

Ramsey Tax Competition with Real Exchange Rate Determination

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Introduction

- **Issue:** Optimal taxation in an international setting
- **Key elements:**
 - 1 Tax competition
 - 2 Nash equilibrium
 - 3 Ramsey
 - 4 Real exchange rate

Key Effects

- 1 Minimize tax distortions → wealth effects
- 2 Population size
- 3 Foreign debt revaluation
- 4 Terms of trade
- 5 Strategic exchange rate manipulation

Model



Households

$$\max_{\{c_{ht}, c_{ft}, h_t, k_t, d_t, a_t\}} \sum_{t=0}^{\infty} \beta^t U(c_{ht}, c_{ft}, h_t) \quad \text{subject to}$$

$$\begin{aligned} (1 + \tau_{ct}) c_{ht} + (1 + \tau_{mt}) e_t c_{ft} + k_t + \frac{d_t}{R_{dt}} + e_t \frac{a_t}{R_{at}} \\ = (1 - \tau_{wt}) w_t h_t + R_{kt} k_{t-1} + d_{t-1} + e_t a_{t-1} \end{aligned}$$

No arbitrage:

$$\underbrace{1 + (1 - \tau_{k,t+1})(r_{t+1} - \delta)}_{R_{k,t+1}} = R_{dt} = \frac{e_{t+1} R_{at}}{e_t}$$

Firms

$$\max_{k_{t-1}, h_t} \{F(k_{t-1}, h_t) - r_t k_{t-1} - w_t h_t\}$$

$$r_t = F_1(k_{t-1}, h_t) \text{ and } w_t = F_2(k_{t-1}, h_t)$$

Government Budget

$$\frac{d_t}{R_{dt}} - d_{t-1} = \underbrace{g - \tau_c c_{ht} - \tau_{mt} e_t c_{ft} - \tau_{wt} w_t h_t - \tau_{kt} (r_t - \delta) k_{t-1}}_{\text{PRDEF}_t}$$

$$d_{-1} + \sum_{t=0}^{\infty} \left(\prod_{j<t} \frac{1}{R_{dj}} \right) \text{PRDEF}_t = 0$$

$$\frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} d_{-1} + \sum_{t=0}^{\infty} \beta^t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \text{PRDEF}_t = 0$$

Balance of Payments

$$\underbrace{\frac{1-n}{n}c_{ht}^* - e_t c_{ft} + e_t a_{t-1}}_{\text{TB}_t} - \frac{e_t a_t}{R_{at}} = 0$$

$$a_{-1} + \sum_{t=0}^{\infty} \left(\prod_{j<t} \frac{1}{R_{aj}} \right) \frac{\text{TB}_t}{e_t} = 0$$

$$e_0 \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} a_{-1} + \sum_{t=0}^{\infty} \beta^t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \text{TB}_t = 0$$

Ramsey Planner

Home Ramsey Planner

Choose

$$\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t, \tau_{mt}, \tau_{wt}, \tau_{k,t+1}\}_{t=0}^{\infty}$$

to maximize

$$\sum_{t=0}^{\infty} \beta^t U(c_{ht}, c_{ft}, h_t)$$

subject to:

- 1 Private home behavior
- 2 Private foreign behavior
- 3 International solvency
- 4 Present value (home) government budget constraint

Private home behavior

$$\lambda_{1t} : F(k_{t-1}, h_t) + (1 - \delta)k_{t-1} = c_{ht} + \frac{1 - n}{n} c_{ht}^* + k_t + g$$

$$\lambda_{2t} : \frac{e_t U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} = \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_{mt}}$$

$$\lambda_{3t} : U_3(c_{ht}, c_{ft}, h_t) + \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} (1 - \tau_{wt}) F_2(k_{t-1}, h_t) = 0$$

$$\lambda_{4t} : \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} = \beta \frac{U_1(c_{ht+1}, c_{ft+1}, h_{t+1})}{1 + \tau_c} \\ \times \left[1 + (1 - \tau_{k,t+1}) (F_1(k_t, h_{t+1}) - \delta) \right]$$

International risk-sharing condition

$$\lambda_{5t} : e_t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} = \vartheta \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*}$$

Foreign private behavior

$$\lambda_{6t} : c_{ft}^* + \frac{n}{1-n} c_{ft}^* + k_t^* + g^* = F(k_{t-1}^*, h_t^*) + (1-\delta)k_{t-1}^*$$

$$\lambda_{7t} : \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} = \frac{e_t U_1^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_{mt}^*}$$

$$\lambda_{8t} : U_3^*(c_{ht}^*, c_{ft}^*, h_t^*) + \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} (1 - \tau_{wt}^*) F_2(k_{t-1}^*, h_t^*) = 0$$

$$\lambda_{9t} : \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} = \beta \frac{U_2^*(c_{ht+1}^*, c_{ft+1}^*, h_{t+1}^*)}{1 + \tau_c^*} \\ \times \left[1 + (1 - \tau_{k,t+1}^*) (F_1(k_t^*, h_{t+1}^*) - \delta) \right]$$

International Solvency

$$\Omega : e_0 \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} a_{-1} + \sum_{t=0}^{\infty} \beta^t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \left[\frac{1-n}{n} c_{ht}^* - e_t c_{ft} \right] = 0$$

Present value government budget constraint

$$\begin{aligned}\Lambda : & \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} d_{-1} \\ & = \sum_{t=0}^{\infty} \beta^t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \left[\tau_c c_{ht} + \tau_{mt} c_{ft} e_t + \tau_{wt} F_2(k_{t-1}, h_t) h_t \right. \\ & \quad \left. + \tau_{kt} (F_1(k_{t-1}, h_t) - \delta) k_{t-1} - g \right]\end{aligned}$$

International Tax Cooperation

Choose

$$\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t\}_{t=0}^{\infty}$$

to maximize

$$\sum_{t=0}^{\infty} \beta^t \{ \phi U(c_{ht}, c_{ft}, h_t) + (1 - \phi) U^*(c_{ht}^*, c_{ft}^*, h_t^*) \}$$

subject to:

- 1 Home implementability condition
- 2 Foreign implementability condition
- 3 Home feasibility
- 4 Foreign feasibility
- 5 International risk-sharing condition
- 6 International solvency

Tax Competition

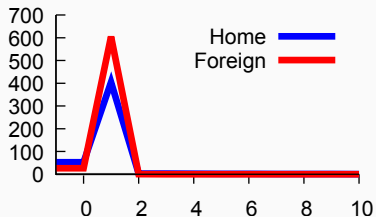
Calibration

- Model period: annual
- Home: UK
- Foreign: EMU

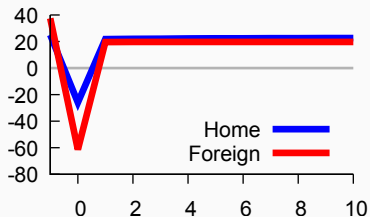
Parameter/Target	Home	Foreign
Consumption tax, τ_c	0.140	0.166
Import tax, τ_m	0.140	0.166
Labor income tax, τ_w	0.250	0.374
Capital income tax, τ_k	0.530	0.265
Population share (n or $1 - n$)	0.250	0.750
Consumption Import Share	0.225	0.079
Net foreign assets \div output	-0.100	0.030

Tax Competition: Fiscal Policy

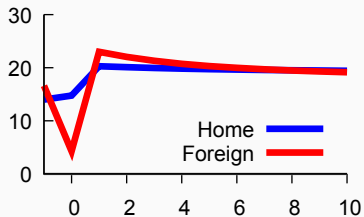
Capital income tax



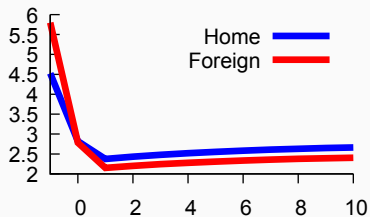
Labor income tax



Import tax



Government debt-output

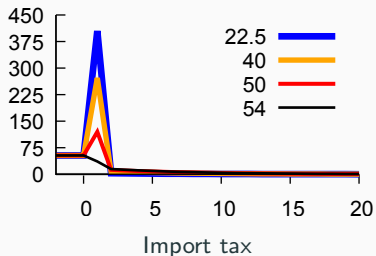


Key Effects

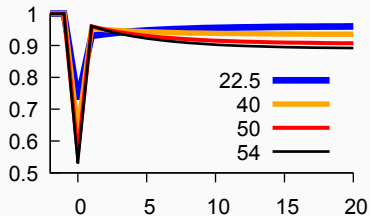
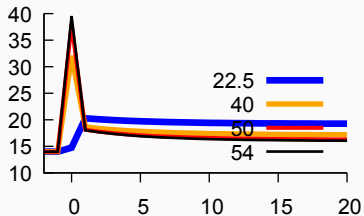
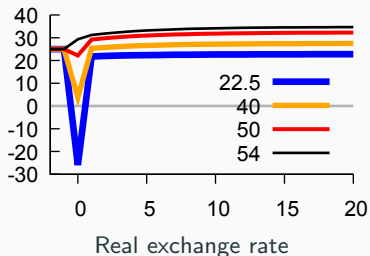
- 1 Minimize tax distortions → wealth effects
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Higher Imports: Home

Capital income tax



Labor income tax

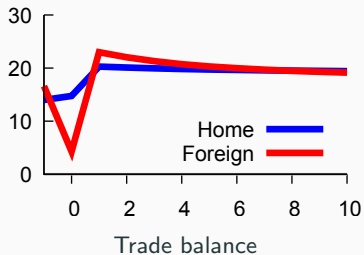


Key Effects

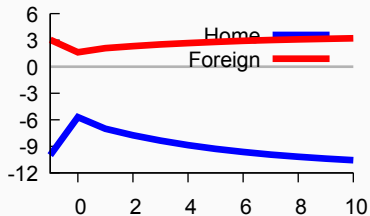
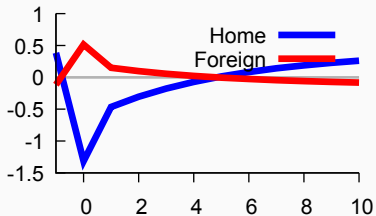
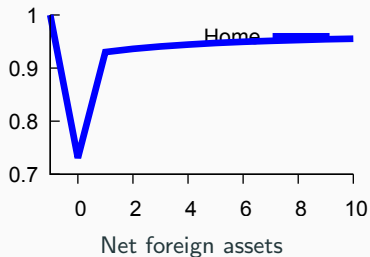
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Tax Competition: International

Import tax



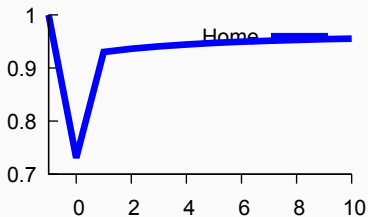
Exchange rate



No-arbitrage

$$\frac{e_{t-1}}{e_t} \underbrace{[1 + (1 - \tau_{kt})(F_1(k_{t-1}, h_t) - \delta)]}_{R_{kt}} = \underbrace{1 + (1 - \tau_{kt}^*)(F_1^*(k_{t-1}^*, h_t^*) - \delta)}_{R_{kt}^*}$$

Real exchange rate:



Small Open Economy

Capital income tax



Labor income tax



Sherlock Holmes

Once you eliminate the impossible, whatever remains, no matter how improbable, must be the truth.

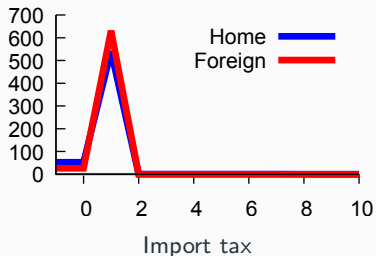
Key Effects

- 1 Minimize tax distortions
- 2 Population size
- 3 ~~Foreign debt revaluation~~
- 4 ~~Terms of trade~~
- 5 Strategic exchange rate manipulation

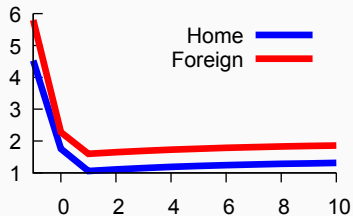
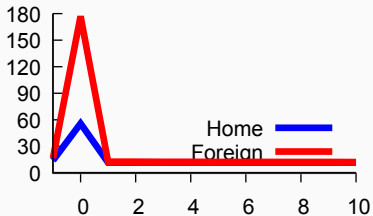
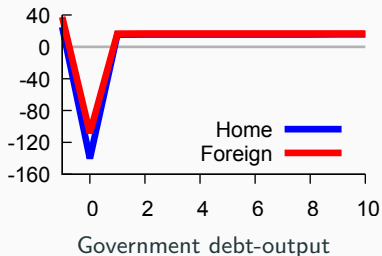
Tax Cooperation

Tax Cooperation: Fiscal Policy

Capital income tax

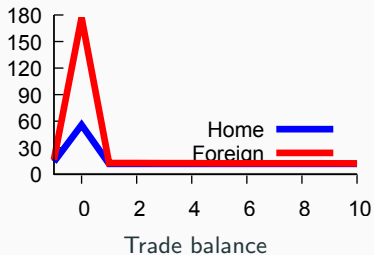


Labor income tax

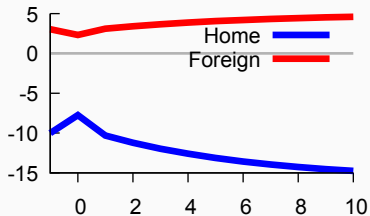
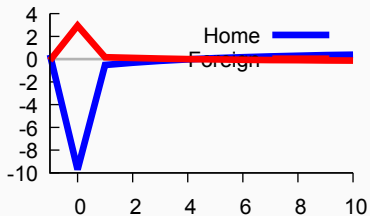
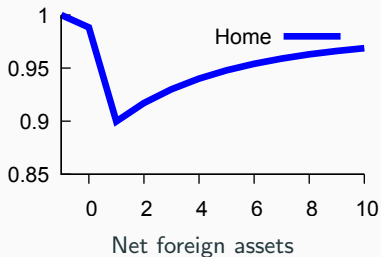


Tax Cooperation: International

Import tax



Exchange rate



Welfare

Welfare Criterion:

$$\sum_{t=0}^{\infty} \beta^t U((1 - \zeta)c_{ht}, (1 - \zeta)c_{ft}, h_t) = \frac{U(\bar{c}_h, \bar{c}_f, \bar{h})}{1 - \beta}.$$

Case	Home	Foreign
<i>Tax Competition</i>	5.548	4.883
<i>Tax Cooperation</i>	5.548	4.925

Key Effects

- 1 Minimize tax distortions
- 2 Population size
- 3 ~~Foreign debt revaluation~~
- 4 ~~Terms of trade~~
- 5 Strategic exchange rate manipulation

Bonus Features

Related Literature

- Closed economy, Ramsey:
 - Chamley (1986)
 - Judd (1985)
- Small open economy, Ramsey:
 - Correia (1996)
 - Auray, Eyquem and Gomme (2018)
- Two countries, tax competition
 - Mendoza and Tesar (1995)
 - Gross, Klein and Makris (2018)

Home Implementability Condition

Substitute home households' and firms' first-order conditions into the home present value budget constraint,

$$\sum_{t=0}^{\infty} q_t \left[(1 - \tau_{wt}) w_t h_t + R_{kt} k_{t-1} + d_{t-1} + e_t a_{t-1} - (1 + \tau_{ct}) p_t c_t - k_t - \frac{d_t}{R_{dt}} - e_t \frac{a_t}{R_{at}} \right]$$

to obtain

$$\begin{aligned} & \sum_{t=0}^{\infty} \beta^t [U_1(c_{ht}, c_{ft}, h_t) c_{ht} + U_2(c_{ht}, c_{ft}, h_t) c_{ft} + U_3(c_{ht}, c_{ft}, h_t) h_t] \\ & = \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} [R_{k0} k_{-1} + d_{-1} + e_0 a_{-1}] \end{aligned}$$

A Partial Primal Approach

Choose

$$\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t\}_{t=0}^{\infty}$$

to maximize

$$\sum_{t=0}^{\infty} \beta^t U(c_{ht}, c_{ft}, h_t)$$

subject to:

- 1 Home Implementability Condition
- 2 Home feasibility
- 3 Private foreign behavior
- 4 International solvency

A Familiar Result

Define

$$W(c_{ht}, c_{ft}, h_t) \equiv U(c_{ht}, c_{ft}, h_t) \\ + \Lambda [U_1(c_{ht}, c_{ft}, h_t)c_{ht} + U_2(c_{ht}, c_{ft}, h_t)c_{ft} + U_3(c_{ht}, c_{ft}, h_t)h_t]$$

First-order condition with respect to k_t :

$$W_1(c_{ht}, c_{ft}, h_t) = \beta W_1(c_{ht+1}, c_{ft+1}, h_{t+1}) [F_1(k_t, h_{t+1}) + 1 - \delta]$$

Steady state:

$$1 = \beta [F_1(k, h) + 1 - \delta]$$

From households' first-order conditions,

$$1 = \beta [1 + (1 - \tau_k)(F_1(k, h) - \delta)]$$

Competitive Equilibrium

Competitive Equilibrium

Given feasible fiscal policies,

$$\{\tau_{ct}, \tau_{mt}, \tau_{wt}, \tau_{kt}, \tau_{ct}^*, \tau_{mt}^*, \tau_{wt}^*, \tau_{kt}^*\}_{t=0}^{\infty},$$

a *competitive equilibrium* is given by a set of home quantities,

$$\{c_{ht}, c_{ft}, h_t, k_t, d_t, a_t\}_{t=0}^{\infty},$$

a set of foreign quantities,

$$\{c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, d_t^*, a_t^*\}_{t=0}^{\infty},$$

returns and prices

$$\{R_{dt}, R_{dt}^*, R_{at}, r_t, w_t, r_t^*, w_t^*, e_t\}_{t=0}^{\infty},$$

such that

Competitive Equilibrium (cont.)

- 1 The quantities for the households solve their problem given prices and government policy
- 2 The quantities for the firms solve their problems given prices
- 3 The international risk-sharing condition holds:

$$e_t \xi_t = \vartheta \xi_t^*.$$

- 4 Markets clear: goods markets

$$c_{ht} + \frac{1-n}{n} c_{ht}^* + k_t + g = F(k_{t-1}, h_t) + (1-\delta)k_{t-1}$$
$$c_{ft}^* + \frac{n}{1-n} c_{ft} + k_t^* + g^* = F(k_{t-1}^*, h_t^*) + (1-\delta)k_{t-1}^*$$

standard factor market clearing conditions, and the balance of payments

Risk-sharing Condition

$$R_{at} = \frac{\beta e_{t+1} U_1(c_{ht+1}, c_{ft+1}, h_{t+1}) / (1 + \tau_{c,t+1})}{e_t U_1(c_{ht}, c_{ft}, h_t) / (1 + \tau_{ct})} = \frac{\beta U_1^*(c_{ht+1}^*, c_{ft+1}^*, h_{t+1}^*) / (1 + \tau_{c,t+1}^*)}{U_1^*(c_{ht}^*, c_{ft}^*, h_t^*) / (1 + \tau_{ct}^*)}$$

\Rightarrow

$$\frac{e_t U_1(c_{ht}, c_{ft}, h_t) / (1 + \tau_{ct})}{U_1^*(c_{ht}^*, c_{ft}^*, h_t^*) / (1 + \tau_{ct}^*)} = \frac{e_{t+1} U_1(c_{ht+1}, c_{ft+1}, h_{t+1}) / (1 + \tau_{c,t+1})}{U_1^*(c_{ht+1}^*, c_{ft+1}^*, h_{t+1}^*) / (1 + \tau_{c,t+1}^*)}$$

\Rightarrow

$$\frac{e_t U_1(c_{ht}, c_{ft}, h_t) / (1 + \tau_{ct})}{U_1^*(c_{ht}^*, c_{ft}^*, h_t^*) / (1 + \tau_{ct}^*)} = \frac{e_0 U_1(c_{h0}, c_{f0}, h_0) / (1 + \tau_{c0})}{U_1^*(c_{h0}^*, c_{f0}^*, h_0^*) / (1 + \tau_{c0}^*)}$$

Calibration

Calibration

- Model period: annual
- Home: UK
- Foreign: EMU

Functional Forms

$$U(c_h, c_f, h) = \begin{cases} \ln C(c_h, c_f) - \omega h^{1+1/\kappa} & \eta = 1 \\ \frac{C(c_h, c_f)^{1-\sigma} [1 - \omega(1-\sigma)h^{1+1/\kappa}]^\sigma - 1}{1-\sigma} & \eta \in (0, 1) \cup (1, \infty) \end{cases}$$

$$C(c_h, c_f) = \left[\varphi c_h^{\frac{\mu-1}{\mu}} + (1-\varphi) c_f^{\frac{\mu-1}{\mu}} \right]^{\frac{\mu}{\mu-1}}$$

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

Parameter Values

Parameter	Home	Foreign
Consumption tax, τ_c	0.140	0.166
Import tax, τ_m	0.140	0.166
Labor income tax, τ_w	0.250	0.374
Capital income tax, τ_k	0.530	0.265
Discount factor, β	0.962	0.962
Risk aversion, σ	1.000	1.000
Labor weight, ω	8.520	7.251
Frisch elasticity, κ	1.000	1.000
Trade elasticity, μ	1.500	1.500
Capital share, α	0.300	0.300
Capital depreciation, δ	0.075	0.075
φ	0.695	0.156
ϑ	1.074	1.074
Population share (n or $1 - n$)	0.250	0.750

Initial Steady state

Output	0.262	0.287
Consumption: Home	0.137	0.014
Consumption: Foreign	0.040	0.172
Consumption: Aggregate	0.177	0.186
Hours worked	0.200	0.200
Capital stock	0.490	0.665
Capital-output ratio	1.874	2.318
Government share	0.180	0.180
Tax Revenues	0.093	0.116
Primary deficit	-0.046	-0.064
Public debt	1.185	1.663
Debt-output ratio	4.527	5.800
Exchange rate	1.000	1.000
Trade balance	0.001	-0.000
Net foreign assets	-0.026	0.009

Full Ramsey Problems

Home Ramsey Planner Problem

$$\begin{aligned}
 & \max_{\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t, \tau_{mt}, \tau_{wt}, \tau_{k,t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left\{ U(c_{ht}, c_{ft}, h_t) \right. \\
 & + \lambda_{1t} \left[F(k_{t-1}, h_t) + (1 - \delta)k_{t-1} - c_{ht} - \frac{1-n}{n}c_{ht}^* - k_t - g \right] \\
 & + \lambda_{2t} \left[\frac{e_t U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} - \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_{mt}} \right] \\
 & + \lambda_{3t} \left[U_3(c_{ht}, c_{ft}, h_t) + \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} (1 - \tau_{wt}) F_2(k_{t-1}, h_t) \right] \\
 & + \lambda_{4t} \left[\beta \frac{U_1(c_{ht+1}, c_{ft+1}, h_{t+1})}{1 + \tau_c} [1 + (1 - \tau_{k,t+1}) (F_1(k_t, h_{t+1}) - \delta)] - \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \right] \\
 & + \lambda_{5t} \left[e_t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} - \vartheta \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \right]
 \end{aligned}$$

Home Ramsey Planner Problem (continued)

$$\begin{aligned}
 & +\lambda_{6t} \left[F(k_{t-1}^*, h_t^*) + (1 - \delta)k_{t-1}^* - c_{ft}^* - \frac{n}{1-n}c_{ft}^* - k_t^* - g^* \right] \\
 & +\lambda_{7t} \left[\frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} - \frac{e_t U_1^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_{mt}^*} \right] \\
 & +\lambda_{8t} \left[U_3^*(c_{ht}^*, c_{ft}^*, h_t^*) + \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} (1 - \tau_{wt}^*) F_2(k_{t-1}^*, h_t^*) \right] \\
 & +\lambda_{9t} \left[\beta \frac{U_2^*(c_{ht+1}^*, c_{ft+1}^*, h_{t+1}^*)}{1 + \tau_c^*} [1 + (1 - \tau_{k,t+1}^*) (F_1(k_t^*, h_{t+1}^*) - \delta)] - \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \right] \\
 & +\Omega \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \left[\frac{1-n}{n}c_{ht}^* - e_t c_{ft} \right] \\
 & -\Lambda \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} [g - \tau_c c_{ht} - \tau_{mt} c_{ft} e_t - \tau_{wt} F_2(k_{t-1}, h_t) h_t - \tau_{kt} (F_1(k_{t-1}, h_t) - \delta) k_t - \\
 & +\Omega e_0 \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} a_{-1} - \Lambda \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} d_{-1}.
 \end{aligned}$$

Foreign Ramsey Planner Problem

$$\begin{aligned}
 & \max_{\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t, \tau_{mt}^*, \tau_{wt}^*, \tau_{k,t+1}^*\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left\{ U^*(c_{ht}^*, c_{ft}^*, h_t^*) \right. \\
 & + \lambda_{1t}^* \left[F(k_{t-1}^*, h_t^*) + (1 - \delta)k_{t-1}^* - c_{ft}^* - \frac{n}{1-n}c_{ft}^* - k_t^* - g^* \right] \\
 & + \lambda_{2t}^* \left[\frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} - \frac{e_t U_1^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_{mt}^*} \right] \\
 & + \lambda_{3t}^* \left[U_3^*(c_{ht}^*, c_{ft}^*, h_t^*) + \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} (1 - \tau_{wt}^*) F_2(k_{t-1}^*, h_t^*) \right] \\
 & + \lambda_{4t}^* \left[\beta \frac{U_2^*(c_{ht+1}^*, c_{ft+1}^*, h_{t+1}^*)}{1 + \tau_c^*} [1 + (1 - \tau_{k,t+1}^*) (F_1(k_t^*, h_{t+1}^*) - \delta)] - \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \right] \\
 & + \lambda_{5t}^* \left[e_t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} - \vartheta \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \right]
 \end{aligned}$$

Foreign Ramsey Planner Problem (continued)

$$\begin{aligned}
 & + \lambda_{6t}^* \left[F(k_{t-1}, h_t) + (1 - \delta)k_{t-1} - c_{ht} - \frac{1-n}{n}c_{ht}^* - k_t - g \right] \\
 & + \lambda_{7t}^* \left[\frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_{mt}} - \frac{e_t U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \right] \\
 & + \lambda_{8t}^* \left[U_3(c_{ht}, c_{ft}, h_t) + \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} (1 - \tau_{wt}) F_2(k_{t-1}, h_t) \right] \\
 & + \lambda_{9t}^* \left[\beta \frac{U_2(c_{ht+1}, c_{ft+1}, h_{t+1})}{1 + \tau_c} [1 + (1 - \tau_{k,t+1}) (F_1(k_t, h_{t+1}) - \delta)] - \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} \right] \\
 & + \Omega^* \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_c^*} \left[\frac{n}{1-n} c_{ft} - \frac{c_{ht}^*}{e_t} \right] \\
 & - \Lambda \frac{U_2(c_{ht}, c_{ft}, h_t)}{1 + \tau_c^*} \left[g^* - \tau_c^* c_{ft}^* - \tau_{mt}^* \frac{c_{ht}^*}{e_t} - \tau_{wt}^* F_2(k_{t-1}^*, h_t^*) h_t^* - \tau_{kt}^* (F_1(k_{t-1}^*, h_t^*) - \delta) k_{t-1}^* \right] \\
 & + \Omega^* \frac{U_2^*(c_{h0}^*, c_{f0}^*, h_0^*)}{1 + \tau_c^*} a_{-1}^* - \Lambda \frac{U_2^*(c_{h0}^*, c_{f0}^*, h_0^*)}{1 + \tau_c^*} d_{-1}^*.
 \end{aligned}$$

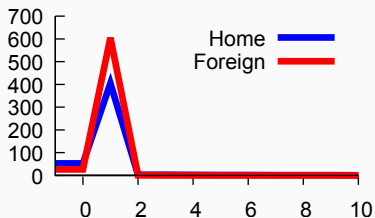
World Ramsey Planner Problem

$$\begin{aligned}
 & \max_{\{c_{ht}, c_{ft}, h_t, k_t, c_{ht}^*, c_{ft}^*, h_t^*, k_t^*, e_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \left\{ \phi W(c_{ht}, c_{ft}, h_t) + (1 - \phi) W^*(c_{ht}^*, c_{ft}^*, h_t^*) \right. \\
 & + \lambda_{1t} \left[F(k_{t-1}, h_t) + (1 - \delta)k_{t-1} - c_{ht} - \frac{1-n}{n} c_{ht}^* - k_t - g \right] \\
 & + \lambda_{1t}^* \left[F(k_{t-1}^*, h_t^*) + (1 - \delta)k_{t-1}^* - c_{ft}^* - \frac{n}{1-n} c_{ft} - k_t^* - g^* \right] \\
 & + \lambda_{2t} \left[e_t \frac{U_1(c_{ht}, c_{ft}, h_t)}{1 + \tau_c} - \vartheta \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \right] \\
 & \left. + \Omega^* \frac{U_2^*(c_{ht}^*, c_{ft}^*, h_t^*)}{1 + \tau_c^*} \left[\frac{n}{1-n} c_{ft} - \frac{c_{ht}^*}{e_t} \right] \right\} \\
 & + \Omega^* \frac{U_2^*(c_{h0}, c_{f0}, h_0^*)}{1 + \tau_c^*} a_{-1}^* \\
 & - \Lambda \frac{U_1(c_{h0}, c_{f0}, h_0)}{1 + \tau_c} \left[(1 - \delta + (1 - \tau_{k0})F_1(k_{-1}, h_0))k_{-1} + d_{-1} + e_0 a_{-1} \right] \\
 & - \Lambda^* \frac{U_2^*(c_{h0}^*, c_{f0}^*, h_0^*)}{1 + \tau_c^*} \left[(1 - \delta + (1 - \tau_{k0}^*)F_1(k_{-1}^*, h_0^*))k_{-1}^* + d_{-1}^* + a_{-1}^* \right]
 \end{aligned}$$

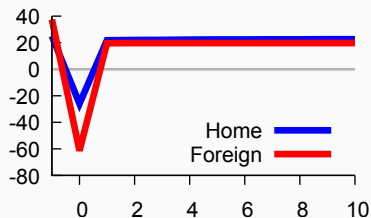
Tax Competition

Tax Competition: Fiscal Policy

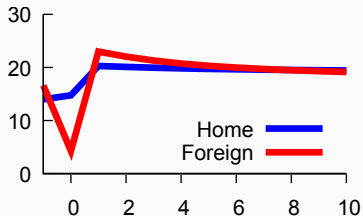
Capital income tax



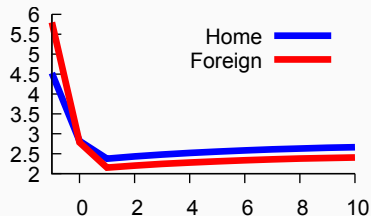
Labor income tax



Import Tax

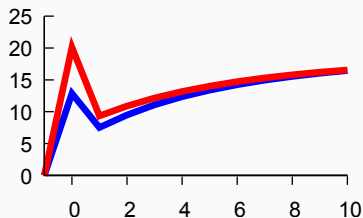


Debt-output

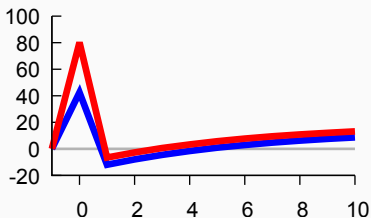


Tax Competition: Macro Variables

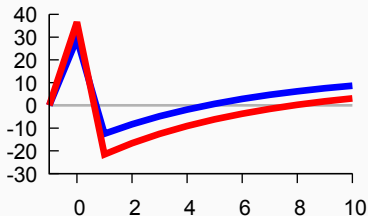
Output



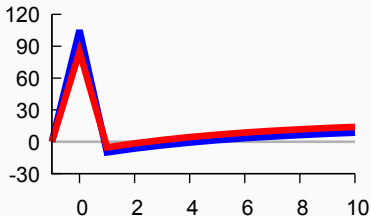
Consumption



Consumption: home

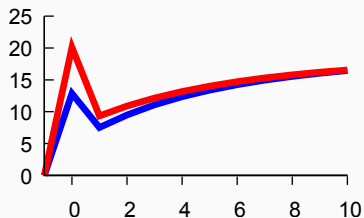


Consumption: foreign

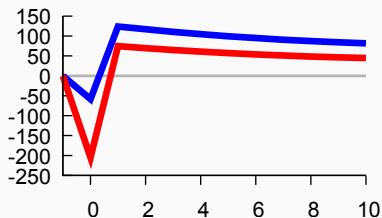


Tax Competition: Macro Variables

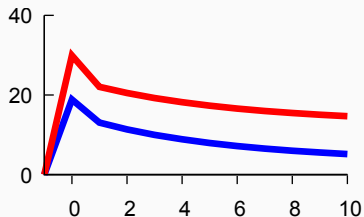
Output



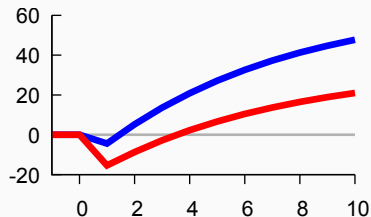
Investment



Hours

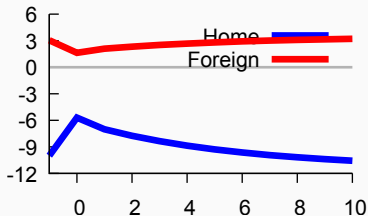


Capital

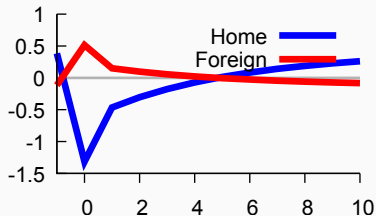


Tax Competition: International Variables

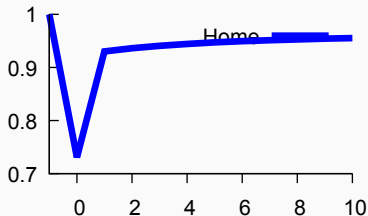
Net foreign assets



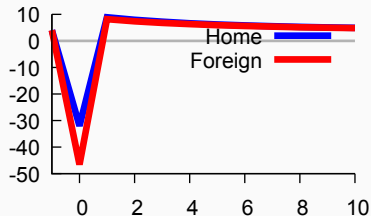
Trade balance



Exchange rate



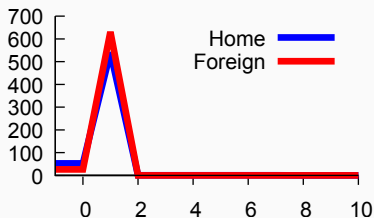
Interest rate



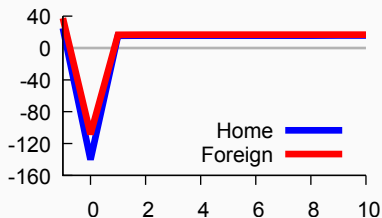
Tax Cooperation

Tax Cooperation: Fiscal Policy

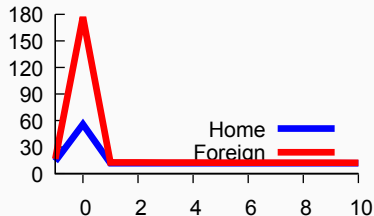
Capital income tax



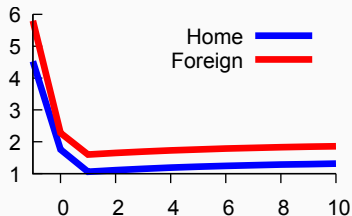
Labor income tax



Import Tax

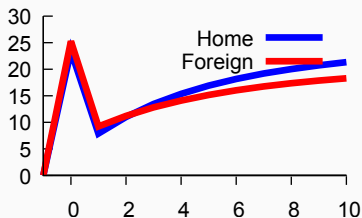


Debt-output

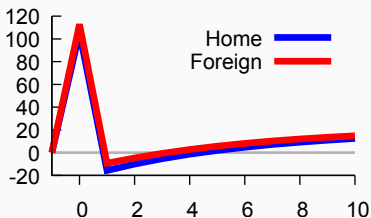


Tax Cooperation: Macro Variables

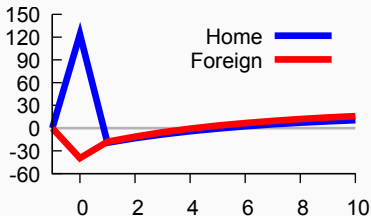
Output



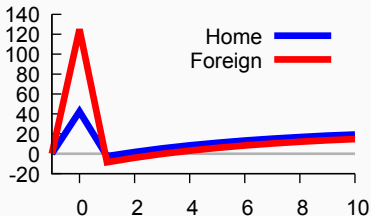
Consumption



Consumption: home

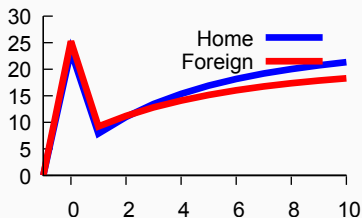


Consumption: foreign

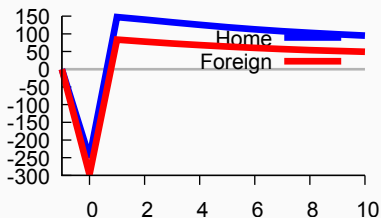


Tax Cooperation: Macro Variables

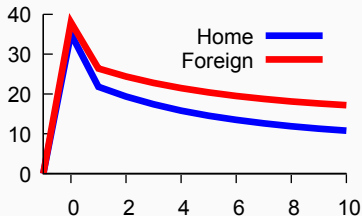
Output



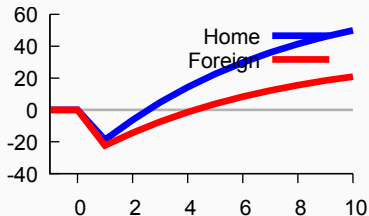
Investment



Hours

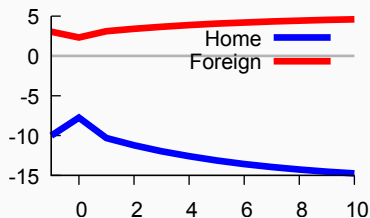


Capital

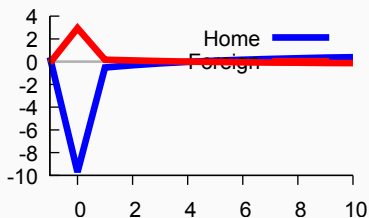


Tax Cooperation: International Variables

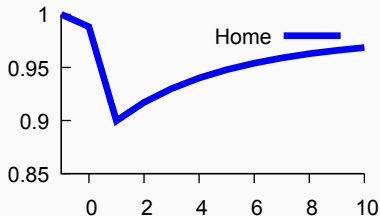
Net foreign assets



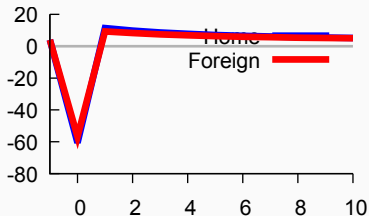
Trade balance



Exchange rate



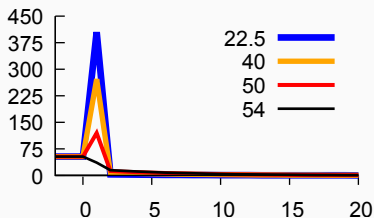
Interest rate



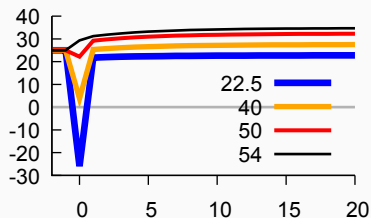
Home, Higher Imports

Home, Higher Imports: Fiscal Policy

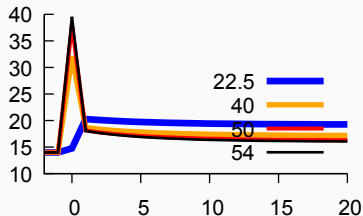
Capital income tax



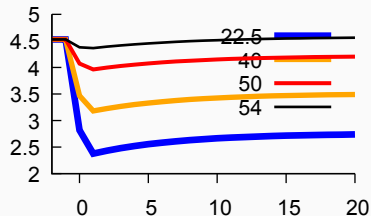
Labor income tax



Import Tax

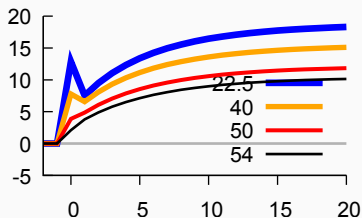


Debt-output

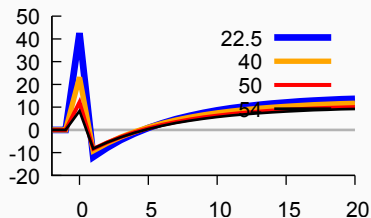


Home, Higher Imports: Macro Variables

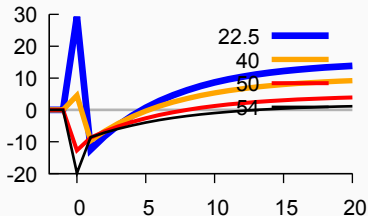
Output



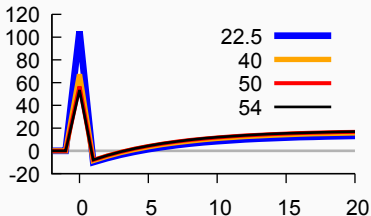
Consumption



Consumption: home

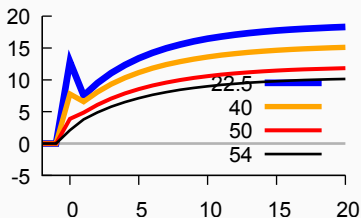


Consumption: foreign

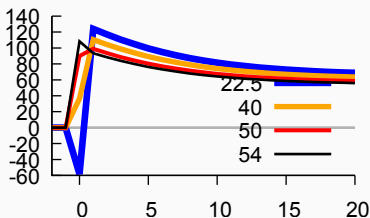


Home, Higher Imports: Macro Variables

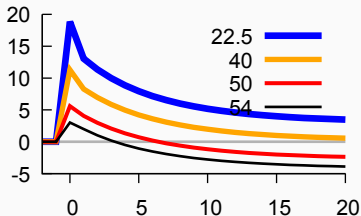
Output



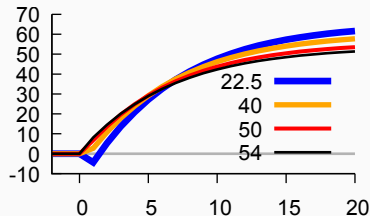
Investment



Hours

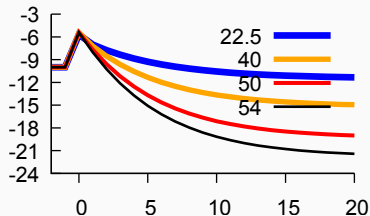


Capital

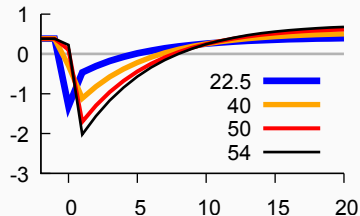


Home, Higher Imports: International Variables

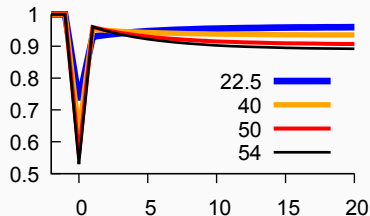
Net foreign assets



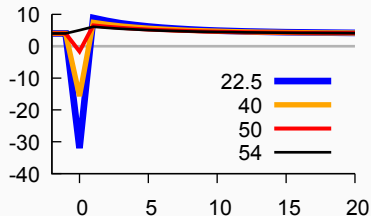
Trade balance



Exchange rate



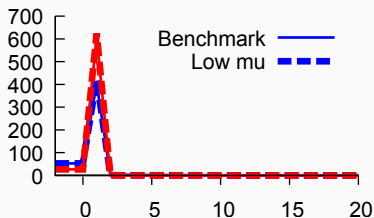
Interest rate



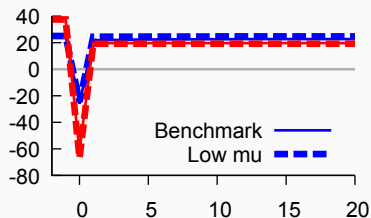
Lower Trade Elasticity

Lower Trade Elasticity: Fiscal Policy

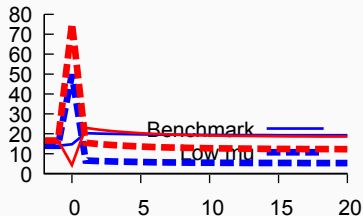
Capital income tax



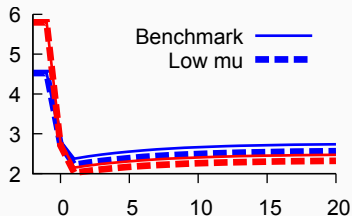
Labor income tax



Import Tax

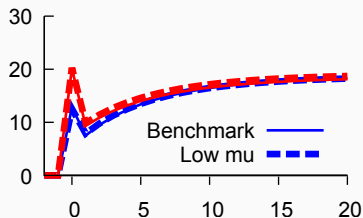


Debt-output

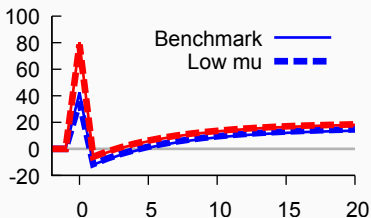


Lower Trade Elasticity: Macro Variables

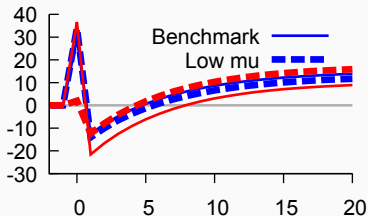
Output



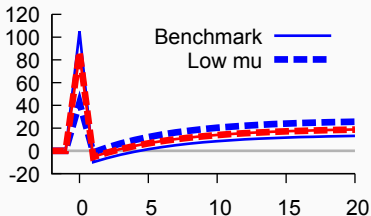
Consumption



Consumption: home

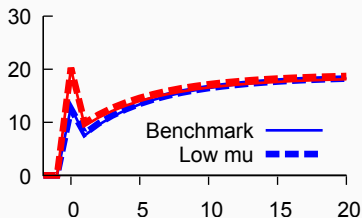


Consumption: foreign

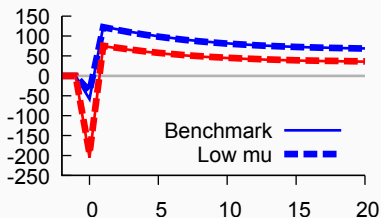


Lower Trade Elasticity: Macro Variables

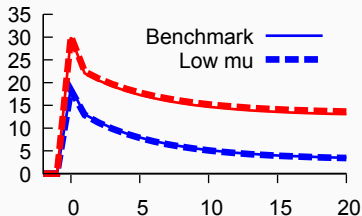
Output



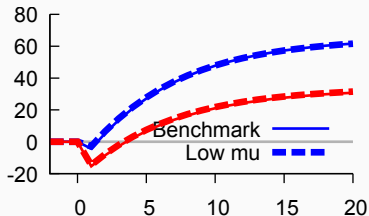
Investment



Hours

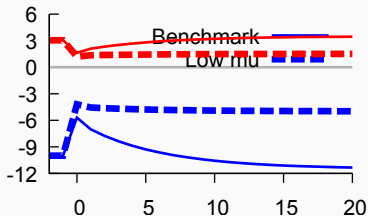


Capital

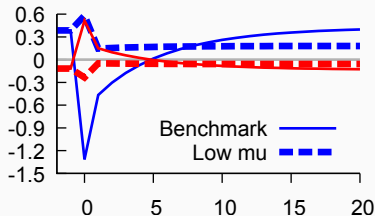


Lower Trade Elasticity: International Variables

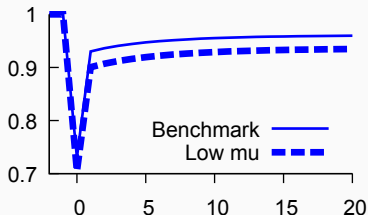
Net foreign assets



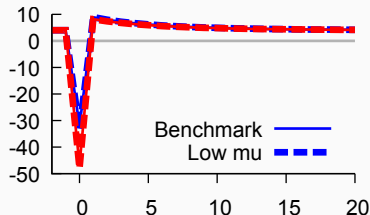
Trade balance



Exchange rate



Interest rate

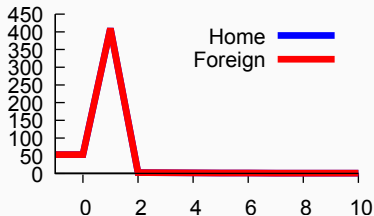


Symmetric

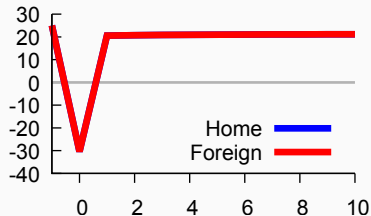


Symmetric: Fiscal Policy

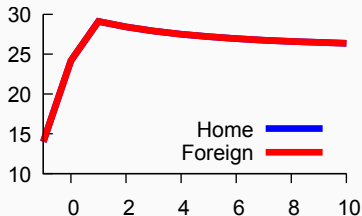
Capital income tax



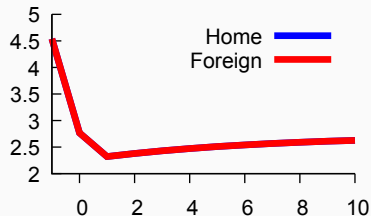
Labor income tax



Import Tax

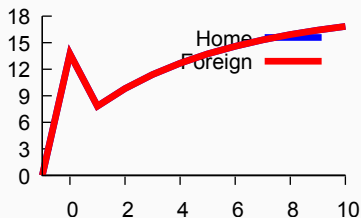


Debt-output

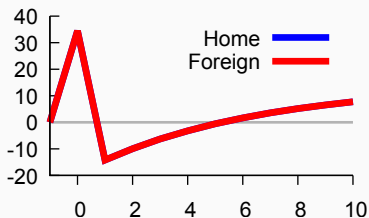


Symmetric: Macro Variables

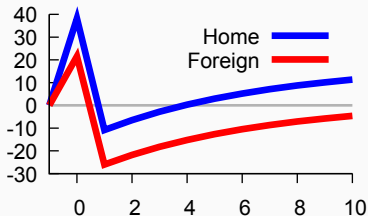
Output



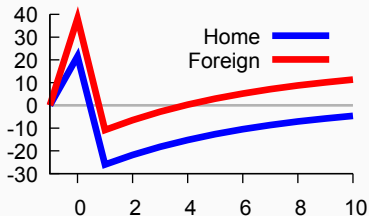
Consumption



Consumption: home

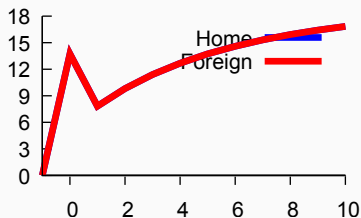


Consumption: foreign

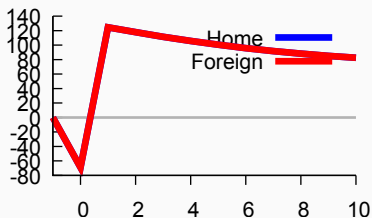


Symmetric: Macro Variables

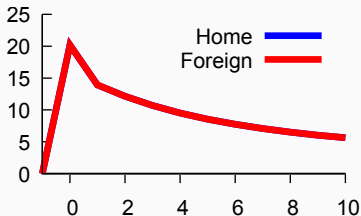
Output



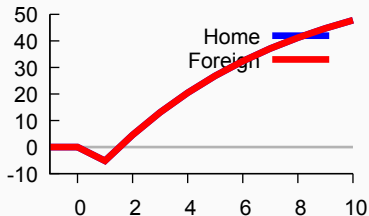
Investment



Hours

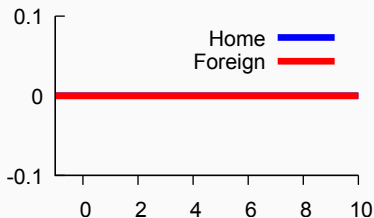


Capital

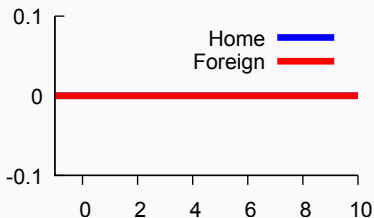


Symmetric: International Variables

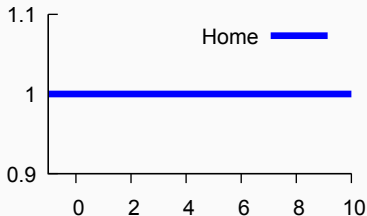
Net foreign assets



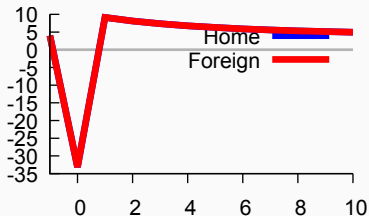
Trade balance



Exchange rate



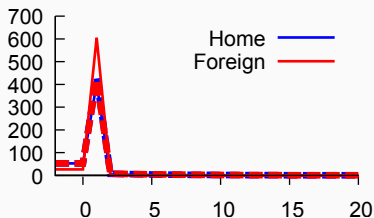
Interest rate



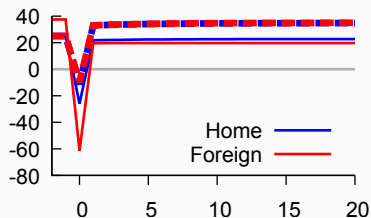
Differences in Initial NFA

Differences in Initial NFA: Fiscal Policy

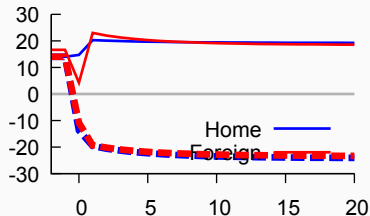
Capital income tax



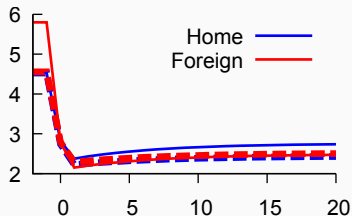
Labor income tax



Import Tax

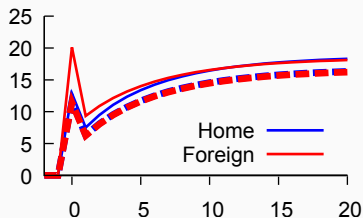


Debt-output

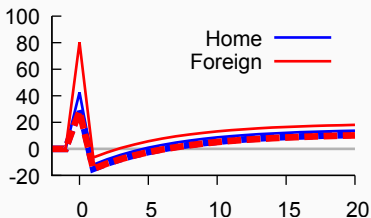


Differences in Initial NFA: Macro Variables

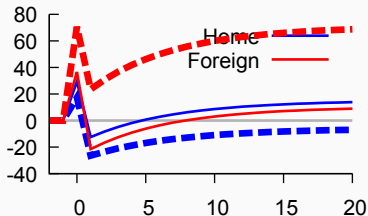
Output



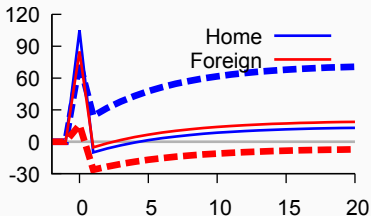
Consumption



Consumption: home

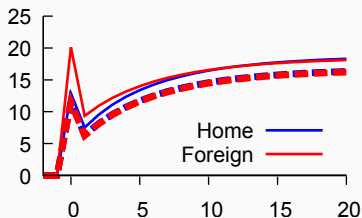


Consumption: foreign

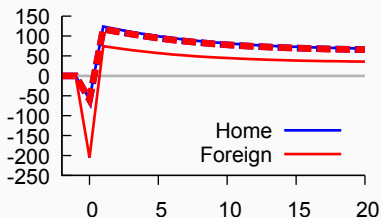


Differences in Initial NFA: Macro Variables

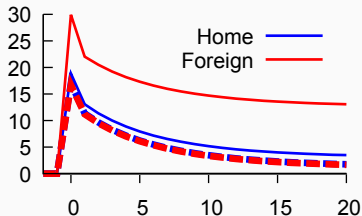
Output



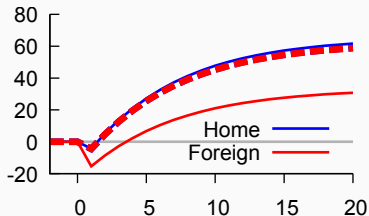
Investment



Hours

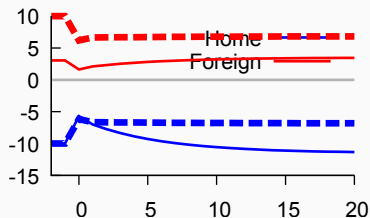


Capital

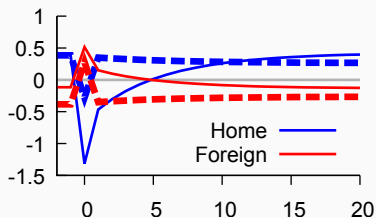


Differences in Initial NFA: International Variables

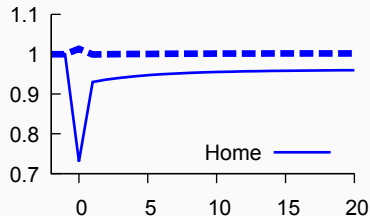
Net foreign assets



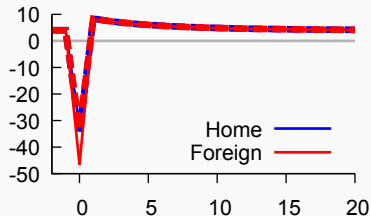
Trade balance



Exchange rate



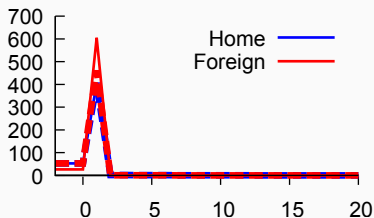
Interest rate



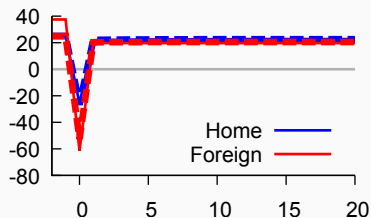
Differences in Country Size

Differences in Country Size: Fiscal Policy

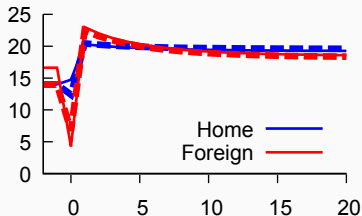
Capital income tax



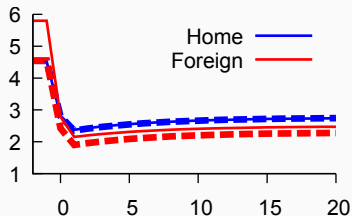
Labor income tax



Import Tax

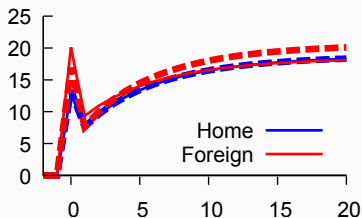


Debt-output

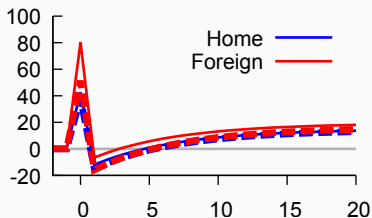


Differences in Country Size: Macro Variables

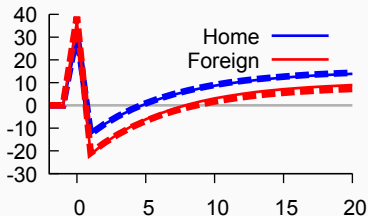
Output



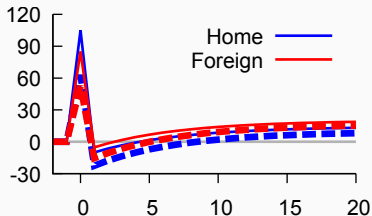
Consumption



Consumption: home

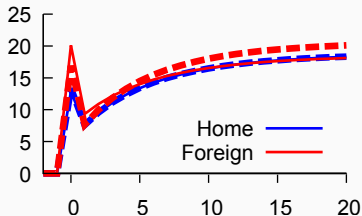


Consumption: foreign

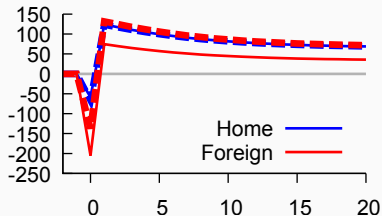


Differences in Country Size: Macro Variables

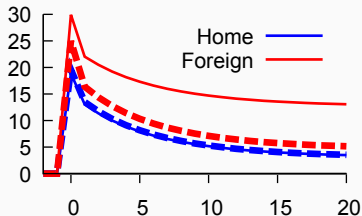
Output



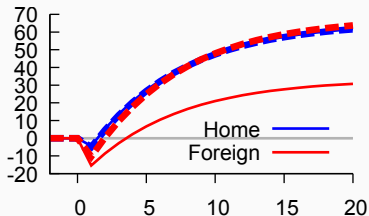
Investment



Hours

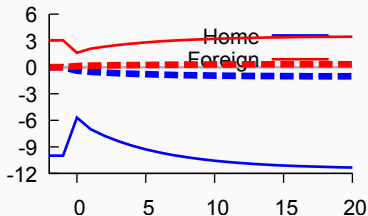


Capital

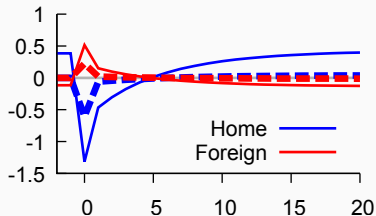


Differences in Country Size: International Variables

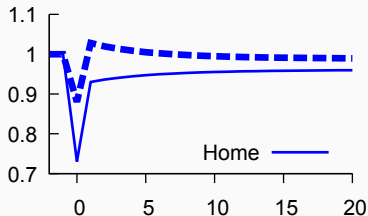
Net foreign assets



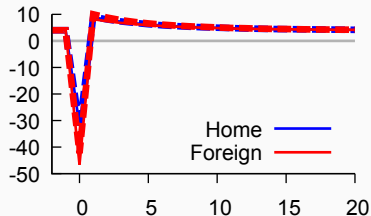
Trade balance



Exchange rate



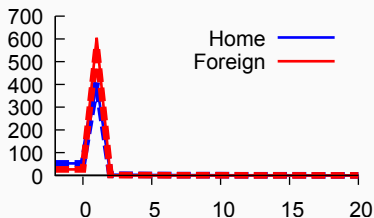
Interest rate



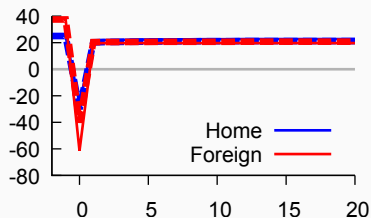
Differences in Initial Taxes

Differences in Initial Taxes: Fiscal Policy

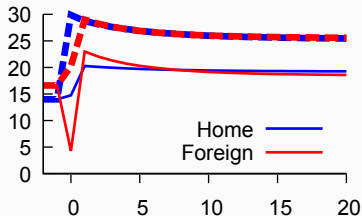
Capital income tax



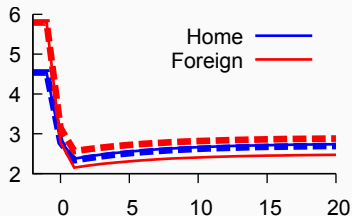
Labor income tax



Import Tax

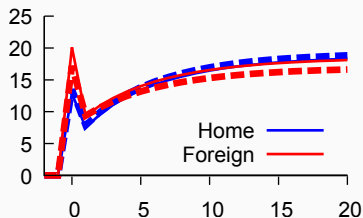


Debt-output

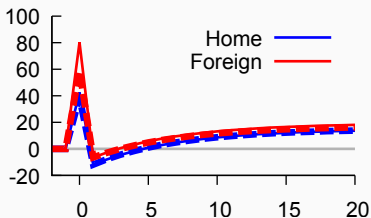


Differences in Initial Taxes: Macro Variables

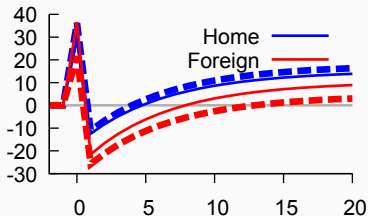
Output



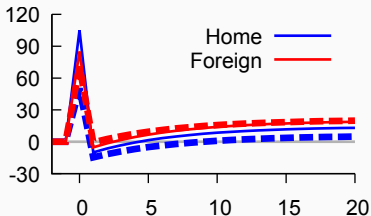
Consumption



Consumption: home

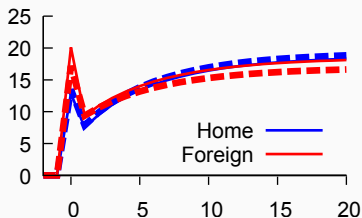


Consumption: foreign

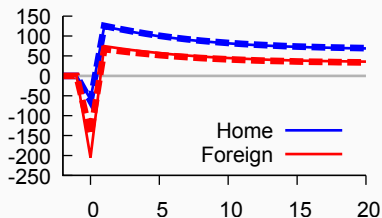


Differences in Initial Taxes: Macro Variables

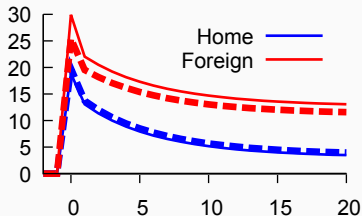
Output



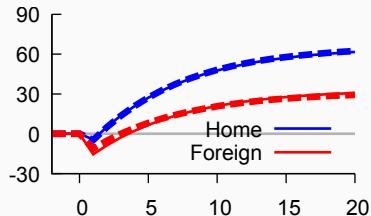
Investment



Hours

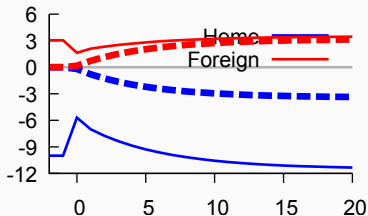


Capital

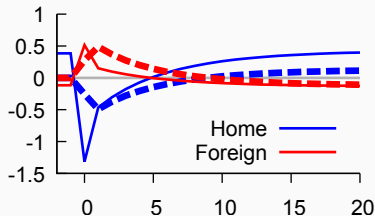


Differences in Initial Taxes: International Variables

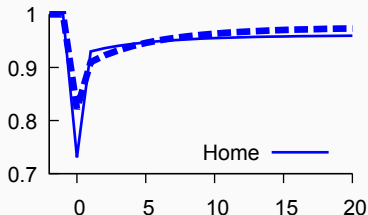
Net foreign assets



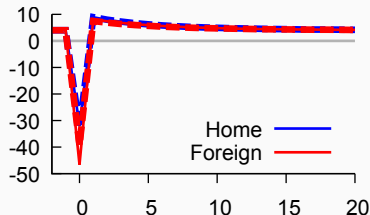
Trade balance



Exchange rate



Interest rate

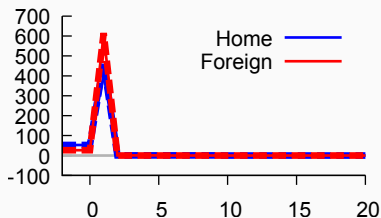


Less Open

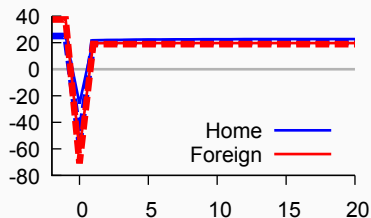


Less Open: Fiscal Policy

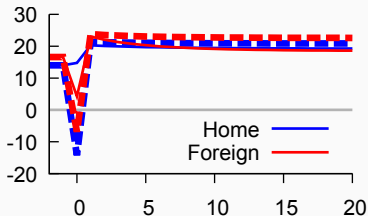
Capital income tax



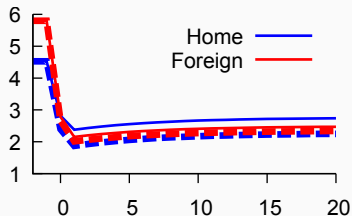
Labor income tax



Import Tax

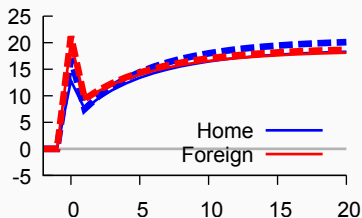


Debt-output

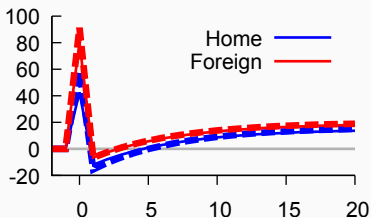


Less Open: Macro Variables

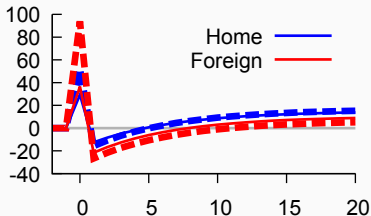
Output



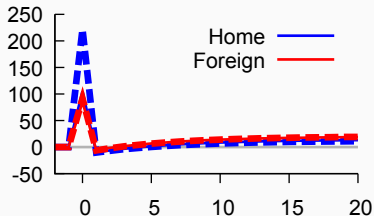
Consumption



Consumption: home

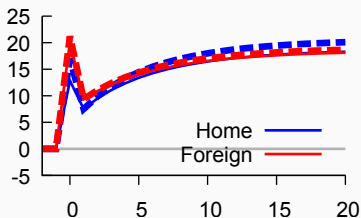


Consumption: foreign

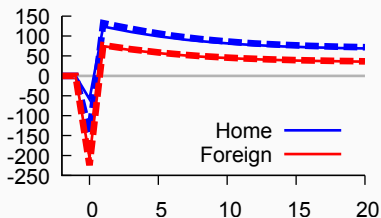


Less Open: Macro Variables

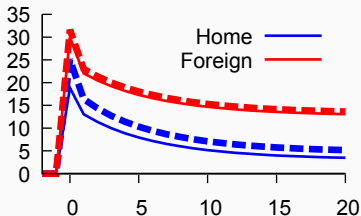
Output



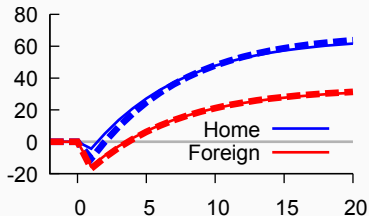
Investment



Hours

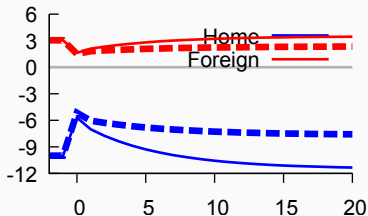


Capital

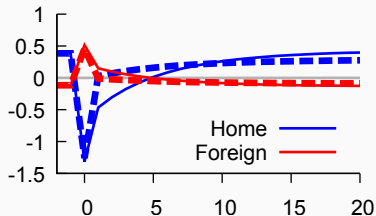


Less Open: International Variables

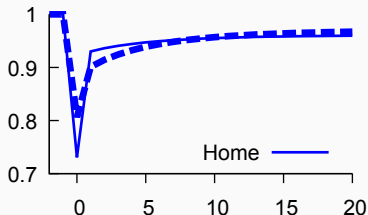
Net foreign assets



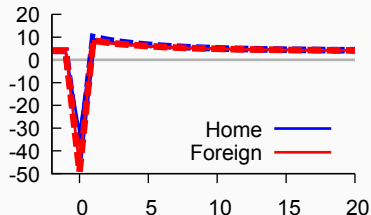
Trade balance



Exchange rate



Interest rate

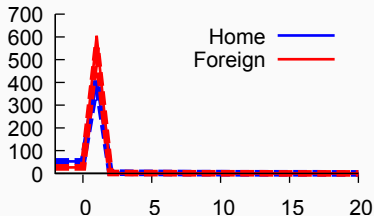


Same Population

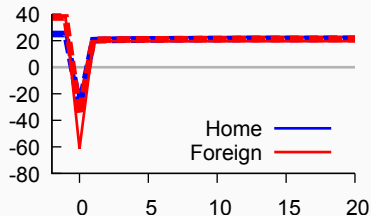


Same Population: Fiscal Policy

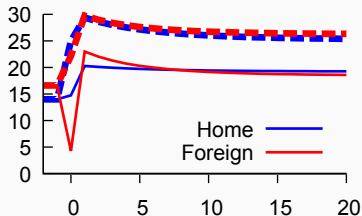
Capital income tax



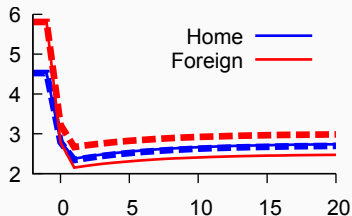
Labor income tax



Import Tax

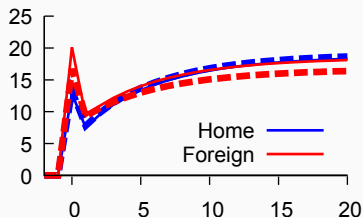


Debt-output

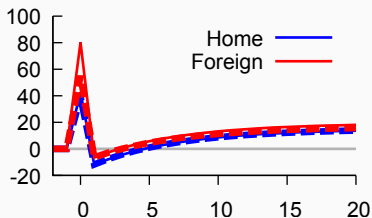


Same Population: Macro Variables

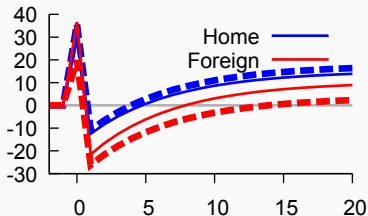
Output



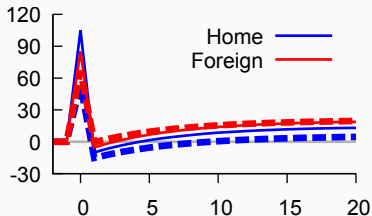
Consumption



Consumption: home

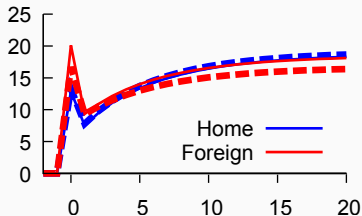


Consumption: foreign

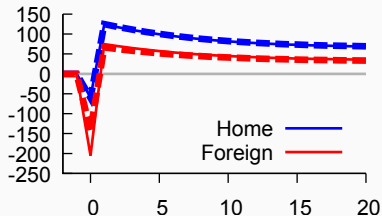


Same Population: Macro Variables

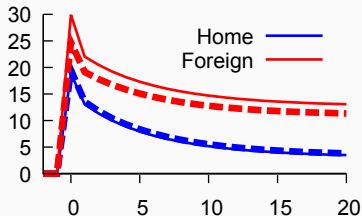
Output



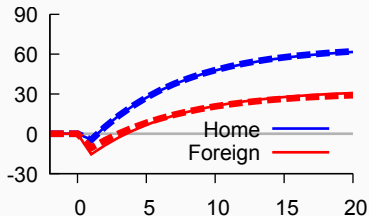
Investment



Hours

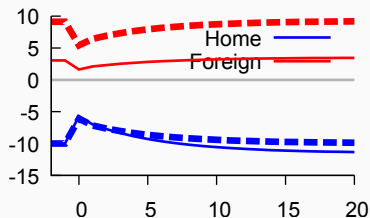


Capital

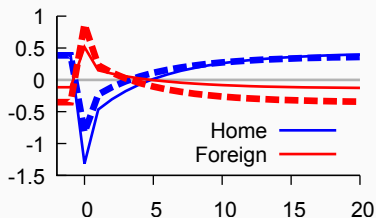


Same Population: International Variables

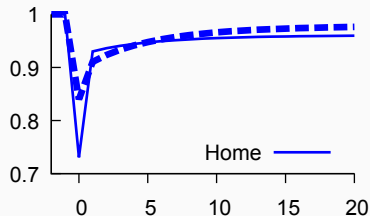
Net foreign assets



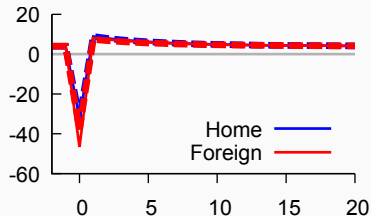
Trade balance



Exchange rate



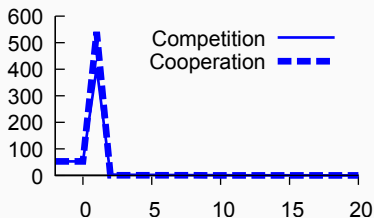
Interest rate



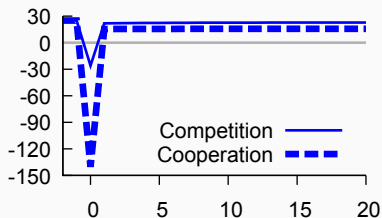
Home, Comp. v Coop.

Home, Comp. v Coop.: Fiscal Policy

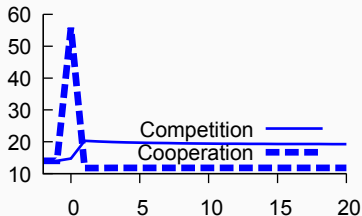
Capital income tax



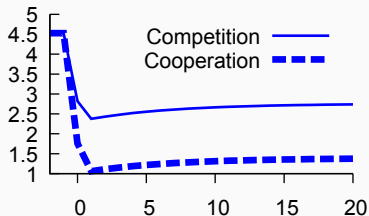
Labor income tax



Import Tax

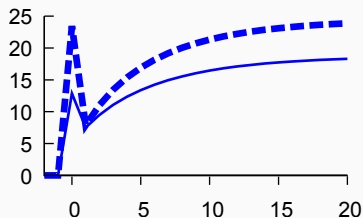


Debt-output

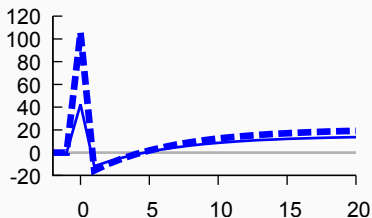


Home, Comp. v Coop.: Macro Variables

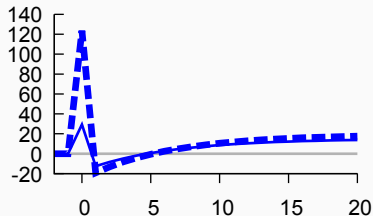
Output



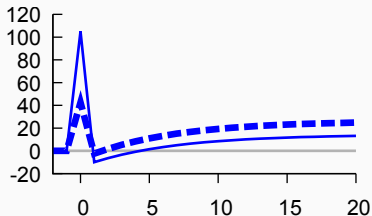
Consumption



Consumption: home

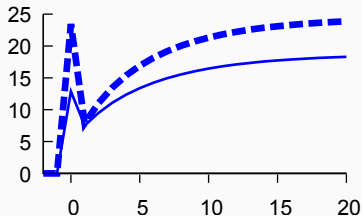


Consumption: foreign

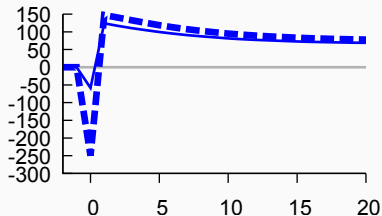


Home, Comp. v Coop.: Macro Variables

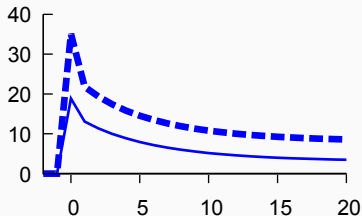
Output



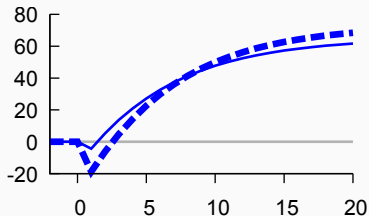
Investment



Hours

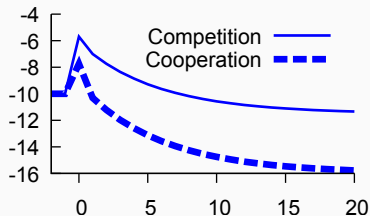


Capital

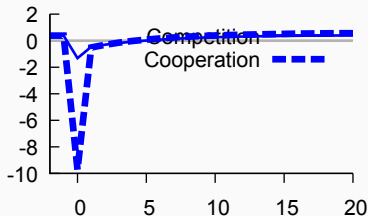


Home, Comp. v Coop.: International Variables

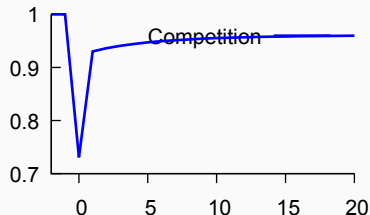
Net foreign assets



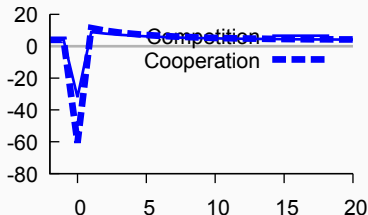
Trade balance



Exchange rate



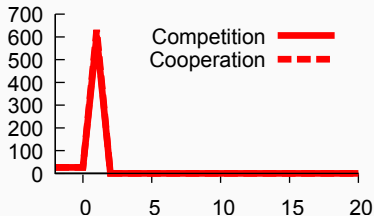
Interest rate



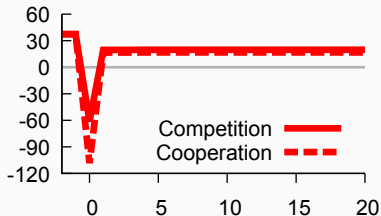
Foreign, Comp. v Coop.

Foreign, Comp. v Coop.: Fiscal Policy

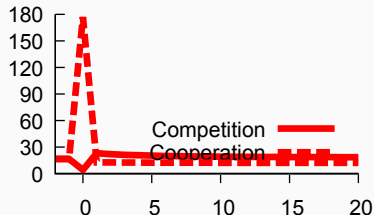
Capital income tax



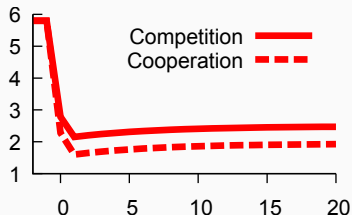
Labor income tax



Import Tax

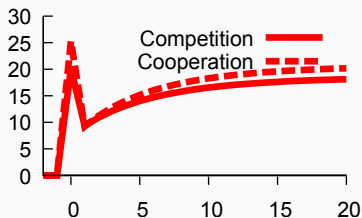


Debt-output

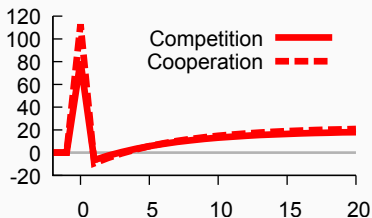


Foreign, Comp. v Coop.: Macro Variables

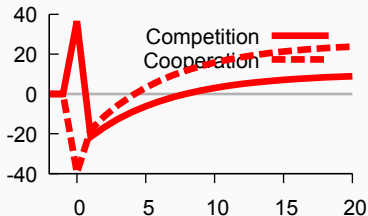
Output



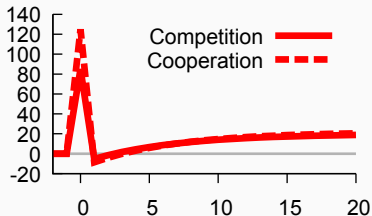
Consumption



Consumption: home

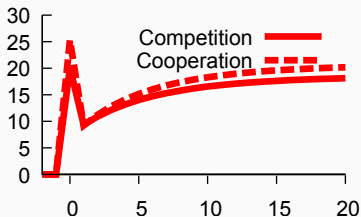


Consumption: foreign

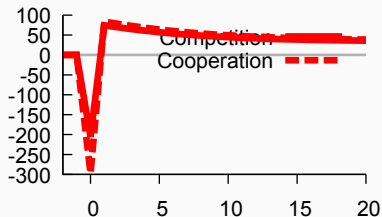


Foreign, Comp. v Coop.: Macro Variables

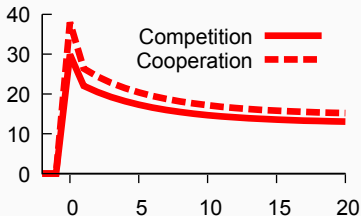
Output



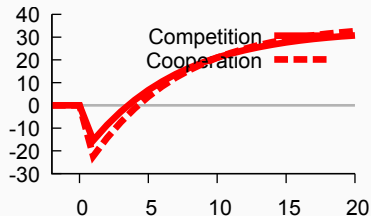
Investment



Hours

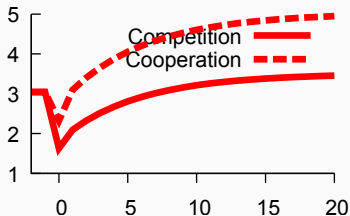


Capital

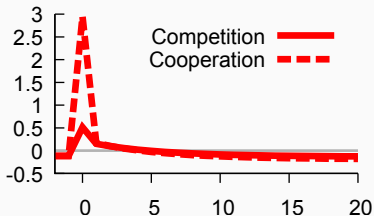


Foreign, Comp. v Coop.: International Variables

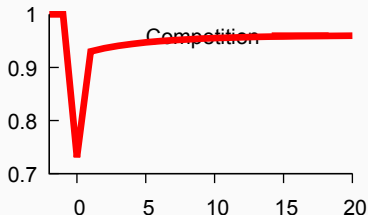
Net foreign assets



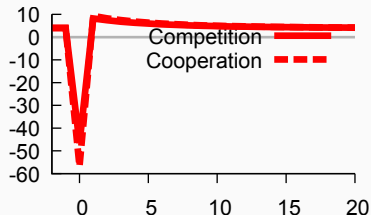
Trade balance



Exchange rate



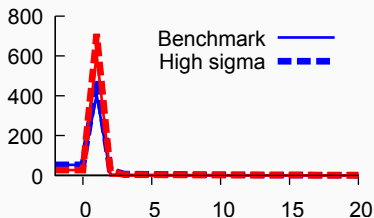
Interest rate



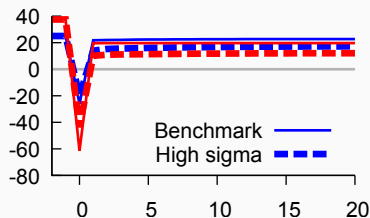
Higher Risk Aversion

Higher Risk Aversion: Fiscal Policy

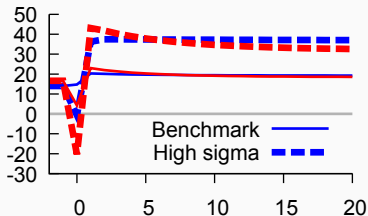
Capital income tax



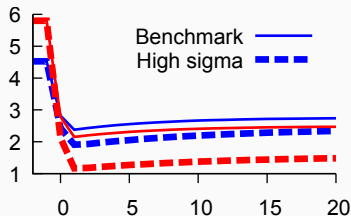
Labor income tax



Import Tax

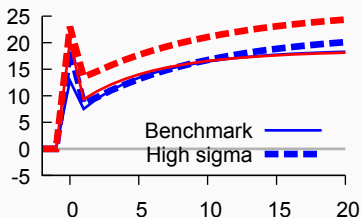


Debt-output

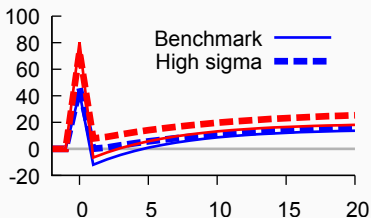


Higher Risk Aversion: Macro Variables

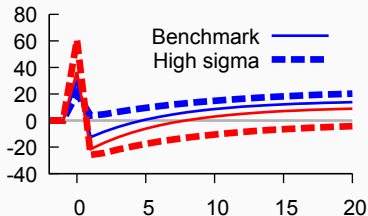
Output



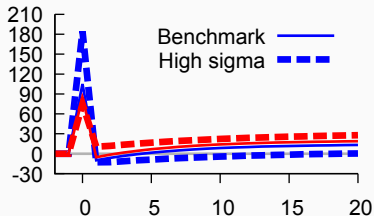
Consumption



Consumption: home

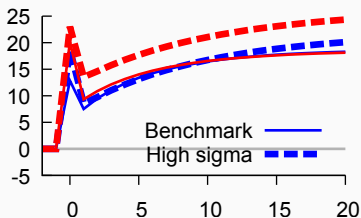


Consumption: foreign

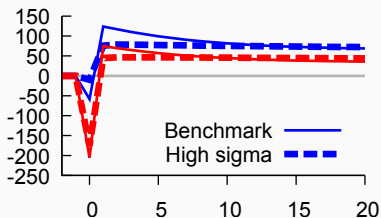


Higher Risk Aversion: Macro Variables

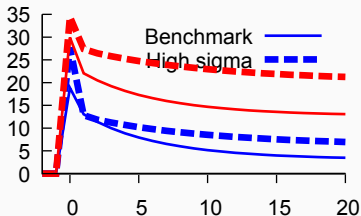
Output



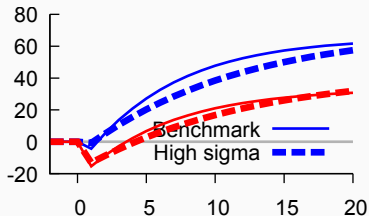
Investment



Hours

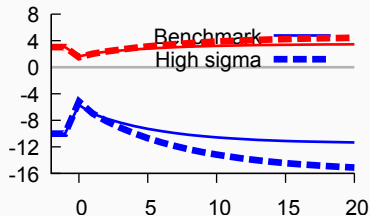


Capital

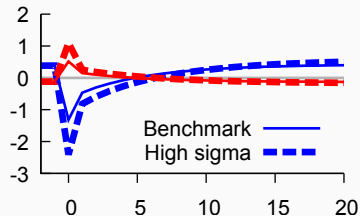


Higher Risk Aversion: International Variables

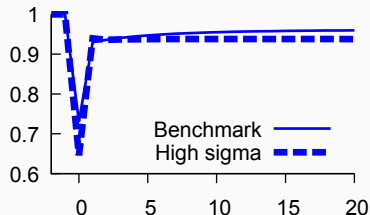
Net foreign assets



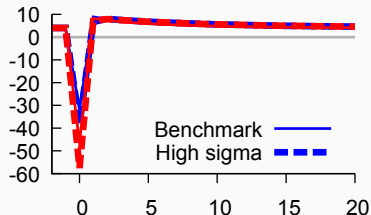
Trade balance



Exchange rate



Interest rate

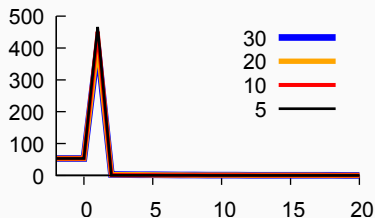


Home, Less Open

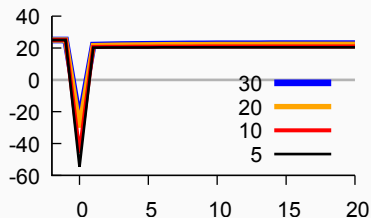


Home, Less Open: Fiscal Policy

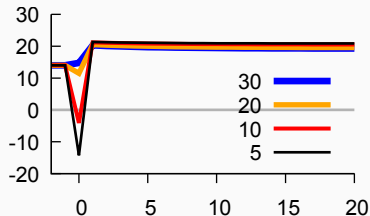
Capital income tax



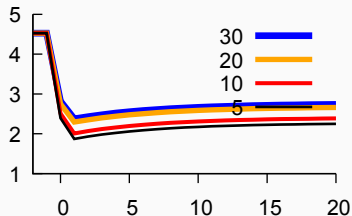
Labor income tax



Import Tax

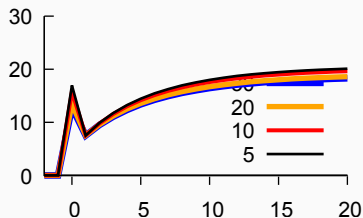


Debt-output

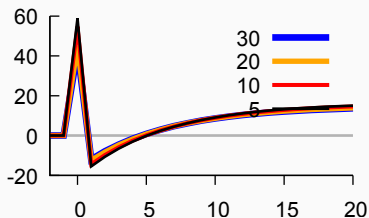


Home, Less Open: Macro Variables

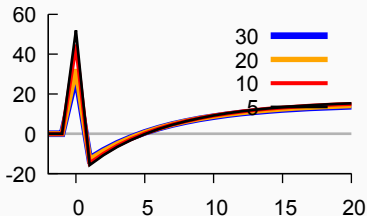
Output



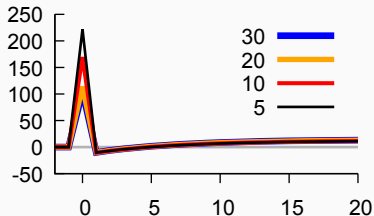
Consumption



Consumption: home

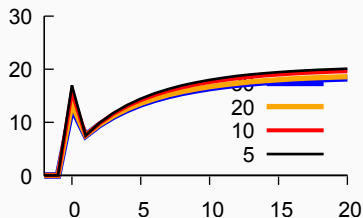


Consumption: foreign

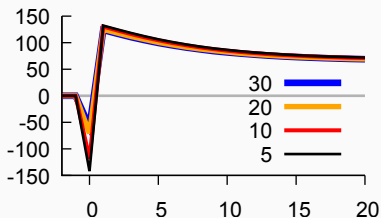


Home, Less Open: Macro Variables

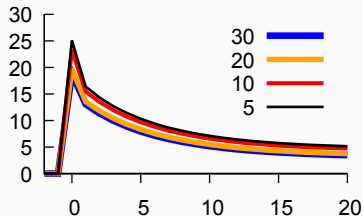
Output



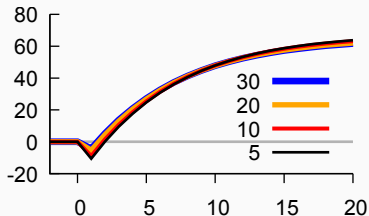
Investment



Hours

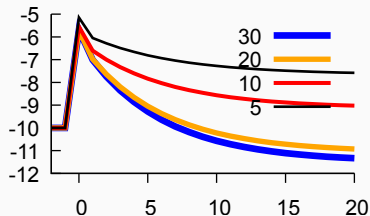


Capital

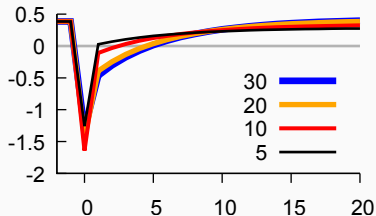


Home, Less Open: International Variables

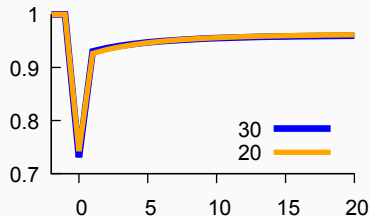
Net foreign assets



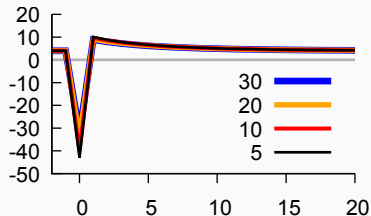
Trade balance



Exchange rate



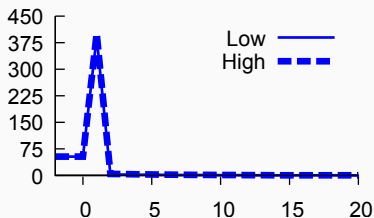
Interest rate



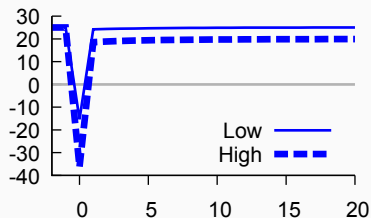
Home, Labor Supply Elasticity

Home, Labor Supply Elasticity: Fiscal Policy

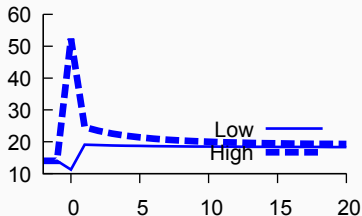
Capital income tax



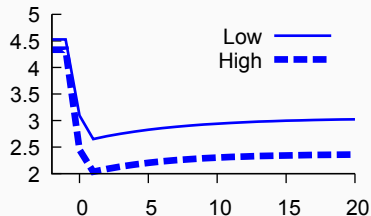
Labor income tax



Import Tax

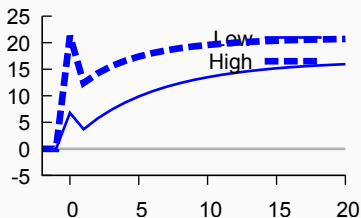


Debt-output

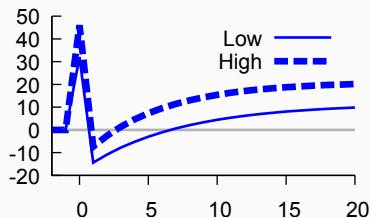


Home, Labor Supply Elasticity: Macro Variables

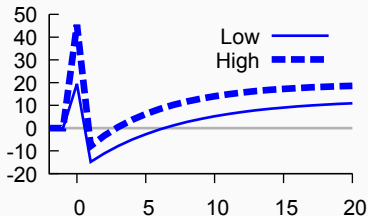
Output



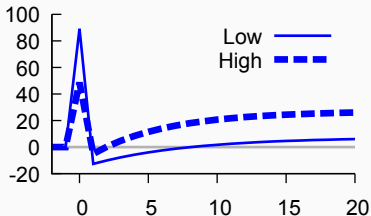
Consumption



Consumption: home

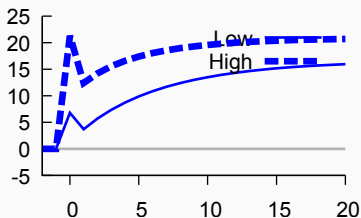


Consumption: foreign

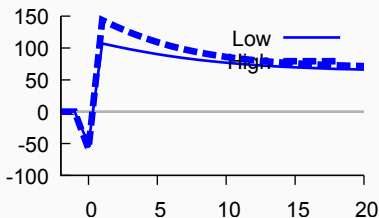


Home, Labor Supply Elasticity: Macro Variables

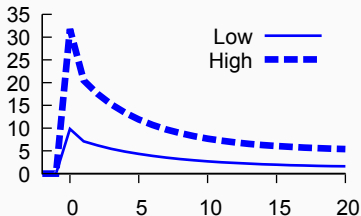
Output



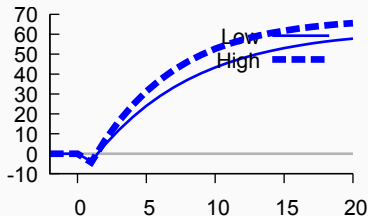
Investment



Hours

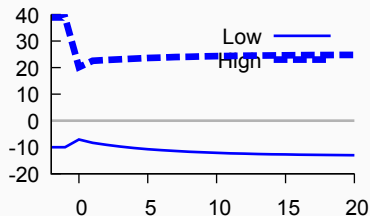


Capital

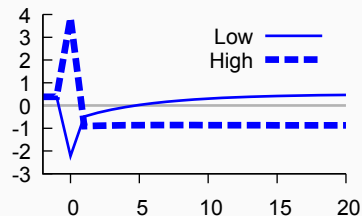


Home, Labor Supply Elasticity: International Variables

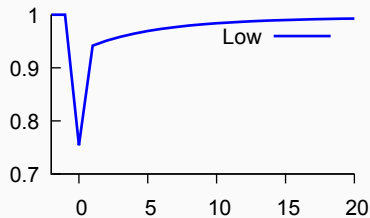
Net foreign assets



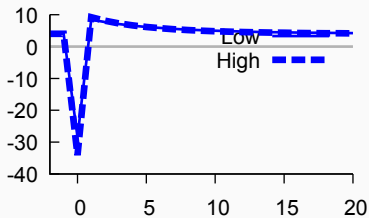
Trade balance



Exchange rate



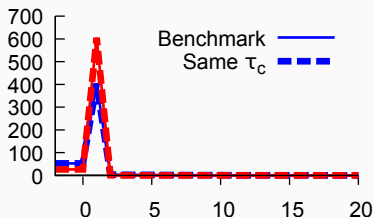
Interest rate



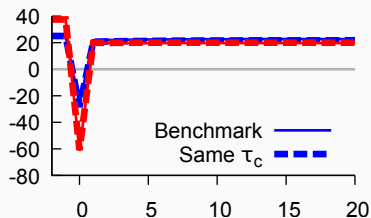
Same Consumption Tax

Same Consumption Tax: Fiscal Policy

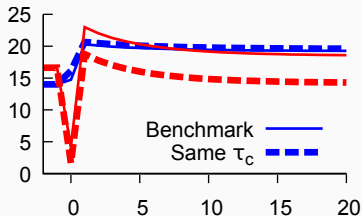
Capital income tax



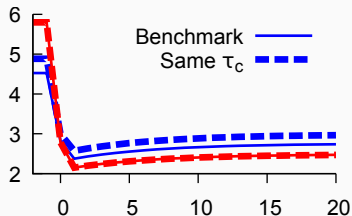
Labor income tax



Import Tax

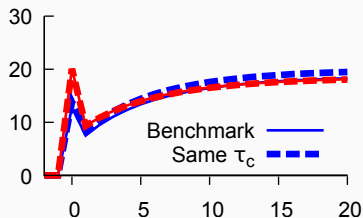


Debt-output

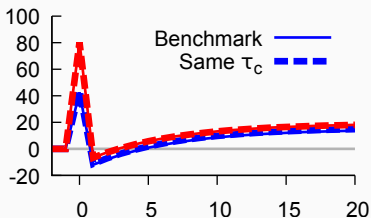


Same Consumption Tax: Macro Variables

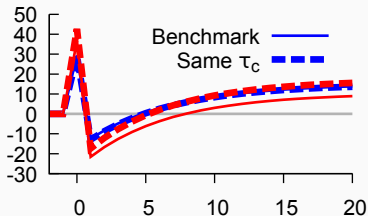
Output



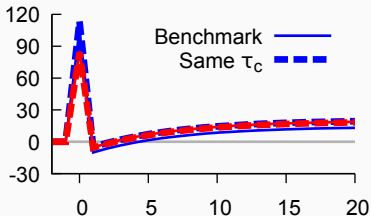
Consumption



Consumption: home

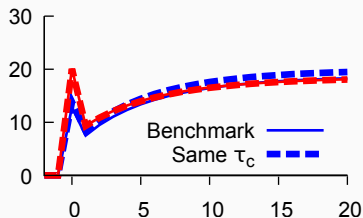


Consumption: foreign

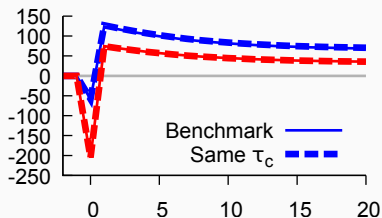


Same Consumption Tax: Macro Variables

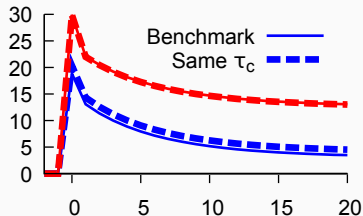
Output



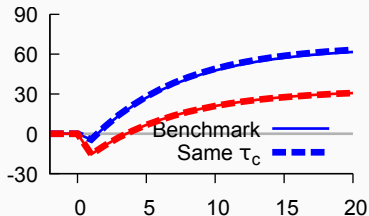
Investment



Hours

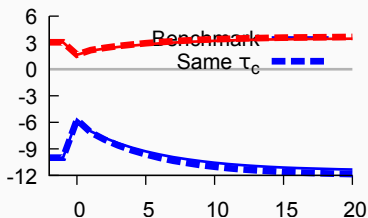


Capital

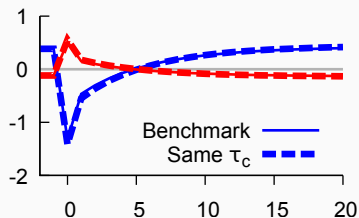


Same Consumption Tax: International Variables

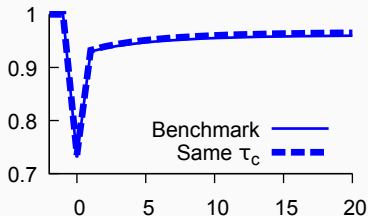
Net foreign assets



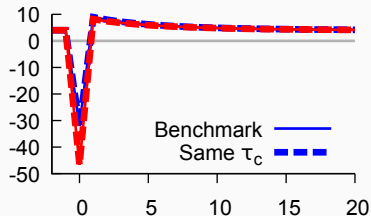
Trade balance



Exchange rate



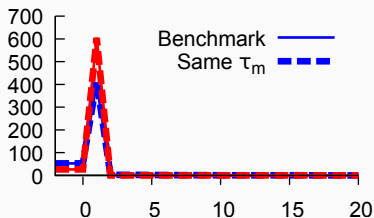
Interest rate



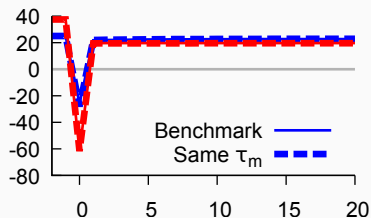
Same Initial Import Tax

Same Initial Import Tax: Fiscal Policy

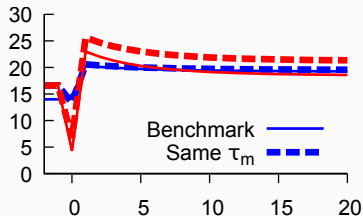
Capital income tax



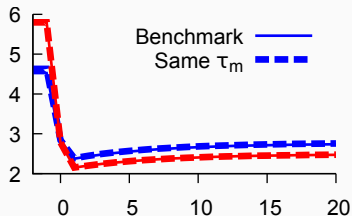
Labor income tax



Import Tax

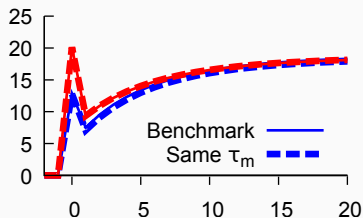


Debt-output

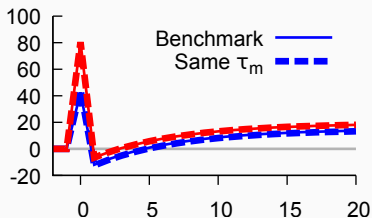


Same Initial Import Tax: Macro Variables

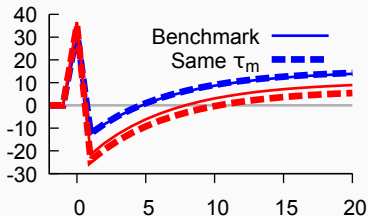
Output



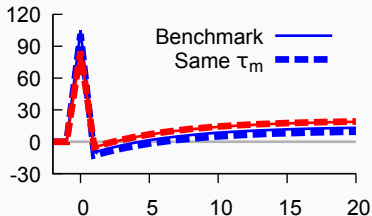
Consumption



Consumption: home

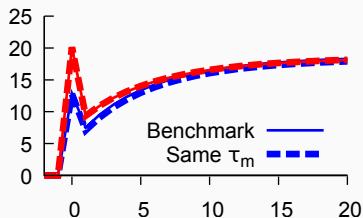


Consumption: foreign

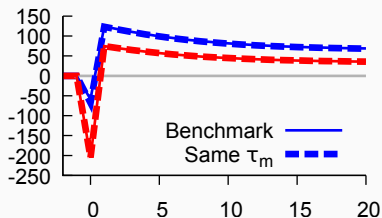


Same Initial Import Tax: Macro Variables

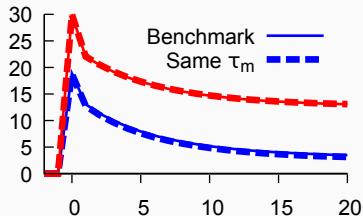
Output



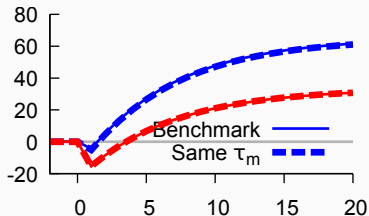
Investment



Hours

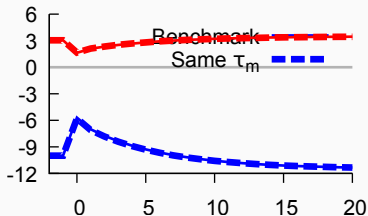


Capital

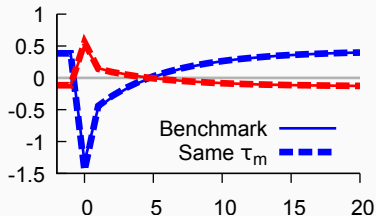


Same Initial Import Tax: International Variables

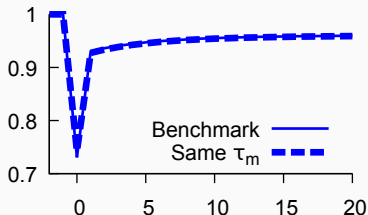
Net foreign assets



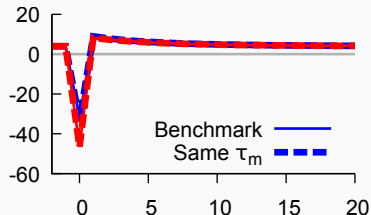
Trade balance



Exchange rate



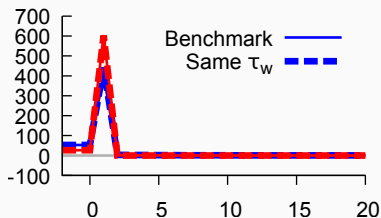
Interest rate



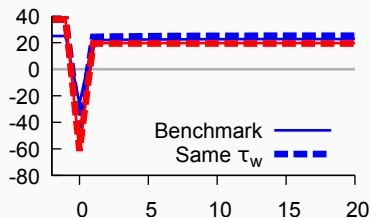
Same Initial Labor Tax

Same Initial Labor Tax: Fiscal Policy

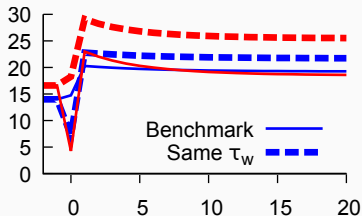
Capital income tax



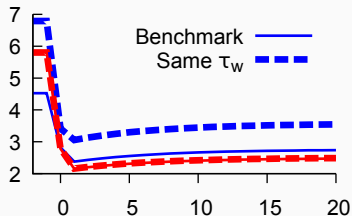
Labor income tax



Import Tax

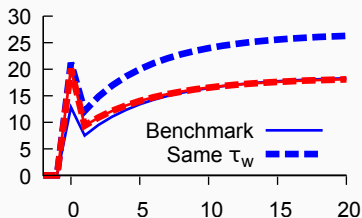


Debt-output

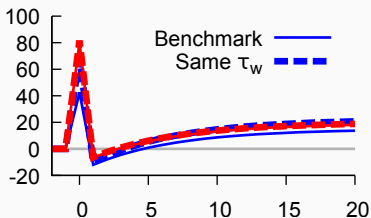


Same Initial Labor Tax: Macro Variables

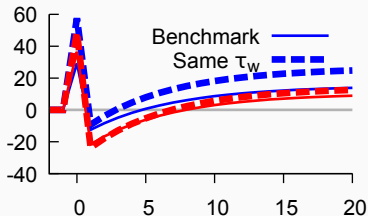
Output



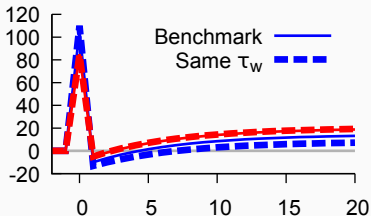
Consumption



Consumption: home

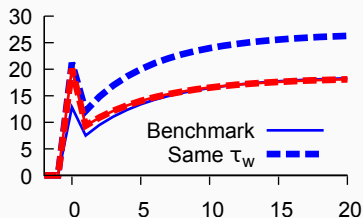


Consumption: foreign

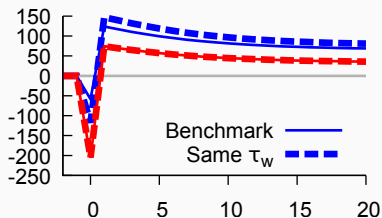


Same Initial Labor Tax: Macro Variables

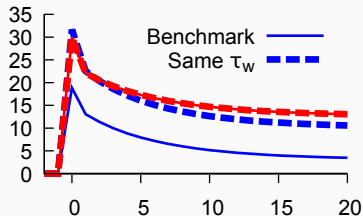
Output



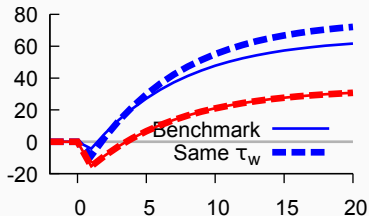
Investment



Hours

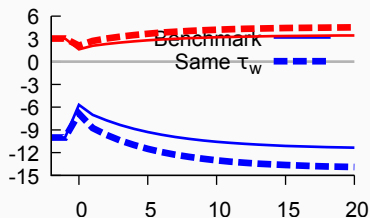


Capital

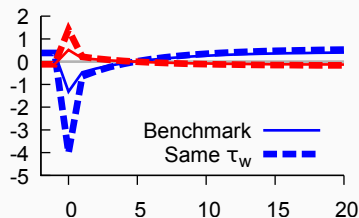


Same Initial Labor Tax: International Variables

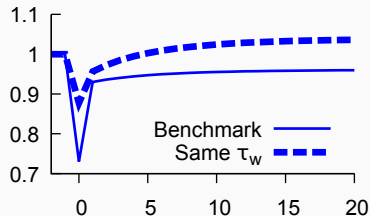
Net foreign assets



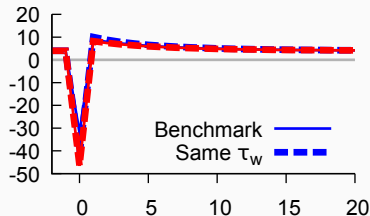
Trade balance



Exchange rate



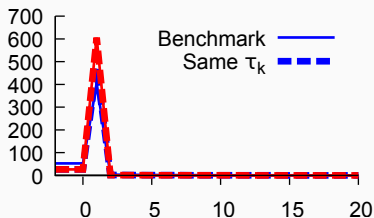
Interest rate



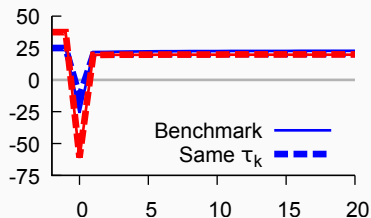
Same Initial Capital Tax

Same Initial Capital Tax: Fiscal Policy

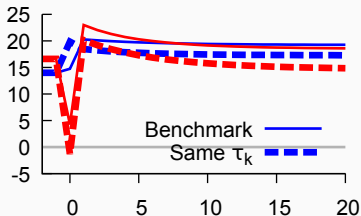
Capital income tax



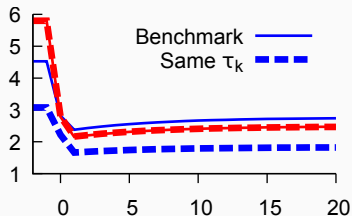
Labor income tax



Import Tax

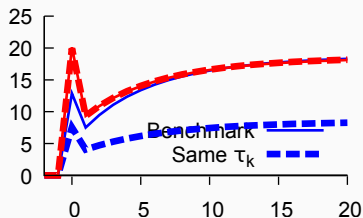


Debt-output

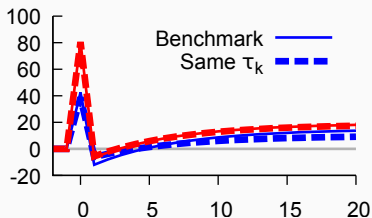


Same Initial Capital Tax: Macro Variables

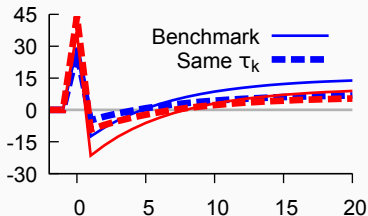
Output



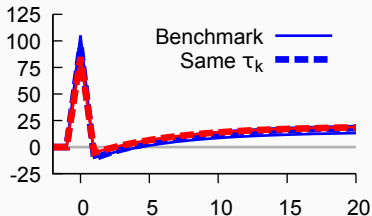
Consumption



Consumption: home

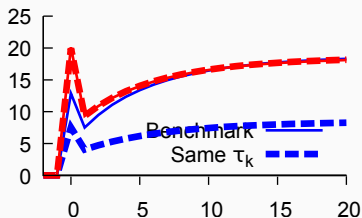


Consumption: foreign

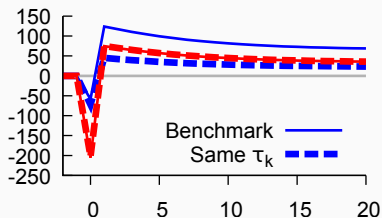


Same Initial Capital Tax: Macro Variables

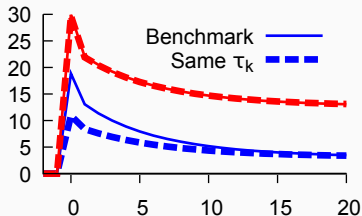
Output



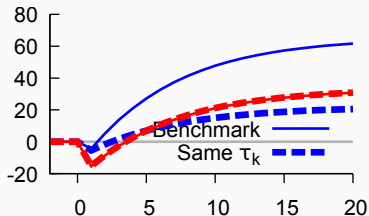
Investment



Hours

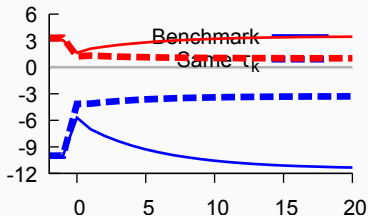


Capital

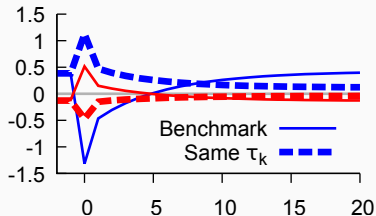


Same Initial Capital Tax: International Variables

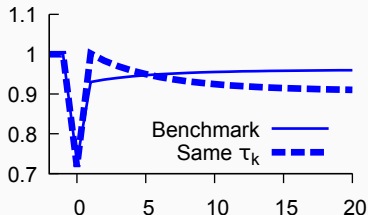
Net foreign assets



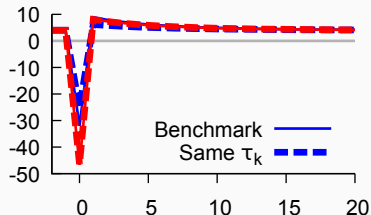
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Exchange rate



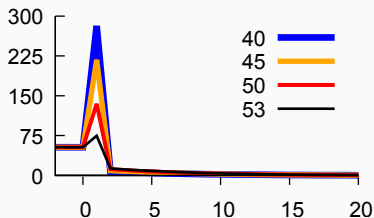
Interest rate



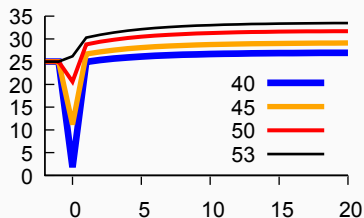
Home Net Foreign Creditor

Home Net Foreign Creditor: Fiscal Policy

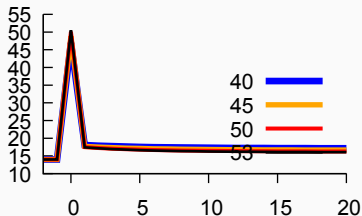
Capital income tax



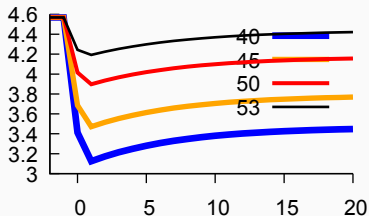
Labor income tax



Import Tax

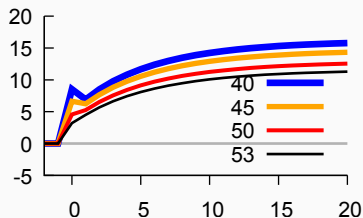


Debt-output

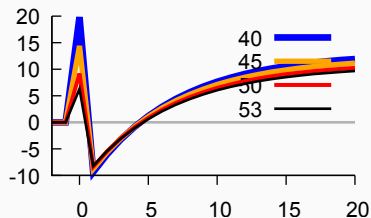


Home Net Foreign Creditor: Macro Variables

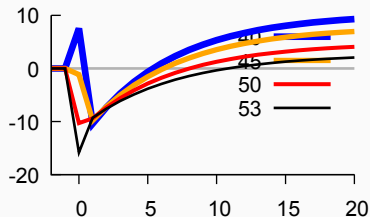
Output



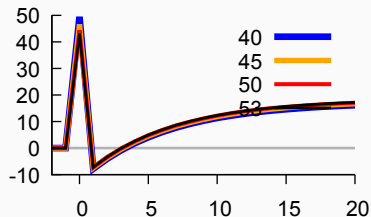
Consumption



Consumption: home

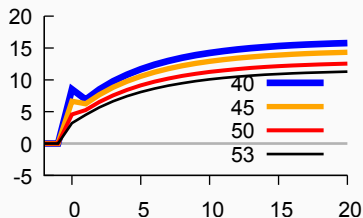


Consumption: foreign

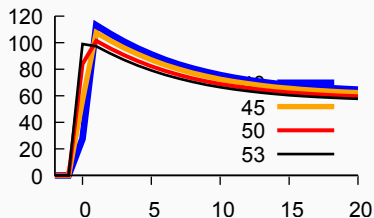


Home Net Foreign Creditor: Macro Variables

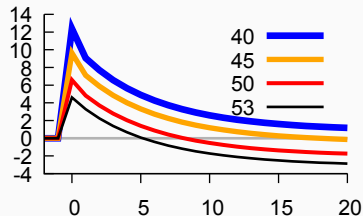
Output



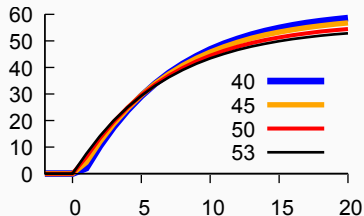
Investment



Hours

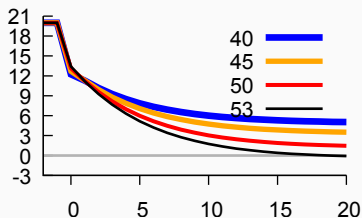


Capital

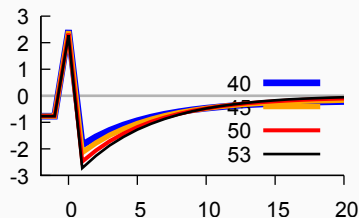


Home Net Foreign Creditor: International Variables

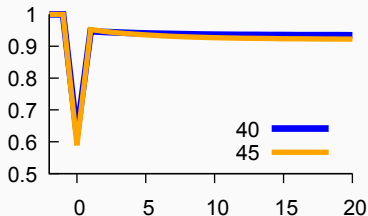
Net foreign assets



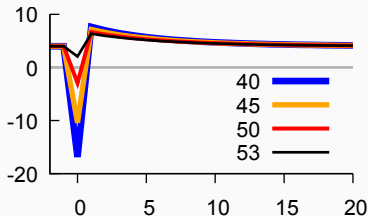
Trade balance



Exchange rate



Interest rate



Small Open Economy

Small Open Economy: Government Policy

Capital income tax

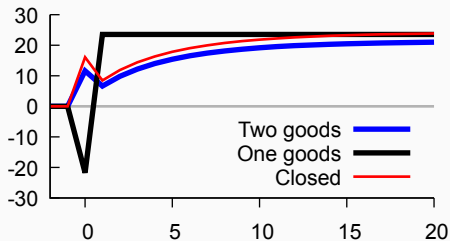


Labor income tax



Small Open Economy: Macroeconomic Effects

Output

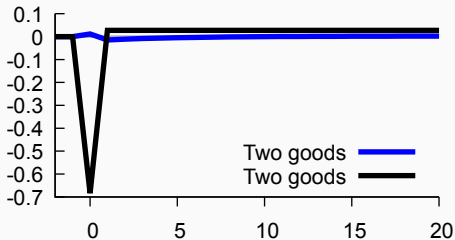


Consumption



Small Open Economy: International Effects

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Tax Cooperation	Same Population
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