Macroeconomic Theory

——From the Classical to the New Keynesian

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Contents

1 Overlapping Generations Models (OLG)

See Heer and NauBner, 2009 2nd ed., Dynamic General Equilibrium Modeling–Computatoinal Methods and Applications.

Ch.9 Deterministic Overlapping Generations Models
Ch.10 Stochastic Overlapping Generations Models

1) The OLG model vs. The Solow model: The Savings rate is given exogenously or endogenously;

2) The OLG model vs. The Ramsey model: The household is homogenous or heterogeneous.

The heterogenous household $(\overbrace{\text{Endowment Economies vs. Production Economies}}^{\text{Exchange Economies}})$
Samuelson (1958) vs. Diamond (1965)

In each period, some old generations die and a new generation is born.

$$
\begin{aligned}
C_t &= L_t c_{1t}^{\text{young}} + L_{t-1} c_{2t}^{\text{old}}, \qquad \text{note that } c_{1t}^{\text{young}} = c_{2,t+1}^{\text{old}}, \quad c_{2t}^{\text{old}} = c_{1,t-1}^{\text{young}}, \\
L_t &= (1+n)L_{t-1} \quad \Leftrightarrow \quad L_t = (1+n)^t L_0 = (1+n)^t \quad \because L_0 \equiv 1, \\
S_t &= s_t L_t. \quad \leftarrow \text{total savings of generation t}
\end{aligned}
$$

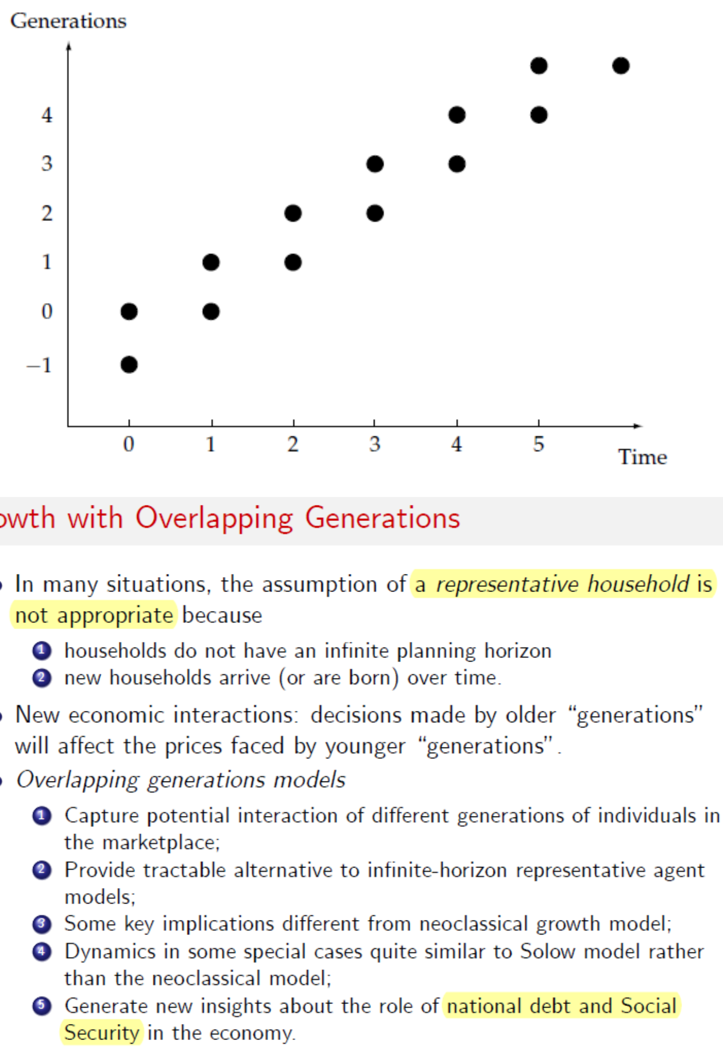


Figure 1: Overlapping generations [1]

[1] Source: Croix and Michel (20??, 4th ed.) and Acemoglu (2019).

1.1 The Baseline OLG Model

a. Households (individual born in period t solves the problem of life-time utility maximization)

$$\max_{c_{1t},c_{2,t+1},s_t} u(c_{1t})+\beta u(c_{2,t+1}),$$
$$\text{s.t.}\quad c_{1t}+s_t\le w_t,\quad \leftarrow \text{individuals only work when young and supply 1 unit of labor}$$
$$c_{2,t+1}\le R_{t+1}s_t \quad \text{where } R_{t+1}\equiv 1+r_{t+1}.$$

$$\mathcal{L}=u(c_{1t})+\beta u(c_{2,t+1})+\lambda_{1t}(w_t-c_{1t}-s_t)+\lambda_{2,t+1}(R_{t+1}s_t-c_{2,t+1}),$$
$$\frac{\mathcal{L}}{c_{1t}}=0 \Rightarrow u'(c_{1t})-\lambda_{1t}=0 \Rightarrow u'(c_{1t})=\lambda_{1t},$$
$$\frac{\mathcal{L}}{c_{2,t+1}}=0 \Rightarrow \beta u'(c_{2,t+1})-\lambda_{2,t+1}=0 \Rightarrow \beta u'(c_{2,t+1})=\lambda_{2,t+1},$$
$$\frac{\mathcal{L}}{s_t}=0 \Rightarrow -\lambda_{1t}+\lambda_{2,t+1}R_{t+1}=0 \Rightarrow \frac{\lambda_{1t}}{\lambda_{2,t+1}}=R_{t+1},$$
$$\Downarrow$$
$$u'(c_{1t})=\beta R_{t+1}u'(c_{2,t+1}).\quad \leftarrow \text{the consumption Euler equation}$$

$$u(c_{gt})=\underbrace{\frac{c_{gt}^{1-\theta}-1}{1-\theta}}_{\text{one of form}},\quad \text{for } 0<\theta\neq 1,\ g=1,2.$$
$$\Downarrow$$
$$\begin{cases} c_{1t}^{-\theta}=\beta R_{t+1}c_{2,t+1}^{-\theta}, \\ c_{1t}=w_t-s_t, \\ c_{2,t+1}=R_{t+1}s_t. \end{cases}$$
$$\Downarrow$$
$$(w_t-s_t)^{-\theta}=\beta R_{t+1}(R_{t+1}s_t)^{-\theta},$$
$$\Rightarrow \left(\frac{w_t-s_t}{s_t}\right)^{-\theta}=\beta R_{t+1}^{1-\theta},$$
$$\Rightarrow \frac{w_t}{s_t}=(\beta R_{t+1}^{1-\theta})^{-\frac{1}{\theta}}+1,$$
$$\Rightarrow s_t=\frac{w_t}{\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1>1} \Leftrightarrow s_t=s(w_t,R_{t+1}),\quad s_1>0,\ s_2\overset{?}{\lesseqgtr}0,$$

$$\Rightarrow s_t<w_t.\quad \leftarrow \text{savings are always less than earnings}$$
$$\Rightarrow s_w\equiv\frac{\partial s_t}{\partial w_t}\quad \leftarrow \text{the impact of wage on savings}$$
$$=\frac{1}{\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1},$$
$$\Rightarrow s_w\in(0,1);$$
$$\Rightarrow s_R\equiv\frac{\partial s_t}{\partial R_{t+1}}\quad \leftarrow \text{the impact of gross interest rate on savings}$$
$$=-\left(\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1\right)^{-1-1}w_t\left(-\frac{1-\theta}{\theta}\right)\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}-1}$$
$$=\frac{1-\theta}{\theta}\frac{w_t}{\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1}\frac{1}{\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1}(\beta R_{t+1})^{-\frac{1}{\theta}}$$
$$=\frac{1-\theta}{\theta}\frac{s_t}{\beta^{-\frac{1}{\theta}}R_{t+1}^{-\frac{1-\theta}{\theta}}+1}(\beta R_{t+1})^{-\frac{1}{\theta}},$$
$$\Rightarrow \begin{cases} s_R>0, & 0<\theta<1, \quad \rightarrow \text{the substitution effects wins out} \\ s_R=0, & \theta=1, \quad \rightarrow \text{the substitution and income effects cancel out} \\ s_R<0, & \theta>1. \quad \rightarrow \text{the substitution effects loses out} \end{cases}$$

① The elasticity of inter-temporal substitution

$$\max_{C_t} U_0 = u(C_t) + \beta u(C_{t+1}), \quad \text{s.t.} \quad C_t + \frac{C_{t+1}}{1+r_t} = Y_t + \frac{Y_{t+1}}{1+r_t},$$

$$\begin{aligned}
\text{F.O.C.} \quad u'(C_t) &= \beta(1+r_t)u'(C_{t+1}),\\
u'(C_t) &= \beta(1+r_t)u'[(1+r_t)(Y_t - C_t) + Y_{t+1}].\\
\log(1+r_t) &= \log U'(C_t) - \log u'(C_{t+1}),\\
\mathrm{d}\log(1+r_t) &= \frac{U''(C_t)}{U'(C_t)}\mathrm{d}C_t - \frac{U''(C_{t+1})}{U'(C_{t+1})}\mathrm{d}C_{t+1},\\
\mathrm{d}\log(1+r_t) &= \frac{C_t U''(C_t)}{U'(C_t)}\mathrm{d}\log C_t - \frac{C_{t+1}U''(C_{t+1})}{U'(C_{t+1})}\mathrm{d}\log C_{t+1},\\
\mathrm{d}\log(1+r_t) &= \frac{CU''(C)}{U'(C)}\mathrm{d}\log\left(\frac{C_t}{C_{t+1}}\right) = -\frac{CU''(C)}{U'(C)}\mathrm{d}\log\left(\frac{C_{t+1}}{C_t}\right),\\
\frac{\mathrm{d}\log\left(\frac{C_{t+1}}{C_t}\right)}{\mathrm{d}\log\left(\frac{1+r_t}{1}\right)} &= -\frac{U'(C)}{CU''(C)} = \sigma(C).
\end{aligned}$$

$$\begin{aligned}
u(C) &= \frac{C^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}, \quad \sigma > 0, \quad \frac{1}{\sigma} \equiv \theta,\\
&= \log(C), \quad \sigma = 1.\\
F(C_t, r_t) &= u'(C_t) - \beta(1+r_t)u'[(1+r_t)(Y_t - C_t) + Y_{t+1}] = 0,\\
F(C_t, r_t) &= 0 \quad \Rightarrow \quad F_{Ct}\mathrm{d}C_t + F_{rt}\mathrm{d}r_t = 0,\\
\frac{\mathrm{d}C_t}{\mathrm{d}r_t} &= -\frac{F_{rt}}{F_{Ct}} = \frac{\beta u'(C_{t+1}) + \beta(1+r_t)u''(C_{t+1})(Y_t - C_t)}{u''(C_t) + \beta(1+r_t)^2 u''(C_{t+1})},\\
\frac{\mathrm{d}C_t}{\mathrm{d}r_t} &= \frac{\beta\frac{u'(C_{t+1})}{u'(C_{t+1})/C_{t+1}} + \beta(1+r_t)\frac{u''(C_{t+1})}{u'(C_{t+1})/C_{t+1}}(Y_t - C_t)}{\frac{u''(C_t)}{u'(C_{t+1})/C_{t+1}} + \beta(1+r_t)^2\frac{u''(C_{t+1})}{u'(C_{t+1})/C_{t+1}}},\\
&= \frac{\beta C_{t+1} + \beta(1+r_t)(-\frac{1}{\sigma})(Y_t - C_t)}{\frac{C_{t+1}u''(C_{t+1})}{u'(C_{t+1})}\frac{u''(C_t)}{u''(C_{t+1})} + \beta(1+r_t)^2(-\frac{1}{\sigma})},\\
&= \frac{\beta C_{t+1} + \beta(1+r_t)(-\frac{1}{\sigma})(Y_t - C_t)}{(-\frac{1}{\sigma})\frac{u''(C_t)}{u''(C_{t+1})} + \beta(1+r_t)^2(-\frac{1}{\sigma})} = \frac{-\sigma\beta C_{t+1} + \beta(1+r_t)(Y_t - C_t)}{\frac{u''(C_t)}{u''(C_{t+1})} + \beta(1+r_t)^2},\\
&= \frac{\frac{-\sigma C_{t+1}}{1+r_t} + (Y_t - C_t)}{\frac{1}{\beta(1+r_t)}\frac{u''(C_t)}{u''(C_{t+1})} + (1+r_t)} = \frac{(Y_t - C_t) - \frac{\sigma C_{t+1}}{1+r_t}}{\frac{u'(C_{t+1})}{u'(C_t)}\frac{u''(C_t)}{u''(C_{t+1})} + (1+r_t)},\\
&= \frac{(Y_t - C_t) - \frac{\sigma C_{t+1}}{1+r_t}}{\frac{u'(C_{t+1})}{u''(C_{t+1})}/\frac{u'(C_t)}{u''(C_t)} + (1+r_t)} = \frac{(Y_t - C_t) - \frac{\sigma C_{t+1}}{1+r_t}}{\frac{C_{t+1}}{C_t} + (1+r_t)}.
\end{aligned}$$

② The substitution, income, and wealth effects

$$\frac{\mathrm{d}C_t}{\mathrm{d}r_t} = \frac{(Y_t - C_t) - \frac{\sigma C_{t+1}}{1+r_t}}{\frac{C_{t+1}}{C_t} + (1+r_t)}.$$

Obviously, when $Y_t < C_t$ (Borrower), a rise in r_t has a negative effect on current consumption; However, if $Y_t > C_t$ (Saver), a rise in r_t has an ambiguous effect on current consumption. Recall that we have $C_t + \frac{C_{t+1}}{1+r_t} = Y_t + \frac{Y_{t+1}}{1+r_t}$.

$$\begin{aligned}
u(C_t) &= \log C_t \quad \Rightarrow \quad \frac{1}{C_t} = \beta(1+r_t)\frac{1}{C_{t+1}} \quad \Rightarrow \quad C_{t+1} = \beta(1+r_t)C_t,\\
C_t &= \frac{1}{1+\beta}\left(Y_t + \frac{Y_{t+1}}{1+r_t}\right) \quad \Rightarrow \quad \frac{\partial C_t}{\partial r_t} = -\frac{Y_{t+1}}{1+\beta}(1+r_t)^{-2};\\
u(C_t) &= \frac{C_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} \quad \Rightarrow \quad C_t^{-\frac{1}{\sigma}} = \beta(1+r_t)C_{t+1}^{-\frac{1}{\sigma}} \quad \Rightarrow \quad C_{t+1} = \beta^\sigma(1+r_t)^\sigma C_t,\\
C_t &= \frac{1}{1+\beta^\sigma(1+r_t)^{\sigma-1}}\left(Y_t + \frac{Y_{t+1}}{1+r_t}\right).
\end{aligned}$$

This consumption function reflects three distinct ways in which a change in the interest rate affects the household:

1) Substitution effect. A rise in r_t is a rise in the price of C_t in terms of C_{t+1}. $\rightarrow C_t \downarrow, S_t \uparrow$. When $\sigma > 1$ this effect dominates because consumers are relatively willing to substitute consumption between periods;

2) Income effect. A rise in r_t also allows higher C_{t+1} given $Y_t + \frac{Y_{t+1}}{1+r_t}$. This expansion of the feasible consumption set is a positive income effect that leads people $\rightarrow C_t \uparrow$ and $S_t \downarrow$. When $\sigma < 1$ this effect wins out.

When $\sigma = 1$ and $Y_{t+1} = 0$, the previous two effects would exactly cancel out.

3) Wealth effect. The above two effects refer to the fraction of lifetime income devoted to present consumption. The wealth effect, however, comes from the change in lifetime income caused by an interest rate change and reinforces the interest rate's substitution effect.

I refer the reader to Obstfeld and Rogoff (1996, ch.1, pp.28-31).

b. Firms

$$\max_{K_t, L_t} \Pi_t = Y_t - w_t L_t - R_t K_t,$$

$$Y_t = F(K_t, L_t), \quad \text{note that generation t-1 don't work when old in period t}$$

$$\Downarrow$$

$$\pi_t \equiv \frac{\Pi_t}{L_t}, \quad y_t \equiv \frac{Y_t}{L_t}, \quad k_t \equiv \frac{K_t}{L_t}, \quad \frac{K_{t+1}}{L_t} = \frac{K_{t+1}}{L_{t+1}}\frac{L_{t+1}}{L_t} = (1+n)k_{t+1}, \quad s_t \equiv \frac{S_t}{L_t}$$

$$\Downarrow$$

$$\max_{k_t} \pi_t = y_t - w_t - R_t k_t,$$

$$\text{s.t.} \quad y_t = f(k_t) \underbrace{= k_t^\alpha}_{\text{one of form}},$$

$$\Rightarrow \begin{cases} R_t = f'(k_t), \\ w_t = f(k_t) - k_t f'(k_t). \quad \leftarrow \text{Euler's theorem} \end{cases}.$$

c. Equilibrium

$$K_{t+1} - \cancel{(1-\delta)K_t} = I_t = S_t = s_t L_t = s(w_t, R_{t+1})L_t, \quad \text{with } \delta = 1,$$

$$\Rightarrow \quad k_{t+1} = \frac{s(w_t, R_{t+1})}{1+n} = \frac{w_t}{\left(1 + \beta^{-\frac{1}{\theta}} R_{t+1}^{-\frac{1-\theta}{\theta}}\right)(1+n)} = \frac{f(k_t) - k_t f'(k_t)}{\left[1 + \beta^{-\frac{1}{\theta}} f'(k_{t+1})^{-\frac{1-\theta}{\theta}}\right](1+n)},$$

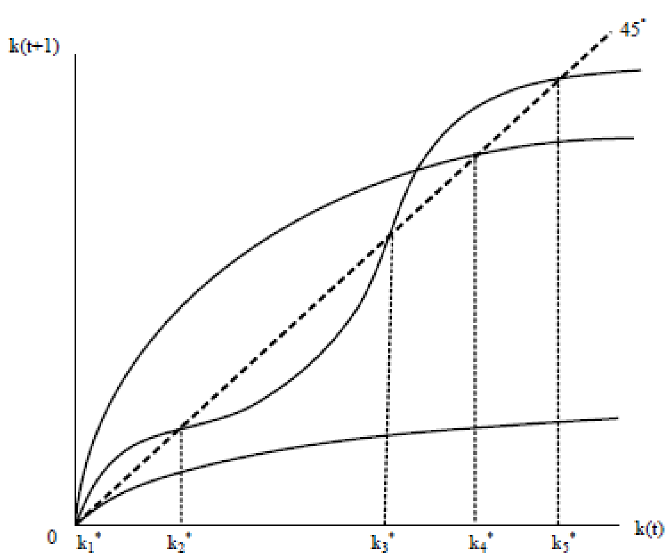
$$\underbrace{\begin{cases} \begin{cases} L_t = L \\ \frac{S_t}{L} \equiv s_t = s y_t \equiv s\frac{Y_t}{L} \end{cases} \\ k_{t+1} = (1-\delta)k_t + s f(k_t) \end{cases}}_{\text{the Solow model}} \quad \Rightarrow \quad \underbrace{\begin{cases} L_t = (1+n)L_{t-1} \\ k_{t+1} = \frac{s(f(k_t) - k_t f'(k_t), f'(k_{t+1}))}{1+n} \end{cases}}_{\text{the OLG model}} \quad \underbrace{\begin{cases} \begin{cases} L_t = L \\ \frac{K_{t+1}}{L} \equiv k_{t+1} = i_t \equiv \frac{I_t}{L} \end{cases} \\ \begin{cases} k_{t+1} = f(k_t) + c_t \\ \frac{u'(c_t)}{u'(c_{t+1})} = \beta f'(k_{t+1}) \end{cases} \end{cases}}_{\text{The Ramsey model}},$$

$$\Rightarrow \quad k^* = \frac{s(f(k^*) - k^* f'(k^*), f'(k^*))}{1+n}, \quad \xleftarrow{k_{t+1}=k_t=k^*} \text{a steady state}$$

$$= \frac{f(k^*) - k^* f'(k^*)}{\left[1 + \beta^{-\frac{1}{\theta}} f'(k^*)^{-\frac{1-\theta}{\theta}}\right](1+n)}, \quad \xleftarrow{\text{the CRRA utility function}} \text{a steady state}$$

$$= \frac{(1-\alpha)(k^*)^\alpha}{\left\{1 + \beta^{-\frac{1}{\theta}} [\alpha(k^*)^{\alpha-1}]^{-\frac{1-\theta}{\theta}}\right\}(1+n)}. \quad \xleftarrow{\text{the C-D production function}} \text{a steady state}$$

$$\Rightarrow \quad k^* = \text{a unique solution.}$$



Possible patterns [2]

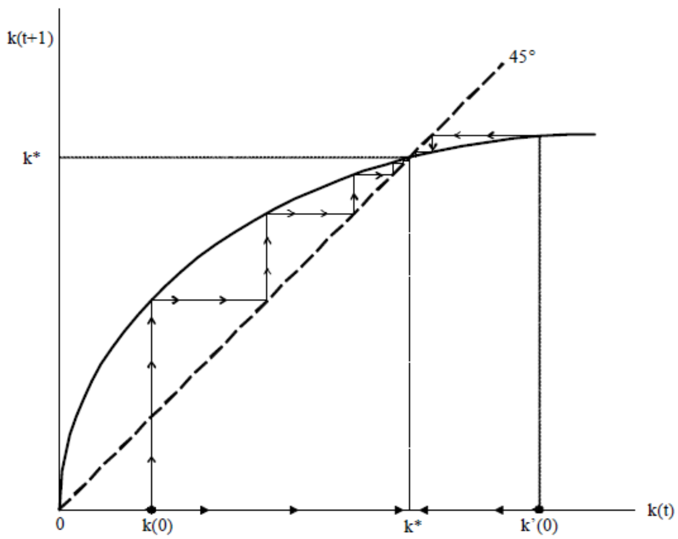
[2]Source: Acemoglu (2019, Lecture Notes for Economic Growth)

$\boldsymbol{\theta = 1}$ (use log preferences)

Income and substitution effects exactly cancel each other: changes in the interest rate (and thus in the capital-labor ratio of the economy) have no effect on the saving rate.

Structure of the equilibrium is essentially identical to the basic Solow model (cf. Acemoglu, 2019).

$$\begin{aligned}
& \log c_{1t} + \beta \log c_{2,t+1}, \quad \beta \in (0,1], \\
\Rightarrow \quad & \frac{c_{2,t+1}}{c_{1t}} = \beta R_{t+1}, \\
\Rightarrow \quad & s_t = \frac{w_t}{\beta^{-\frac{1}{\theta}} R_{t+1}^{-\frac{1-\theta}{\theta}} + 1}, \\
& \quad = \frac{w_t}{\beta^{-1} + 1}, \quad \leftarrow \theta = 1 \\
& \quad = \underbrace{\frac{\beta}{1+\beta}}_{s\text{: constant saving rate}} w_t.
\end{aligned}$$



Log preferences [3]

$$\begin{aligned}
k_{t+1} &= \frac{s_t}{1+n}, \\
&= \frac{\beta w_t}{(1+\beta)(1+n)}, \\
&= \frac{\beta(1-\alpha)k_t^{\alpha}}{(1+\beta)(1+n)}, \\
\Rightarrow \quad k^* &= \left[\frac{\beta(1-\alpha)}{(1+\beta)(1+n)}\right]^{\frac{1}{1-\alpha}}.
\end{aligned}$$

[3]Source: Acemoglu (2019, Lecture Notes for Economic Growth)

1.2 The Social Planner's Problem

$$\begin{aligned} \max \quad & \sum_{t=0}^{\infty} \beta_s^t L_t[u(c_{1t}) + \beta u(c_{2,t+1})], \\ \text{s.t.} \quad & \underbrace{L_t c_{1t} + L_{t-1} c_{2t}}_{C_t} + \underbrace{K_{t+1}}_{I_t} = \underbrace{F(K_t, L_t)}_{Y_t}. \end{aligned}$$

$$\Downarrow$$

$$\begin{aligned} & c_{1t} + \frac{L_{t-1} c_{2t}}{L_t} + \frac{K_{t+1}}{L_{t+1}} \frac{L_{t+1}}{L_t} = \frac{F(K_t, L_t)}{L_t}, \\ \Rightarrow \quad & c_{1t} + \frac{c_{2t}}{1+n} + (1+n)k_{t+1} = f(k_t), \end{aligned}$$

$$\Updownarrow$$

$$\begin{aligned} \max \quad & \sum_{t=0}^{\infty} \beta_s^t [u(c_{1t}) + \beta u(c_{2,t+1})], \\ \text{s.t.} \quad & c_{1t} + \frac{c_{2t}}{1+n} + (1+n)k_{t+1} = f(k_t). \end{aligned}$$

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta_s^t \{u(c_{1t}) + \beta u(c_{2,t+1}) + \lambda_t [f(k_t) - c_{1t} - \frac{c_{2t}}{1+n} - (1+n)k_{t+1}]\}$$

$$\begin{aligned} \frac{\partial \mathcal{L}}{\partial c_{1t}} = 0 \quad & \Rightarrow \quad \beta_s^t (u'(c_{1t}) - \lambda_t) = 0 & \Rightarrow \quad & u'(c_{1t}) = \lambda_t, \\ \frac{\partial \mathcal{L}}{\partial c_{2t}} = 0 \quad & \Rightarrow \quad \beta_s^{t-1} \beta u'(c_{2t}) - \beta_s^t \lambda_t \frac{1}{1+n} = 0 & \Rightarrow \quad & \beta u'(c_{2t}) = \beta_s \lambda_t \frac{1}{1+n}, \\ \frac{\partial \mathcal{L}}{\partial c_{2,t+1}} = 0 \quad & \Rightarrow \quad \beta_s^t \beta u'(c_{2,t+1}) - \beta_s^{t+1} \lambda_{t+1} \frac{1}{1+n} = 0 & \Rightarrow \quad & \beta u'(c_{2,t+1}) = \beta_s \lambda_{t+1} \frac{1}{1+n}, \\ \frac{\partial \mathcal{L}}{\partial k_{t+1}} = 0 \quad & \Rightarrow \quad -\beta_s^t \lambda_t (1+n) + \beta_s^{t+1} \lambda_{t+1} f'(k_{t+1}) = 0 & \Rightarrow \quad & f'(k_{t+1}) = \frac{\lambda_t}{\lambda_{t+1}} \frac{1+n}{\beta_s}. \end{aligned}$$

$$\Downarrow$$

$$\begin{cases} \frac{u'(c_{1t})}{\beta u'(c_{2t})} = \frac{1}{\beta_s \frac{1}{1+n}}; \\ \frac{u'(c_{1t})}{\beta u'(c_{2,t+1})} = \frac{\lambda_t}{\beta_s \lambda_{t+1} \frac{1}{1+n}} = f'(k_{t+1}). \end{cases}$$

$$\Downarrow$$

$$\begin{cases} u'(c_{1t}) = \frac{\beta}{\beta_s}(1+n)u'(c_{2t}); \\ u'(c_{1t}) = \beta f'(k_{t+1}) u'(c_{2,t+1}) \quad \xLeftrightarrow{R_{t+1} = f'(k_{t+1})} \quad u'(c_{1t}) = \beta R_{t+1} u'(c_{2,t+1}). \end{cases}$$

Acemoglu (2019, Lecture Notes for Economic Growth):

Not surprising: allocate consumption of a given individual in exactly the same way as the individual himself would do.

No "market failures" in the over-time allocation of consumption at given prices.

1.3 Dynamic Inefficiency

In steady state

$$c^* \equiv c_1^* + \frac{c_2^*}{1+n} = f(k^*) - (1+n)k^*.$$

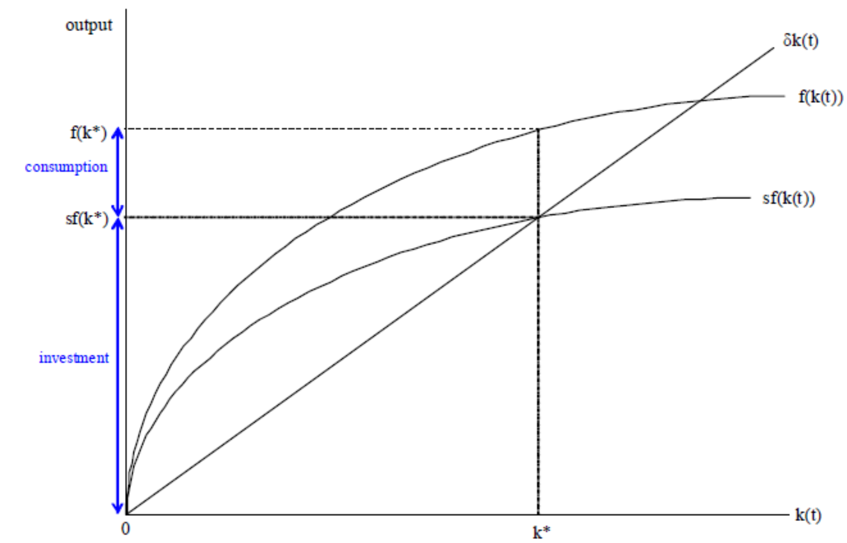
$$\begin{cases} \frac{\partial c^*}{\partial k^*} = f'(k^*) - (1+n) = 0 \quad \Rightarrow \quad f'(k^*) = f'(k_{\text{gold}}) \equiv 1+n, \\ \frac{\partial c^*}{\partial k^*} = f'(k^*) - (1+n) < 0 \quad \Leftarrow \quad f'(k^*) = \alpha (k^*)^{\alpha-1} = \alpha \left\{ \left[\frac{\beta(1-\alpha)}{(1+\beta)(1+n)} \right]^{\frac{1}{1-\alpha}} \right\}^{\alpha-1} = \frac{\alpha}{1-\alpha} \frac{1+\beta}{\beta}(1+n) < 1+n \quad \Rightarrow \quad k^* > k_{\text{gold}}. \end{cases}$$

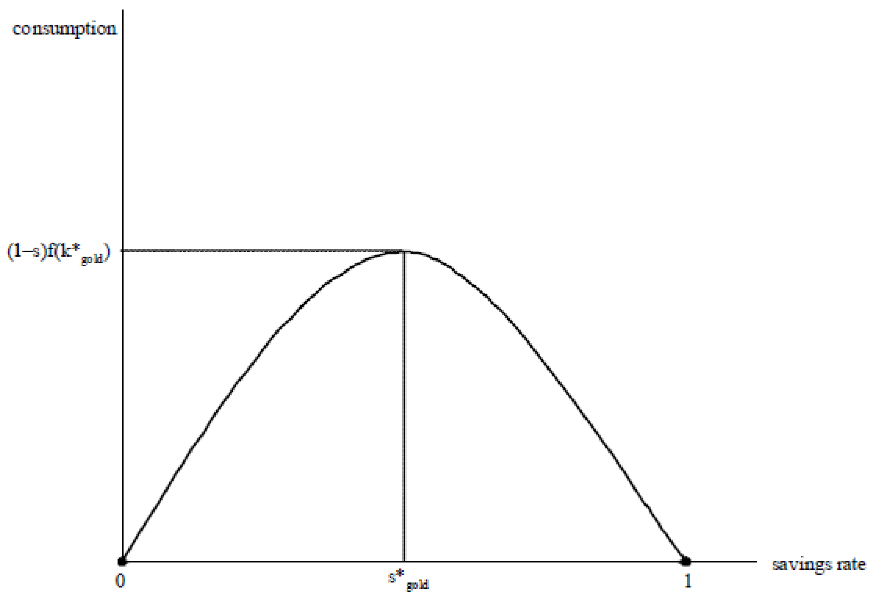
Pareto Suboptimal/Dynamically Inefficient:

if $k^* > k_{\text{gold}}$, then $\frac{\partial c^*}{\partial k^*} < 0$ (reducing savings can increase total consumption for everybody).

With dynamic inefficiency, discouraging savings may lead to a Pareto improvement.

[4]Source: Acemoglu (2019, Lecture Notes for Economic Growth)





c^* & s^*_{gold} [4]