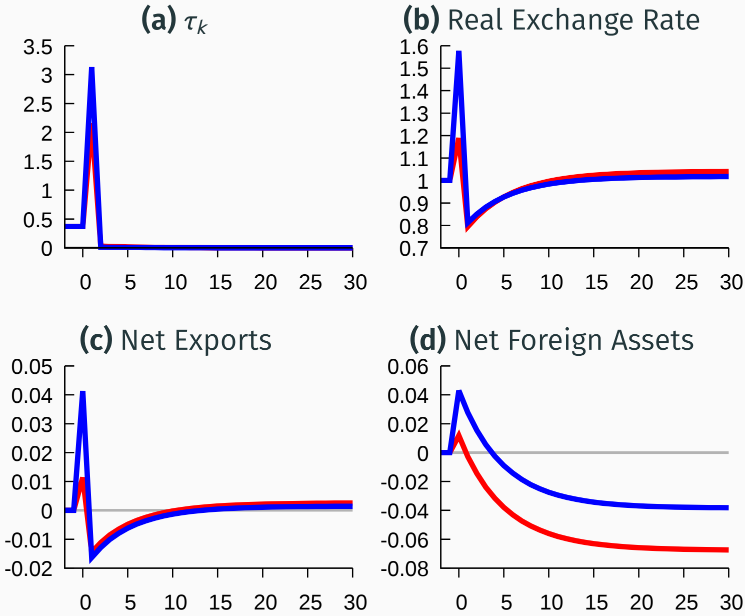


$\gamma = 0.7$: Return Arbitrage

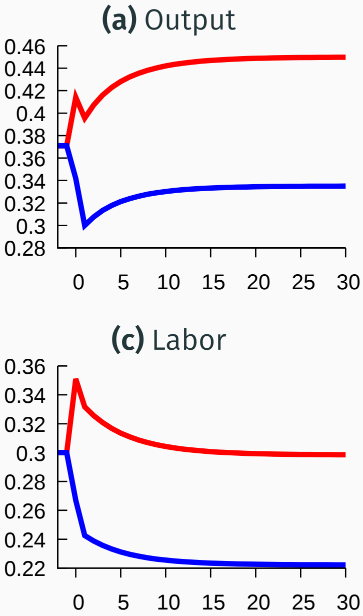


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1}R^b}{e_t}$$

$\gamma = 0.7$: Balance of Payments

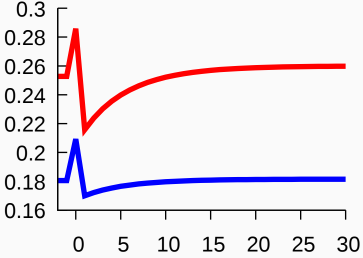


$\gamma = 0.7$: Macro Variables

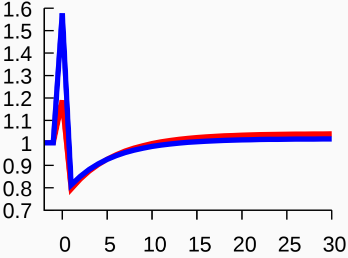


$\gamma = 0.7$: Consumption Dynamics

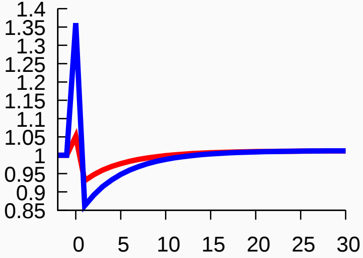
(a) Consumption



(b) Real Exchange Rate



(c) Price of Consumption

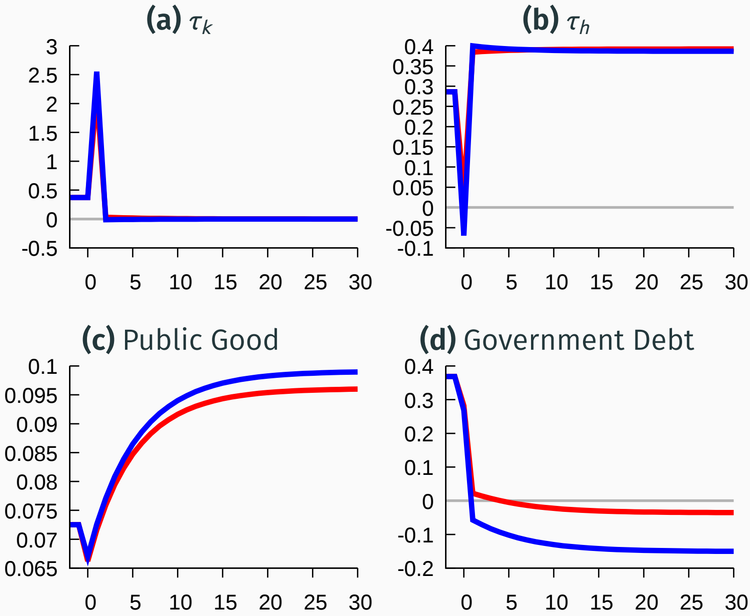


(d) Risk Sharing

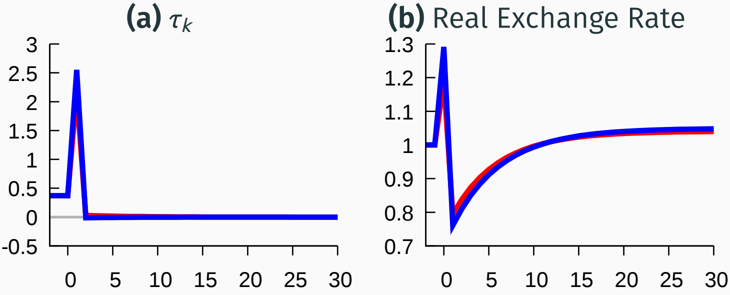
$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

$\mu = 0.8$

$\mu = 0.8$: Government Policy

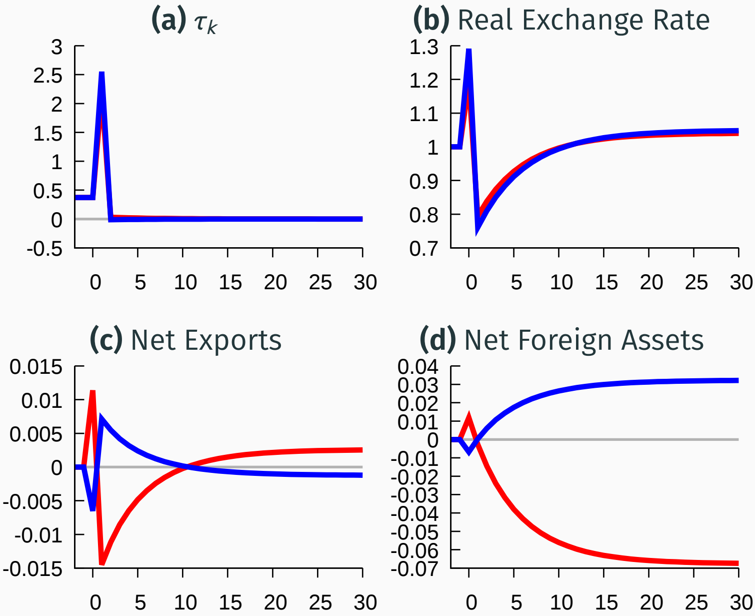


$\mu = 0.8$: Return Arbitrage

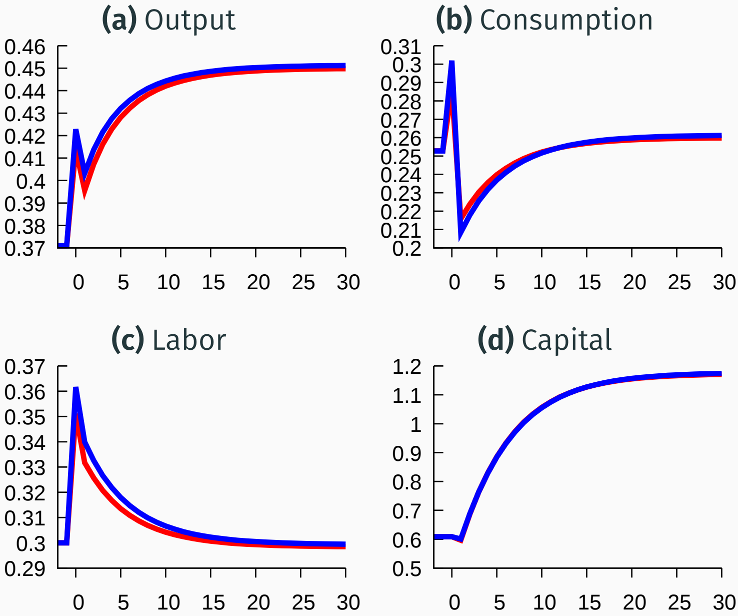


$$R^k_{t+1} = (1 - \tau_{k,t+1})F_1(k_t, h_{t+1}) + 1 - \delta = \frac{e_{t+1}R^b}{e_t}$$

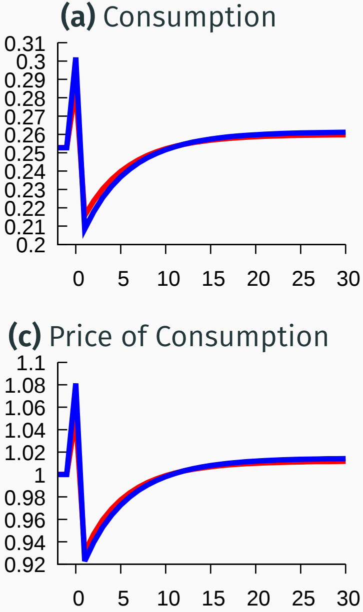
$\mu = 0.8$: Balance of Payments



$\mu = 0.8$: Macro Variables



$\mu = 0.8$: Consumption Dynamics



(d) Risk Sharing

$$\frac{e_t U_c(t)}{p_t} = \text{CONSTANT}$$

Table of Contents