EE312 Chapter 9
A Real Intertemporal Model with Investment

Panit Wattanakoon
Faculty of Economics, Thammasat University

1 Introduction

- In the previous two chapters, we discussed about the two basic settings.
  - Model 1 (Chapter 7): Static consumption-leisure equilibrium: static production economy (endogenous production, but not dynamic)
  - Model 2 (Chapter 8): Intertemporal consumption-saving model: Intertemporal pure endowment economy (exogenous production, but dynamic)
  - We understood how shocks affect the equilibrium allocations and prices.
- This chapter takes you another step closer to the reality by merging together the two basic models (model 1 and model 2), and then newly introduce an "investment" decision problem as an extension
  - Investment: expenditure on plants, equipment and new housing
  - Firm needs to think about how much to invest for future as the investment affects future's production capacity.
  - All these combined features give rise to a real intertemporal production economy with capital accumulation: "Real business cycle model"
- Structure of the real Intertemporal Model:

  - The model assumes two periods: current v.s. future (1st v.s. 2nd period)
  - The real model (no money) with three actors
    1. Representative consumers (consumption, labor supply and saving)
    2. Representative firms (production, labor demand and investment)
    3. Government (spending, taxes and borrowing).
  - Markets
    1. The labor market: the firm's demand and the consumer's supply of labor ⇒ The real wage rate (labor demand-labor supply)).
    2. The output market: the firm's supply and the consumer's demand for output ⇒ The real interest rate ((output demand-output supply)
    3. The credit market: the supply for funds and demand for funds ⇒ The real interest rate (saving-borrowing)

- Circular flows in current and future periods

2 Consumer's Optimal Decisions

- Work-leisure in current and future periods.
- Consumption-savings in the current period.
- Denote:

  h = total time available

  w and w' = current and future real wages

  r = the real interest rate

  T and T' = current and future lump-sum taxes

  C and C' = current and future consumptions

  L and L' = current and future leisure time

  S^p = private savings.

2.1 Budget Constraint

2.1.1 Current budget csontraint

- The consumer is a price-taker (w, w', r, T and T' are given).

- Denote

  $w(h-l)$ = real-wage income

  π = dividend income from the firm

  T = lump-sum taxes paid to the government.

- Then, disposable income is:

$$C + S^p = w(h-l) + \pi - T$$

  no longer exogenous, but endogenously related to the choice of leisure.

2.1.2 Future budget constraint

- The consumer still receives real wages, dividend income, and pays future taxes.
- Also the principal and interest on savings.
- No bequests (inheritance); all wealth is consumed.
- Future disposable income is then:

$$C' = w'(h-l') + \pi' - T' + (1+r)S^p$$

2.1.3 Lifetime budget constraint

- After some algebra, combine present and future budget constraints and obtain lifetime one:

$$C + \frac{C'}{1+r} = w(h-l) + \pi - T + \frac{1}{1+r}\Big(w'(h-l') + \pi' - T'\Big)$$

- The PV of lifetime consumption equals the PV of lifetime disposable income.
- Decision on the optimal bundles of C, C', l and l' subject to the lifetime budget constraint.

2.2 Consumer's Optimal Choices

- Household chooses the optimal (C, l) and (C', l') that maximize the utility function

$$U(C, l, C', l') = u(C, l) + u(C', l')$$

subject to the lifetime budget constraint given by

$$C + \frac{C'}{1+r} = w(h-l) + \pi - T + \frac{1}{1+r}\Big(w'(h-l') + \pi' - T'\Big)$$

- Household uses up all the resources (budget) with the following three optimality trade-off conditions satisfied:
  - Two (within-period) consumption-leisure trade-off
  - One intertemporal consumption-saving trade-off
  - One intertemporal current/future leisure trade-off

2.2.1 Current period (intratemporal) optimal condition

- The consumer chooses the optimal bundle of current leisure and consumption such that

$$\frac{u_l(C, l)}{u_C(C, l)} = MRS_{l,C} = w$$

The marginal rate of substitution of current leisure for current consumption is equal to the real wage.

w is the relative price of leisure in terms of consumption goods.

- It can also be rewritten as

Intuition

Cost: Taking less leisure 1 unit $\Rightarrow$ utility drops by

Benefit: More wage earned by "w", and hence an increase in consumption by "w" units.$\Rightarrow$ utility increases by

2.2.2 Future period (intratemporal) optimal condition

- The consumer chooses the optimal bundle of future leisure and future consumption:

$$\frac{u_{l'}(C', l')}{u_{C'}(C', l')} = MRS_{l',C'} = w'$$

The marginal rate of substitution of future leisure for future consumption is equal to the future real wage.

w' is the relative price of future leisure in terms of future consumption goods.

2.2.3 Intertemporal consumption-saving condition

- The consumer chooses the optimal bundle of current and future consumption (savings)

$$\frac{u_C(C, l)}{u_{C'}(C', l')} = MRS_{C,C'} = (1 + r)$$

The marginal rate of substitution of current consumption for future consumption is equal to the real interest rate.

$(1 + r)$ is the relative price of current consumption in terms of future consumption

- It can also be rewritten as

Intuition

Cost: Taking less consumption 1 unit $\Rightarrow$ utility drops by

Benefit: More earning by $(1 + r)$ for future consumption $\Rightarrow$ utility increases by

2.2.4 Intertemporal leisure trade-off condition

- The consumer chooses the optimal bundle of current and future leisure:

$$\frac{u_l(C, l)}{u_{l'}(C', l')} = MRS_{l,l'} = \frac{w(1 + r)}{w'}$$

The marginal rate of substitution of current leisure for future leisure is equal to the real $\frac{w(1+r)}{w'}$.

$\frac{w(1+r)}{w'}$ is the relative price of current leisure in terms of future leisure

- It can also be rewritten as $u_l(C,l) = \frac{w(1+r)}{w'} \cdot u_{l'}(C',l')$

  Intuition

  Current Cost: Taking less leisure 1 unit ⇒ utility drops by $u_l(C,l)$

  Current Benefit: More earning by "w"; let's not use it up for now!

  Benefits realized in the future:

  Option 1: More earning by $w \cdot (1+r)$ for future consumption ⇒ utility increases by $w(1+r)u_{C'}(C',l')$

  Option 2: Let's not use for more future consumption, but instead for future leisure ⇒ utility increases by $w(1+r) \cdot \frac{u_{l'}(C',l')}{w'}$, which is equivalent to what we have above (from intratemporal condition)

2.3 Current Labor Supply

2.3.1 Current labor supply curve

- The consumer provides labor supply to the firm through intra/intertemporal consumption-leisure decisions.
- Factors which determine current labor supply:
  - The current real wage
  - The real interest rate
  - Lifetime wealth
- Current labor supply increases with the real wage, given r

An upward sloping curve in "w", assuming the stronger substitution effect.

2.3.2 Effect of An increase in the real interest rate on Labor Supply Curve

- Current labor supply increases as the real interest rate increases
- $\frac{w(1+r)}{w'}$ is the relative price of current leisure in terms of future leisure.
- Given w and w', a higher r means the higher price of current leisure in terms of future leisure.
- Less current leisure, and more current supply of labor, assuming the dominant substitution effect.
- Labor supply increases with r

Given w, labor supply increases with the rising real interest rate ($r_2 > r_1$), assuming the stronger substitution effect.

2.3.3 Effect of an increase in lifetime wealth on labor supply curve

- Current leisure increases and current labor supply decreases with rising lifetime wealth.
- Current and future consumption also increase.

$$C + \frac{C'}{1+r} = w(h-l) + \pi - T + \frac{1}{1+r}\Big(w'(h-l') + \pi' - T'\Big)$$

2.4 Demand for current consumption goods

2.4.1 Derivation of demand for current consumption

- Consumption-leisure decision results in demand for current consumption goods.
- The individual demand for current consumption goods (C^d) is a function of current income (Y), given r.
- Current income $Y = w(h - l) + \pi - T$
- Due to the consumption smoothing motive, the marginal propensity to consume (MPC) < 1.

$$C^d = f(Y, r, we)$$
$$MPC = \frac{\partial C^d}{\partial Y} < 1$$

2.4.2 Effect of an increase in interest rate on demand for current consumption

- A higher real interest rate (r) causes the current consumption demand to fall, assuming the substitution effect dominates the income effect and others remaining the same.

$$C^d = f(Y, r, we)$$
$$\frac{\partial C^d}{\partial r} < 0$$

Given higher real interest rate ($r_2 > r_1$), the consumer reduces current consumption, (assuming stronger substitution effect and a lender.)

2.4.3 Effect of an increase in lifetime wealth on demand for current consumption

- The life-time wealth is given by

$$we = w(h - l) + \pi - T + \frac{w'(h - l') + \pi' - T'}{1 + r}$$

- Higher life-time wealth allows households to have more current consumption and leisure at the same time, assuming that both current consumption and leisure are normal goods.

$$C^d = f(Y, r, we)$$
$$\frac{\partial C^d}{\partial we} > 0$$

With $we_2 > we_1$, an increase in lifetime wealth raises current consumption.

3 The Representative firm

- In this model, firm operates for two periods, using their own production technology (function): Current v.s. future production function
- It aims at maximizing firm's value (V) as given by the present value of lifetime firm's profit, i.e. $\pi + \frac{\pi'}{1+r}$

3.1 Production Technology

- Current production function:

$$Y = zF(K, N)$$

Denote:

Y = current output

z = current total factor productivity

K = current capital stock

N = current labor input.

- The future production function:

$$Y' = z'F(K', N')$$

3.2 Change in Capital Stock

- Future capital stock is current capital stock net of depreciation plus investment.

$$K' = (1 - d)K + I$$

d = the rate of depreciation;

I = current investment.

- Why firm invest?
  - The firm's investment is foregone current profits (consumption) for future profits; increase future capacity
  - Overall firm's value can increase given optimal investment plan

3.3 The Firm's Problem

3.3.1 The firm's current and future profits

- Given the production technology owned, firm chooses for (i) optimal labor (N, N') in each period and (ii) optimal investment (I) so as to maximize the life-time profits.

$$\begin{aligned} V &= \pi + \frac{\pi'}{1+r} \\ \text{where } \pi &= Y - wN - I \\ \pi' &= Y' - w'N' + (1-d)K' \end{aligned}$$

- The leftover capital stock in the future period can be sold off as junk value. Denote:

  $(1-d)K'$ = capital stock remaining as junk at the end of the future period.

3.3.2 Firm's optimal choices

$$\begin{aligned} \max_{N,N',I} V &= \pi + \frac{\pi}{1+r} \\ &= zF(K,N) - wN - I + \frac{z'F(K',N') - w'N' + (1-d)K'}{1+r} \end{aligned}$$

subject to $K' = (1-d)K + I$

First order conditions:

- {N}: $zF_N(K,N) = w$
- {N'}: $z'F_{N'}(K',N') = w'$
- {I}: $1 = \frac{z'F_{K'}(K',N')+(1-d)}{1+r}$

3.3.3 Current labor demand curve

$$\{N\} : zF_N(K,N) = w$$

- The firm hires current labor until the current marginal product of labor equals the current real wage ($MP = zF(K, N) = w$)
- Thus the firm's MP_N curve is also the firm's current labor demand curve: An increase in current z or K raises MP_N and current labor demand.

The current labor demand: $MP_N = w$.

MP_N is falling as the labor input increases.

An increase in current z or K shifts the current labor demand curve to the right.

3.4 The firm's investment decision

$$\{I\} : 1 = \frac{z' F_{K'}(K', N') + (1 - d)}{1 + r}$$

- The firm invests to the point where the marginal cost equals marginal benefit from investment.

- $MC(I)$ = marginal cost of investment = PV of profits (V) given up for one unit of capital.

  One unit of investment reduces current π (and V) by one unit:

  $$MC(I) = 1$$

- $MB(I)$ = marginal benefit of investment = additional units of V (PV of profits) received from one extra unit of current investment.

  Benefit 1: $z'F(K', N') = MP'_K$ = additional output from one extra unit of K'.

  Benefit 2: Quantity of capital left from depreciation at the end of the future period $(1 - d)$ for liquidation.

  Additional future profits = $z'F(K', N') + (1 - d)$

  PV of additional benefits = $\frac{z'F(K',N')+(1-d)}{1+r}$

  $1 = \frac{z'F_{K'}(K',N')+(1-d)}{1+r} \Leftrightarrow MP'_K - d = r$

- The firm chooses for the optimal scale of physical investment where return on physical investment equals to return on financial investment, i.e. opportunity cost of project funding

  r = the opportunity cost of more capital = the rate of return on the alternative asset (bonds) otherwise earned by the consumer who owns the firm.

3.4.1 Optimal investment decision

- With lower "r", firm chooses for higher amount of future physical stock (K'), and hence the optimal scale of investment (I^d)

  $$MP'_K - d = r$$

- Investment demand is downward sloping in "r", given other factors

3.4.2 Changes in z' and K

- Factors affecting future marginal product of capital shift the optimal investment curve.
- Higher future total factor productivity (z') increases future MP'_K and current optimal investment.

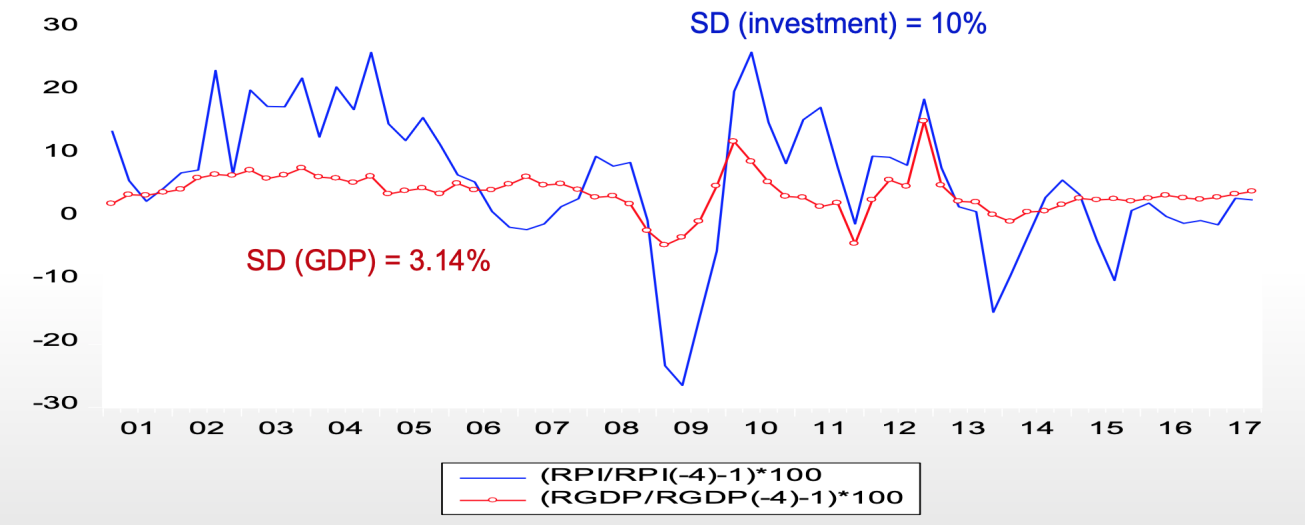
  - The optimal investment curve shifts to the right.

- Higher current capital stock results in larger future net capital stock and lower MP'_K.

  - The optimal investment curve shifts to the left.

3.5 Volatile investment and GDP

- Aggregate consumption is less variable than income due to consumption smoothing.
- Investment is much more volatile: short-run economic fluctuations.
  - Investment responds to perceived marginal rates of return to investment.
  - Changes in the real interest rate cause movements along the investment curve.
  - Changes in future total factor productivity shift the investment curve.



4 Government Sector

- Government purchases of consumption goods (G and G') are exogenously determined.
- Government financing: Current lump-sum taxes and bond sale and Future lump-sum taxes and payments of the principal and interest.

$$G + \frac{G'}{1+r} = T + \frac{T'}{1+r}$$

5 Competitive Equilibrium

- Interaction of the three economics agents; household, firm and government with three markets: labor, goods, and credit markets
- A **competitive equilibrium** is an allocation of C, C', S^p, l, l', N, N', I, Y, Y', B and prices r, w, and w' given the exogenous variables z, z', K, G, G', T, and T' that satisfy:
  - Household optimization choices on current and future consumption, saving, and current and future leisure.
  - Firm optimization choices on current and future labor employment, and investment
  - Government budget constraints
  - Markets: Labor, Credit, and Goods
- Three markets (in detail):
  1. The labor market
     - The consumer supplies labor service.
     - The firm demands labor service.
     - The "real wage" and the level of employment are determined
  2. The goods market:
     - The consumer, the firm and government purchase output.
     - The firm supplies the goods.
     - The "real interest rate" and the level of aggregate output are determined
  3. The credit market
     - Demand for credit (borrowing)
     - Supply for credit (saving)
     - The amount of credit loan, total saving, and interest rate are determined.

     Note: with the Walras's law, we can abstract the analysis of credit market equilibrium. If the other two markets were already in the equilibrium, the equilibrium in credit market would be reached.

5.1 Equilibrium in the Labor Market

- Optimizing labor supply (N^s) is sloped upwards with dominant substitution effect, given r.
- Optimizing labor demand (N^d) is MP_N for the firm.

N^*= equilibrium employment.

5.2 Equilibrium in goods market

- We characterize equilibrium in goods market using AD-AS diagram.
- Our AD-AS diagram is derived from the optimizing behaviors.
- Diagrammatically, aggregate supply is upward sloping in "r" while aggregate demand is downward sloping in "r".
- Different from the conventional AD-AS diagram

5.3 Output Supply

- Aggregate output supplied: With N^* input, Y^* is the quantity of aggregate output supplied, given z and K.

5.3.1 Output supply and interest rate

- The relationship between the real interest rate and the level of aggregate output is that:

  An increase in the real interest rate causes a reduction in current consumption and leisure.

  - The labor market: current labor supply increases.

  - The production function: current aggregate output increases.

- The output supply curve is sloped upwards.

- Output supply curve (Aggregate Supply)
  - The higher r causes more labor supply, employment and output.
  - The labor market is in equilibrium at each level of r.

5.3.2 Output supply shifts

- Changes in exogenous variables shift the output supply curve.
  - Lifetime wealth (labor supply shift);
  - Current total factor productivity or current capital stock (labor demand and production function shifts).
- Changes in the real interest rate move along the output supply curve.

Changes in lifetime wealth

- A decrease in lifetime wealth reduces leisure (income effect) and increases labor supply, given the real wage.
  - An increase in current or future government spending reduce lifetime wealth.
  - The government PV budget constraint implies increases in the PV of taxes.

$$G + \frac{G'}{1+r} = T + \frac{T'}{1+r}$$

- The labor market:
  - The labor supply curve shifts to the right.
  - The real wage falls while employment increases.
- The production function:
  - More labor input increases production.
  - Output increases, given r.
- The output supply curve shifts to the right.

Output supply increases, given r, when lifetime wealth decreases and labor supply increases

Changes in z or current K

- An increase in total factor productivity or current capital stock.
  - The production function shifts up.
  - Marginal product of labor (MP_N) increases.
  - The labor demand curve shifts to the right.
  - Employment increases with the real wage.
  - Output increases, given the real interest rate.
- The output supply curve shifts to the right.

Higher z or K raises labour demand and the real wage.

Rising employment and output supply, given r.

5.4 Output Demand

- Total current expenditure for goods (Y) equals the sum of:
  - The consumer's expenditure for current consumption goods (C^d);
  - The firm's expenditure for investment goods (I^d);
  - The government purchases of current goods (G).
- C^d and I^d are negatively related to the real interest rate.

$$Y^d = AE = C^d(r, I) + I^d(r) + G$$

- For a given r, Y^d is upward sloping in Y (income/output)
  - Consumption expenditure increases in Y
  - I and G are not related to Y^d
  - The slope of Y is equal to MPC.
- Equilibrium: Y^d = Income(output)

5.4.1 Output demand and real interest rate

- An increase in the real interest rate causes a reduction in demand for current output.
  - Shifts towards future consumption: falling demand for current consumption goods.
  - Lower optimal investment: higher opportunity cost of capital.

- The output demand curve is sloped downwards

5.4.2 Rightward shifts in output demand curve

- An increase in current government purchases (G)

- A decrease in the PV of taxes (T or T')

- An increase in future income (Y')

- A decrease in current capital stock (K) or an increase in future total factor productivity (z')

- Higher future MP'_K and rising current I^d;

5.5 General equilibrium of real intertemporal model

The equilibrium is characterized by the allocation (N^*, Y^*) and prices (w^*, r^*) that clear both labor and goods market.

6 Credit Market

- The supply of credit is the consumer's private savings.
- The demand for credit is government's borrowing and the firm's investment demand.
  - Investment is made out of current profit: $\pi = Y - wN - I$
  - But the firm can also finance its investment by borrowing in the credit market.

o The real interest rate is the cost of capital.

o The firm borrows by the amount of I^d in the current period and pays back $I^d(1+r)$ in the future period.

7 Shock Experiments

- Exogenous shocks in the model
  - A shock in the model occurs when one of exogenous variable changes, causing endogenous variables to change accordingly.
  - The macro effect depends on whether it is temporary or permanent.
  - An expected shock in the future has effects in the current period.
- We will cover 4 different shocks:
  - Current government purchases increase temporarily (G)
  - Current capital stock decreases due to a natural disaster or war (K)
  - A temporary increase in current total factor productivity (z)
  - An increase in future total factor productivity (z')

7.1 A temporary increase in G

Assume an increase in G with G' unchanged.

7.1.1 Keynesian analysis (EE212)

- A higher G causes the demand for goods to increase.
  - Output and income increases.
  - Part of the increase in income is spent on consumption goods $\Rightarrow$ more demand for output.
  - Direct and indirect increases in the demand for output: the multiplier effect.

- The Keynesian Y^d multiplier

$$\begin{aligned}\Delta Y^d &= \Delta G \\ \Delta C &= \text{MPC} \cdot \Delta Y^d \text{ where } 0 < \text{MPC} < 1 \\ \Delta Y^d &= \Delta G + \text{MPC} \cdot \Delta Y^d \\ \Delta Y^d &= \frac{1}{1 - \text{MPC}} \Delta G\end{aligned}$$

- The larger is MPC, the larger the Y^d multiplier, and the more powerful ΔG
- The Keynesian Y^d multiplier > 1
  - Assume constant MPC.
  - ΔG =DF
  - $\Delta Y = \Delta Y^d$ = AB = DB.
  - But DB>DF
  - $\frac{\Delta Y}{\Delta G} > 1$
- Keynesian assumptions
  - The increase in G has no negative effect on lifetime wealth and consumption spending.

    But PV of taxes must rise and lifetime wealth falls.
  - Total income or output (Y) increases by the same amount as the demand for goods (Y^d).
  - The effect on the real interest rate is none
  - Increases in C and Y come as a free lunch
- Consider the case when PV of taxes rises: Demand multiplier = 1
  - The increase in government spending ΔG.
  - The multiplier effect = MPC$\cdot\Delta G$.
  - Lifetime wealth drops = PV of taxes = ΔG; so current consumption falls by MPCΔG.

$$\begin{aligned}\Delta Y^d &= \Delta G + \text{MPC} \cdot \Delta G - \text{MPC} \cdot \Delta G \\ \Delta Y^d &= \Delta G\end{aligned}$$

7.1.2 Intertemporal model analysis

Step 1: Direct effect of ΔG

- Effect on Y^s
  - The PV of taxes rises; the consumer's lifetime wealth falls.
  - Leisure decreases and labor supply increases, given w.
  - The output supply curve shifts rightwards.

- Effect on Y^d
  - Government's demand for output (G) increases.
  - Falling lifetime wealth reduces the consumer's demand for current consumption goods (C^d).
  - Current demand for goods increases by the amount of $\Delta Y^d = \Delta G \Rightarrow$ the Y multiplier $= 1$
  - Y shifts rightwards by the amount of ΔG

Both Y^d and Y^s shift to the right; what happens to the real interest rate?

- The real interest rate increases as Y^d shifts more than Y^s .
  - ΔG is temporary and has a small negative effect on lifetime wealth.
  - A small decrease in leisure, and small increases in labor supply and output supply (small Y^s shift).
  - A small decrease in current consumption while the increase in G remains large (larger Y^d shift).

Step 2: Effect of rising r

- A higher r reduces leisure, current consumption and investment.
- Leisure falls and labor supply increases again.
  - The real wage falls further; employment and output increase, a movement along the Y^s (BC).
- Investment decreases due to the higher real interest rate (DC).
- Current consumption falls (DC):
  - Falling lifetime wealth reduces current consumption while higher income raises it: small net effect.
  - The higher r also reduces it: stronger SE.

Credit Market

- Assume the government finances the spending increase by bond sale in the credit market ($\Delta G = \Delta B$).
- Private savings increase:
  - Larger current income (Y) and lower current consumption raise private savings.
  - $\Delta S^p = \Delta Y - \Delta T - \Delta C$ where $\Delta T = 0$ and $\Delta C < 0$
  - The increase in bond sale raises the real interest rate.

The government increases current borrowing (B).

Savings increase from higher r (AC) and larger Y (CD).

The real interest rate increases.

Overall effect of an increase in a temporary government spending

- The total output multiplier is less than 1
  - $\Delta Y = \Delta G = \text{AD} > Y_1Y_2$
  - So $\frac{\Delta Y}{\Delta G} < 1$: Income increases less than the increase in government spending.
  - Although income increases, both current consumption and investment decrease from the higher real interest rate (the crowding-out effect).
  - Employment increases but the real wage drops.
  - Private savings increase to pay for higher future taxes.

- The crowding-out effect on private spendings.
  - A temporary increase in G crowds out both current consumption and investment by raising the real interest rate.
  - The consumer works more for a lower real wage and consumes less.
  - Lower investment means lower future capital stock and future productive capacity.
- Higher government spending and larger output come at a cost – NO free lunch

7.2 A decrease in current capital stock

Reduction in current capital stock (K) due to a natural disaster, war, etc.

7.2.1 Step 1: Direct Effect

Effect on Y^s

- A smaller K with the same N, current MP_N drops.
- The firm reduces its demand for labor. The labor demand curve shifts left (given w).
- The output supply curve (Y^s) shifts left.

Step 1 A lower K reduces MP_N

Step 1 Lower N^d: Y^s shifts left.

Effect on Y^d

- A smaller current K means a smaller future K'.
- Future MP'_K rises; investment increases, given r.
- The optimal investment curve (I^d) shifts right.
- The output demand curve (Y^d) shifts right.

Step 1 Higher MP'_K and rising I^d

Step 1 A rising I^d shifts Y^d right.

7.2.2 Step 2: Rising r

- The higher real interest rate reduces leisure (increases labor supply), current consumption and investment.
- Leisure decreases and labor supply increases.
  - The labor supply curve shifts to the right.
  - The real wage drops further
  - A movement on the Y^s curve.
- Investment increases to make up for the decline in the capital stock:
  - The higher real interest rate depresses investment, but higher MP'_K (due to a fall in current K) raises it.
  - However, investment must rise, because less capital would otherwise cause ever-decreasing investment.

7.2.3 Credit market

- C drops less than Y ($\Delta Y > \Delta C$).
- Consumption smoothing; S^p decreases.
- I^d increases.
- The real interest rate increases.

7.2.4 Overall effect of a drop in K

- A decrease in current K raises the real interest rate but may increase or reduce output.
  - Current consumption and leisure decrease.
  - Investment increases.
  - The real wage decreases.
  - Employment and output may increase or decrease.
- Destruction of K tends to reduce output; but higher investment increases output.

7.3 A temporary increase in z

- Step 1: An increase in current total factor productivity (z) raises MP_N.
  - Labor demand and output supply shift right.
  - The real interest rate decreases.
- Step 2: the lower r raises current consumption, investment and leisure.
  - Labor supply decreases; the labor supply curve shifts left.
  - Employment, output and the real wage increase.

An increase in z

The credit market

- Consumption increases less than income (consumption smoothing)
- Private savings increase.
- The real interest rate decreases.

Overall effect of Δz

- An increase in the current z reduces the real interest rate but increases output.
- Employment increases.
- The real wage increases.
- This is partly offset by the increase in leisure (with lower r and higher current income).
- Investment increases (with lower r).
- Current consumption increases with lower r and larger Y.

7.4 An increase in future z'

- Step 1: Future z' is expected to rise; future MP'_K increases
  - Investment (I^d) increases; higher future income raises current consumption.
  - Output demand shifts right.
  - The real interest rate increases.
- Step 2: the higher r reduces consumption, investment and leisure.
  - The labor supply curve shifts right; the real wage drops.
  - Employment and output increase.
  - Higher current income raises consumption, but the higher real interest rate depresses it.
  - The higher investment from higher MP'_K is partially offset by the higher real interest rate.
  - Investment increases as the effect of MP'_K is stronger .

An expected increase in z'

The credit market

- Investment increases.
- C increases less than Y; private savings increase.
- The real interest rate increases.

Overall effect of $\Delta z'$

- Investment increases with higher expected MP'_K, partly offset by the higher r.
- Both real interest rate and output increase.
- Current consumption rises from higher current and future income but falls due to the higher real interest rate.

- Employment increases with falling real wage.