Business Cycles

Part 3: The Real Business Cycle Model
Lecture 5: The Real Business Cycle Model

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Outline

Part 1: Introduction

Part 2: Microeconomic Foundations

Part 3: The Real Business Cycle Model

- Lecture 5: The real business cycle model
- Lecture 6: Effects of shocks, taking the model to the data, criticism of the RBC model

Part 4: The New Keynesian Model

Part 5: Financial Crises

Learning Objective of Today‘s Lecture

1. Analysis of one of the predominant modern macroeconomics models: the Real Business Cycle model.
2. Understanding why real and nominal variables can be analysed separately: the classical dichotomy.
3. Understanding how real variables are determined.
4. Understanding how nominal variables are determined.

Literature

Required reading:

- Textbook chapter 18.

Optional reading:

- King, Robert G., Rebelo, Sergio T., 1999. Resuscitating real business cycles. In: J. B. Taylor and M. Woodford (ed.), Handbook of Macroeconomics, edition 1, volume 1, chapter 14, 927-1007.

The Real Business Cycle Model

- The optimizing model of the economy with which we have been working is called the "neoclassical model" or "real business cycle" model.
- The model features optimizing agents and frictionless markets
- It emphasizes supply shocks (changes in A_t or θ_t) as the principal drivers of fluctuations in endogenous variables.
- As written, it abstracts from money and nominal variables. In this model, the "classical dichotomy" holds, so this is okay.
- We take the model to be a relevant description of the real world in the "medium run" – frequencies of time between a couple of years and a decade.
- Over this time horizon, investment is an important component of fluctuations of output, but the capital stock can be treated as fixed. Prices and wages are assumed to be completely flexible.
- Medium-term horizon model as well as benchmark model describing the efficient allocation.
- Three actors: representative household, representative firm, government.

Household

- Consumes, saves, holds money, supplies labor
- Gets wage income $W_t N_t$, buys goods at price P_t
- Real prices are relevant for decisions of households: real wage, real price of the consumption good and the real interest rate.
- Decisions rules of the household:
  - Consumption function (implies savings supply: $S_t = Y_t - T_t - C_t$):

$$C_t = C^d\Big(\underbrace{Y_t - T_t}_{+\,(MPC<1)}, \underbrace{Y_{t+1} - T_{t+1}}_{+(MPC<1)}, \underbrace{r_t}_{-}\Big)$$

  - Labor supply function ($w_t = W_t/P_t$: real wage, θ_t: exogenous labor supply shock like changes in unemplyoment benefits, labor taxes, demographic changes, changes in preferences,…)

$$N_t = N^s(\underbrace{w_t}_{+}, \underbrace{\theta_t}_{-})$$

  - Money demand function:

$$M_t = \underbrace{P_t}_{+} M^d\left(\underbrace{i_t}_{-}, \underbrace{Y_t}_{+}\right) = P_t M^d(r_t + \pi^e_{t+1}, Y_t)$$

(Fisher equation: $r_t = i_t - \pi^e_{t+1}$)

Firm I

- Produces output using capital and labor.
- Production function with exogenous productivity shifter A_t:

$$Y_t = A_t F(K_t, N_t)$$

  - Usual properties: $F_K(.) > 0, F_N(.) > 0, F_{KK}(.) < 0, F_{NN}(.) < 0, F_{NK}(.) > 0$

- Law-of-motion of capital:

$$K_{t+1} = I_t + (1 - \delta)K_t$$

Firm II

- Labor demand

$$N_t = N^d(\underbrace{w_t}_{-}, \underbrace{A_t}_{+}, \underbrace{K_t}_{+})$$

  - Effect of wage: Firms higher labor until the marginal product of labor ($MPL = F_N(.)$) equals the real wage. If the real wage increases, reduce N_t to increase MPL.
  - Effect of technology: Increases in A_t increases MPL → need to hire more labor to reduce MPL until it equals w_t.
  - Effect of capital: Increases in K_t increases MPL → need to hire more labor to reduce MPL until it equals w_t.

Firm III

- Investment demand

$$I_t = I^d(\underbrace{r_t}_{-}, \underbrace{A_{t+1}}_{+}, \underbrace{K_t}_{-})$$

  - Important: Investment is a forward looking decision. Benefit of investment in period t: more capital in period $t+1$. Cost: less divident in t.
  - Depends negatively on r_t, opportunity cost of investment. r_t is either the direct borrowing cost of investment or the opportunity cost as alternatively a dividend can be paid out and saved through bonds by households yielding a return of r_t.
  - Increasing in A_{t+1} (not on A_t because capital increases in $t+1$): Increases productivity of capital in $t+1$.
  - Firm has an optimal target for K_{t+1} independently of the current level of K_t. If K_t decreases, need to do more investment to reach target. If K_t increases, need to do less investment to reach target.

Government

- Government consumption in periods t and $t+1$. Government consumes the same good as private households.
- Financed by issuing debt and/or collecting taxes.
- Government consumption is exogenous.
- Ricardian Equivalence:
  - Timing of taxes vs. debt does not matter. In the end government consumption needs to be paid for by taxing households. Household is forward-looking and cares only about the present value of its net income.
  - Important assumption: Taxes are lump-sum, i.e. they do not affect prices relevant to household and firm decisions (no income or capital tax rate).
  - Can act as government balances its budget each period: $G_t = T_t, G_{t+1} = T_{t+1}$. Simplifies analysis as we not need to worry about T_t, T_{t+1}, B_t, and B_{t+1}.
- Impact on household‘s consumption function

$$C_t = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t)$$

- Central bank as part of the government exogenous supplies money: M_t.

Real Equilibrium Conditions

- In equilibrium, the following conditions must hold:

$$C_t = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t)$$
$$N_t = N^s(w_t, \theta_t)$$
$$N_t = N^d(w_t, A_t, K_t)$$
$$I_t = I^d(r_t, A_{t+1}, K_t)$$
$$Y_t = A_t F(K_t, N_t)$$
$$Y_t = C_t + I_t + G_t$$

- First four are optimal decision rules of household and firm; fifth is a technological constraint (production function), and sixth is resource constraint / market-clearing condition.
- Exogenous variables: $A_t, A_{t+1}, G_t, G_{t+1}, K_t, \theta_t$.
- Endogenous: C_t, N_t, I_t, Y_t, w_t, and r_t
- Treat Y_{t+1} as "pseudo-exogenous": not affected by I_t, which impacts K_{t+1}. Medium run assumption: treat capital stock as roughly constant.

Nominal Equilibrium Decisions

- We can analyze nominal variables separately from realvariables as long as there are no nominal frictions (for example price and wage rigidities) in the economy: this is known as the classical dichotomy.
- Money demand function and market clearing on the money market:

$$M_t = P_t M^d(r_t + \pi^e_{t+1}, Y_t)$$

  - Money depends on real variables (r_t and Y_t), but also features two nominal variables (P_t and via π^e_{t+1} and the Fisher equation also i_t)

- Fisher equation relates real to nominal variables:

$$i_t = r_t + \pi^e_{t+1}$$

  - We treat inflation expectations as exogenous.

Graphical Analysis: The demand side, i.e. the IS-curve

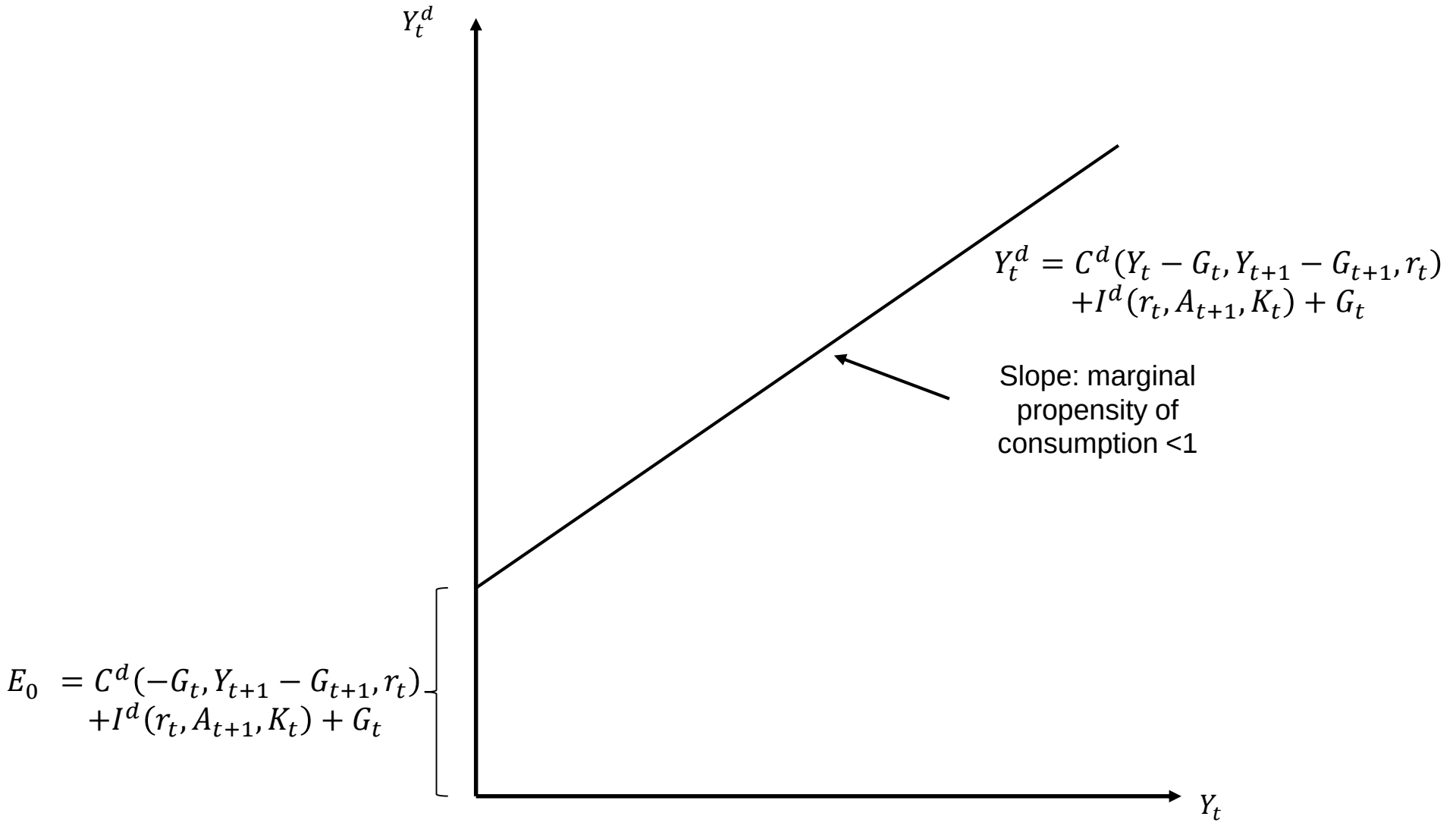
- Demand is summarized by C_t, I_t, and $Y_t = C_t + I_t + G_t$
- IS curve: set of (r_t, Y_t) pairs where household and firm behave optimally with respect to consumption and investment demand and income equals expenditure.
- Summarizes consumption function, investment demand function, and resource constraint.
- Total demand:

$$Y_t^d = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + I^d(r_t, A_{t+1}, K_t) + G_t$$

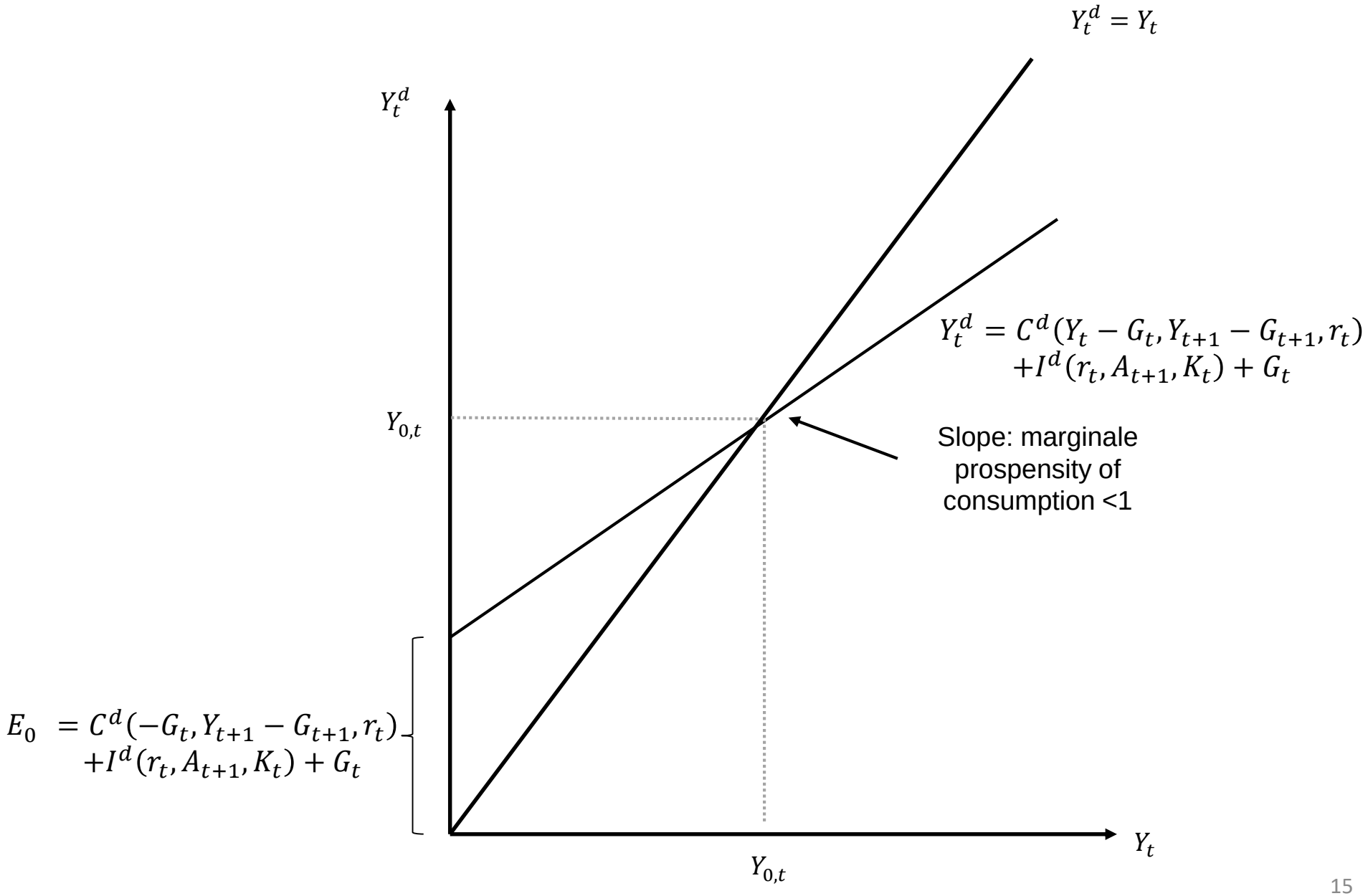
- Impose $Y_t = Y_t^d$
- Graph the set of (r_t,Y_t) pairs where this holds
- IS-curve mathematically

$$Y_t = \underbrace{C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + I^d(r_t, A_{t+1}, K_t) + G_t}_{Y_t^d}$$

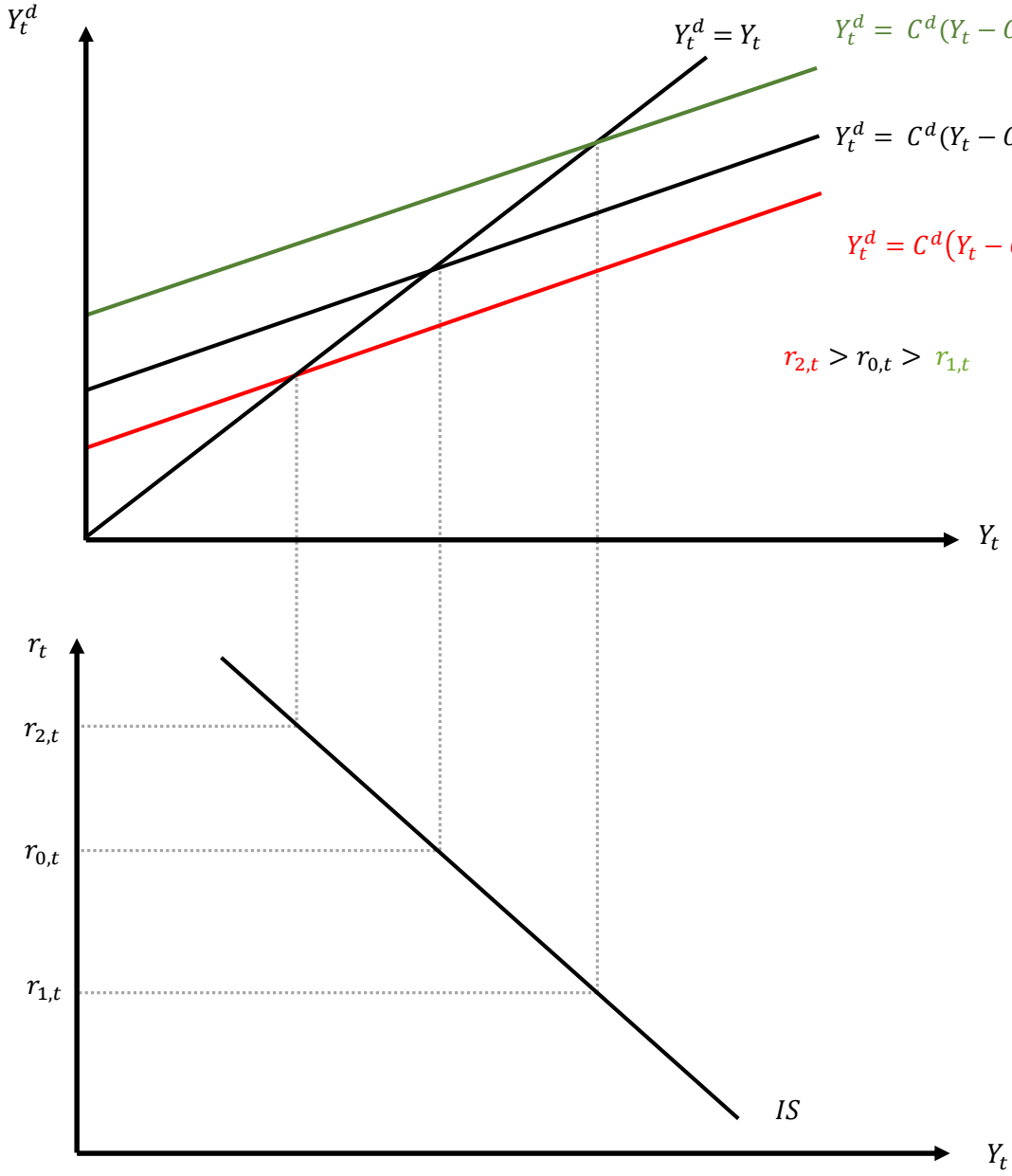
Expenditure vs. Income



Income Equals Expenditure



The IS Curve



$$Y_t^d = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_{1,t}) + I^d(r_{1,t}, A_{t+1}, K_t) + G_t$$

$$Y_t^d = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_{0,t}) + I^d(r_{0,t}, A_{t+1}, K_t) + G_t$$

$$Y_t^d = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_{2,t}) + I^d(r_{2,t}, A_{t+1}, K_t) + G_t$$

$$r_{2,t} > r_{0,t} > r_{1,t}$$

IS Curve Shifts

- $Y_t = \underbrace{C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + I^d(r_t, A_{t+1}, K_t) + G_t}_{Y_t^d}$
- The IS curve will shift if any exogenous variable relevant for desired consumption or investment changes.
- Shifts:
  - $\uparrow A_{t+1}$: IS shifts right
  - $\uparrow G_t$: IS shifts right
  - $\uparrow G_{t+1}$: IS shifts left
  - $\downarrow K_t$: IS shifts right

The supply side

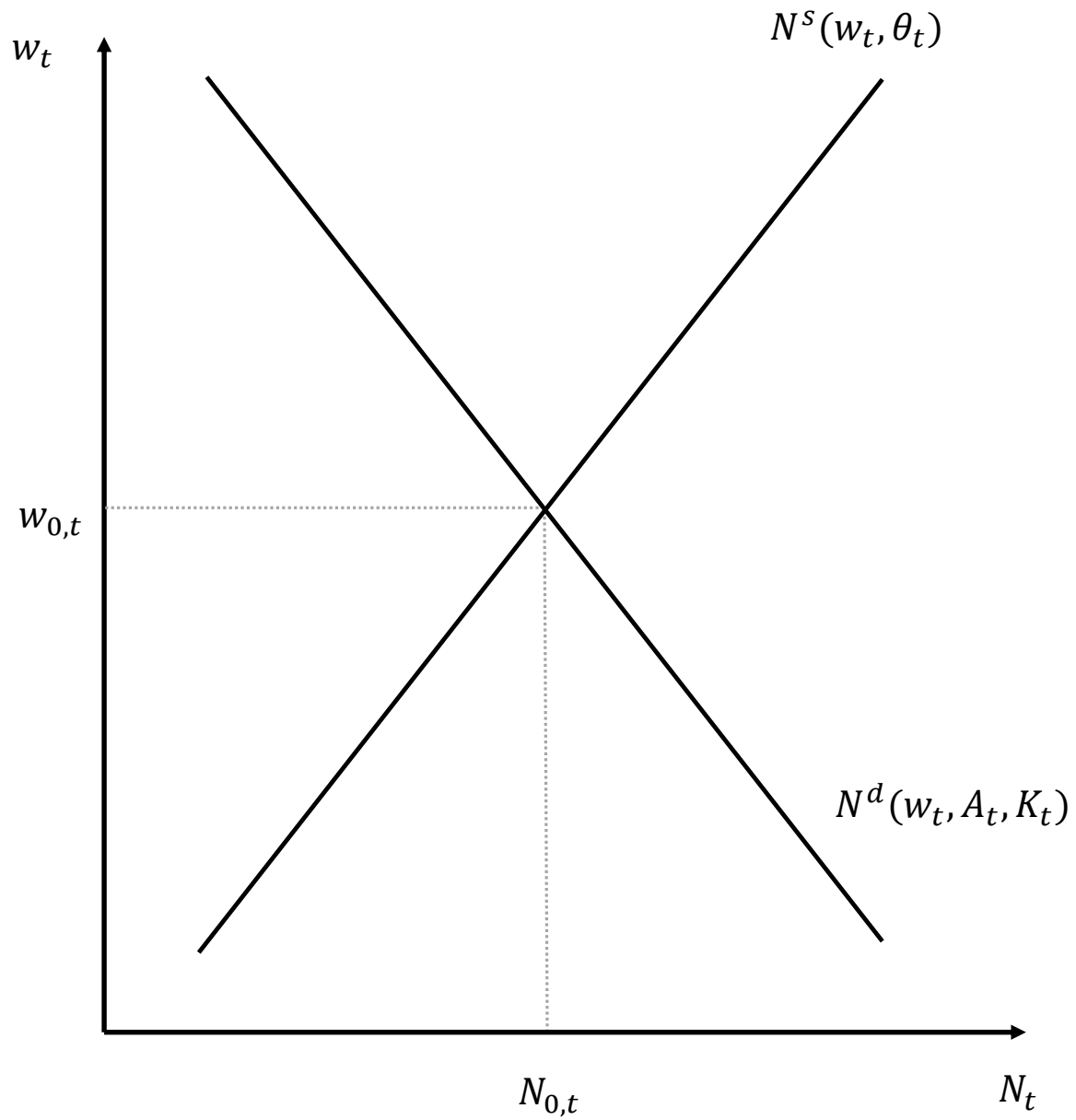
- Supply side: aggregate production function, labor supply, labor demand.
- Taking A_t, K_t and θ_t as given, labor demand and labor supply determine N_t:

$$N_t = N^s(w_t, \theta_t)$$
$$N_t = N^d(w_t, A_t, K_t)$$

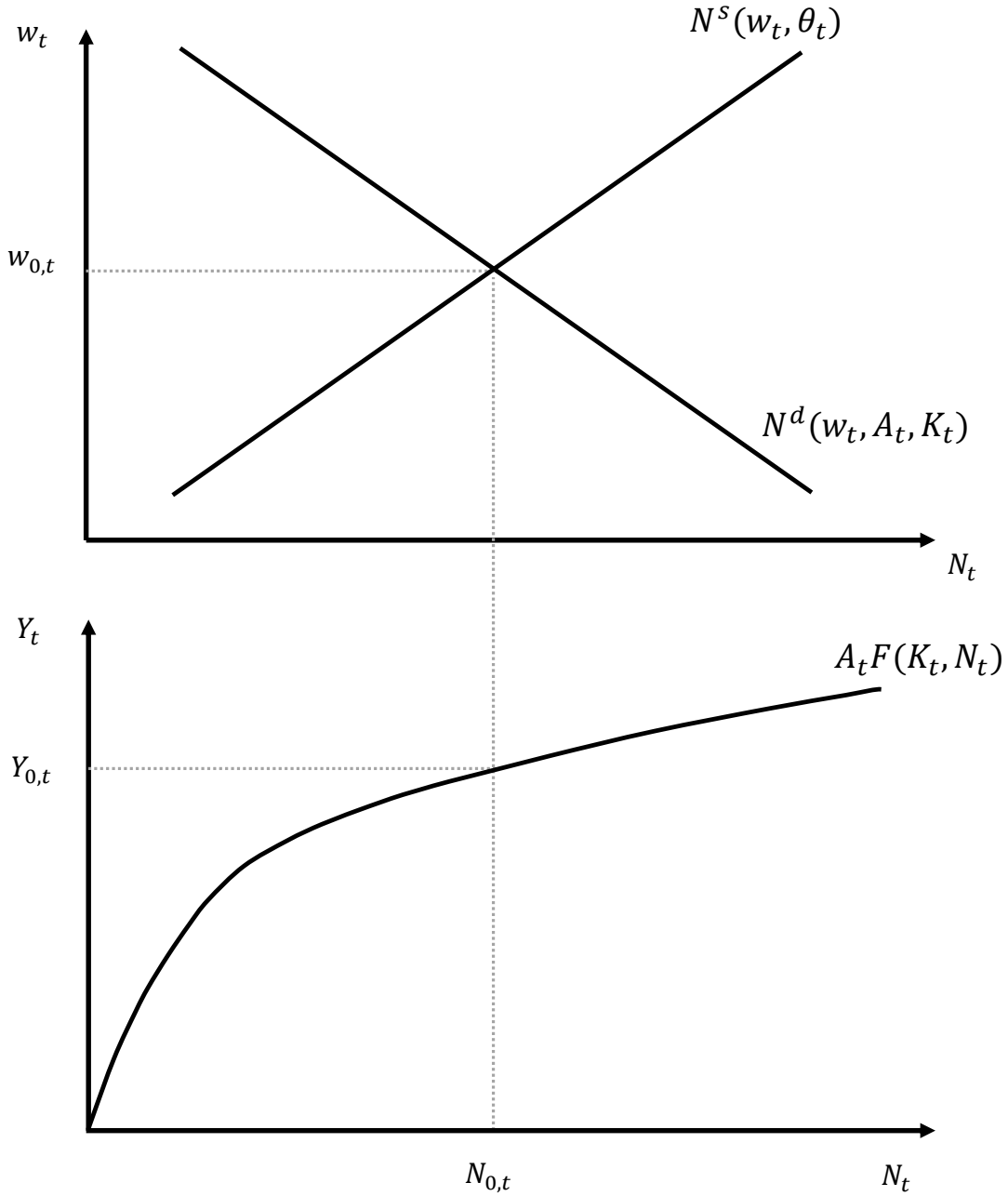
- Knowing N_t, taking A_t and K_t as given, the production function determines Y_t:

$$Y_t = A_t F(K_t, N_t)$$

Labor Market



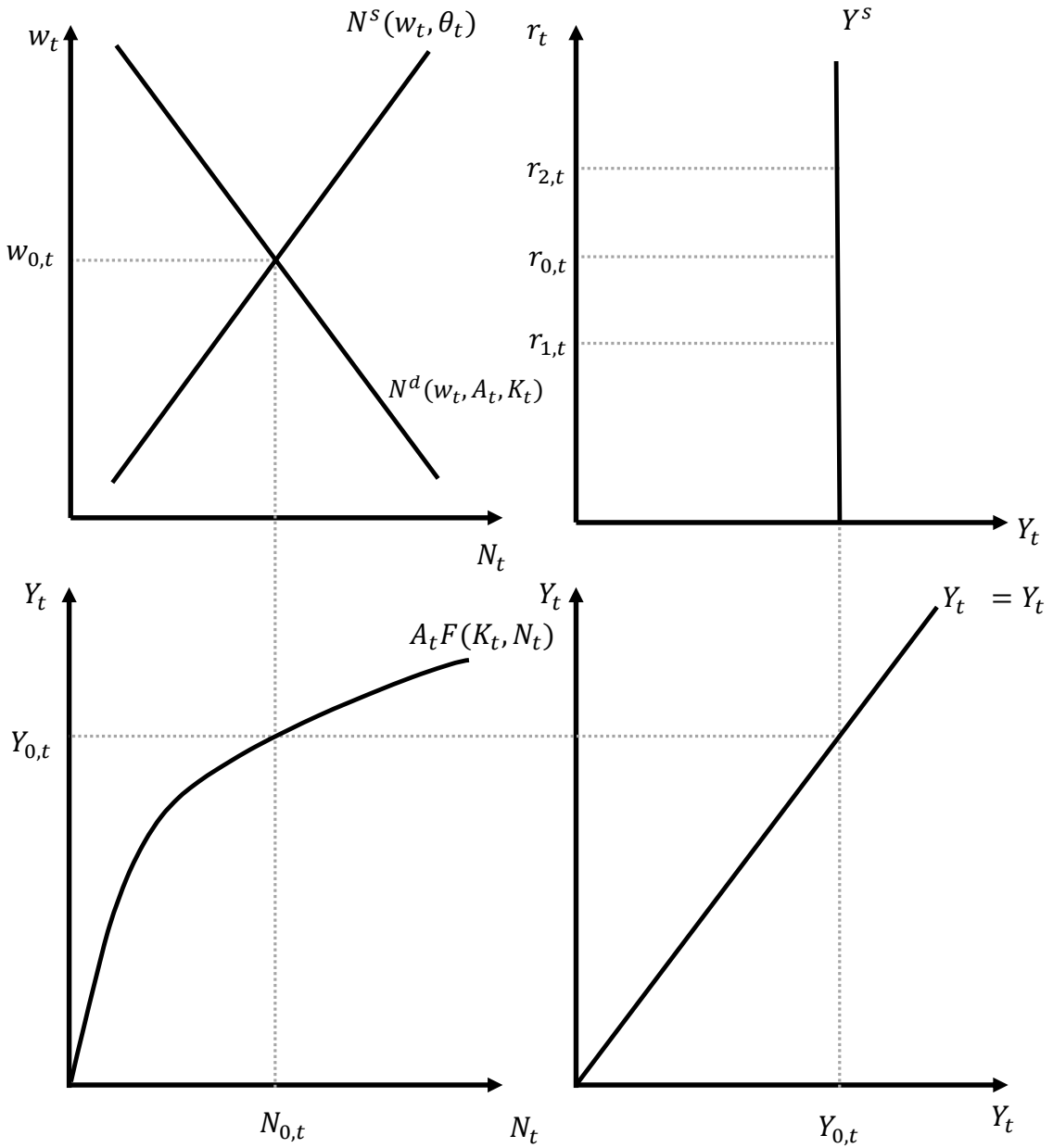
Production Function



The Y^S Curve

- Y^S curve: set of (r_t, Y_t) pairs where household and firm behave optimally, labor market clears, and production function holds.
- Summarizes labor supply, demand, and production function.
- r_t irrelevant for labor demand, supply, and the production function: Y^S curve is vertical.

The Y^s Curve


w_t
$N^s(w_t, \theta_t)$
$w_{0,t}$
$N^d(w_t, A_t, K_t)$
N_t
r_t
Y^s
$r_{2,t}$
$r_{0,t}$
$r_{1,t}$
Y_t
Y_t
$A_t F(K_t, N_t)$
$Y_{0,t}$
$N_{0,t}$
N_t
Y_t
$Y_t = Y_t$
$Y_{0,t}$
Y_t

Shifts of the Y^S Curve

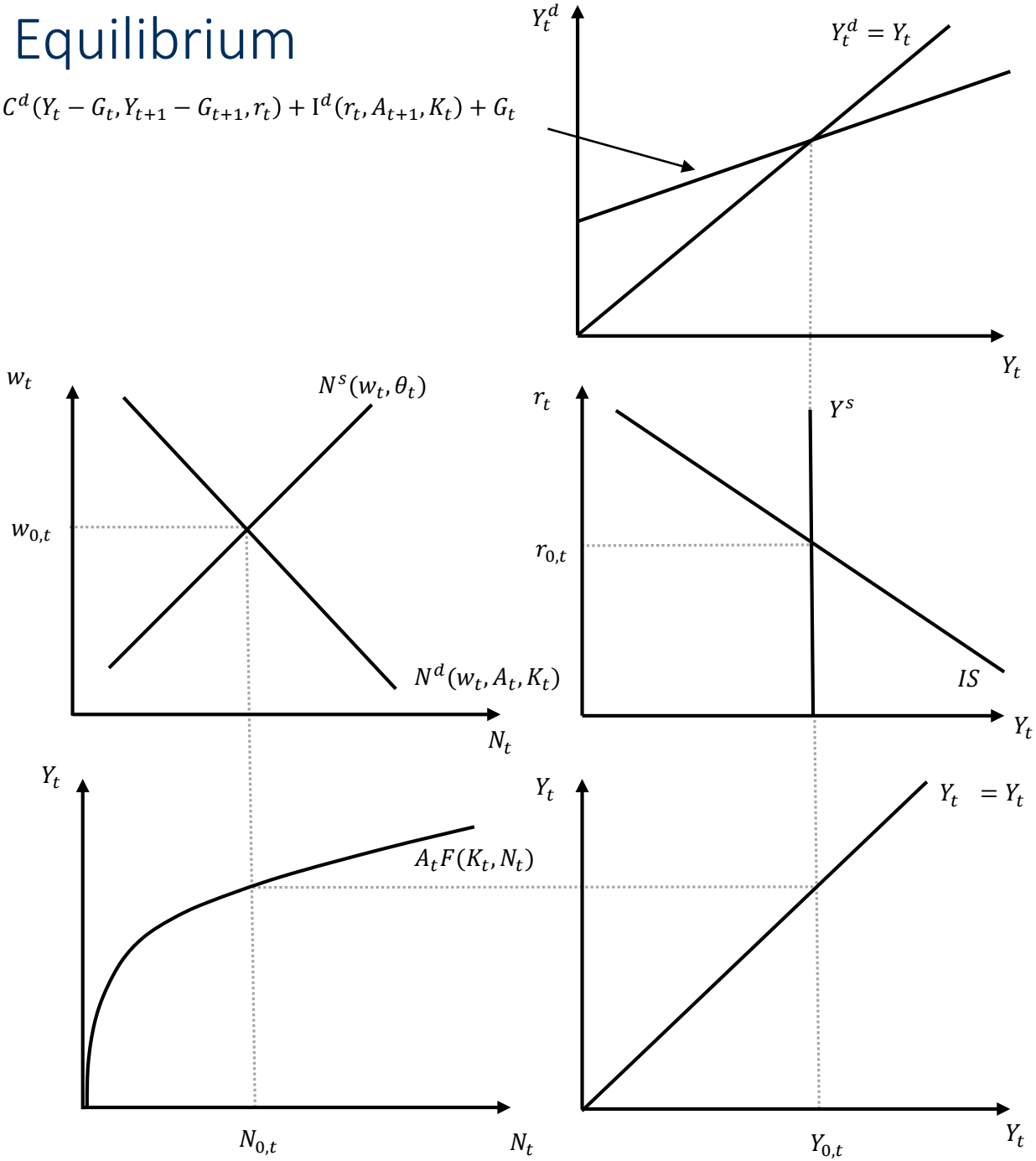
- The Y^S curve will shift if any exogenous variable relevant for the positions of the labor demand, labor supply, or production functions changes.
- Shifts:
  - $\uparrow A_t$: Y^S shifts right
  - $\uparrow \theta_t$: Y^S shifts left
  - $\downarrow K_t$: Y^S shifts left

General Equilibrium

- We postpone the nominal side for a moment as it can be analyzed separately. There is an effect of real variables on nominal variables, but not vice versa.
- In equilibrium, economy must be on both the IS and Y^s curves.
- Intersection jointly determines Y_t, r_t, N_t, and w_t.
- Figure out split between C_t and I_t, given Y_t and r_t, by looking at consumption and investment demand functions.

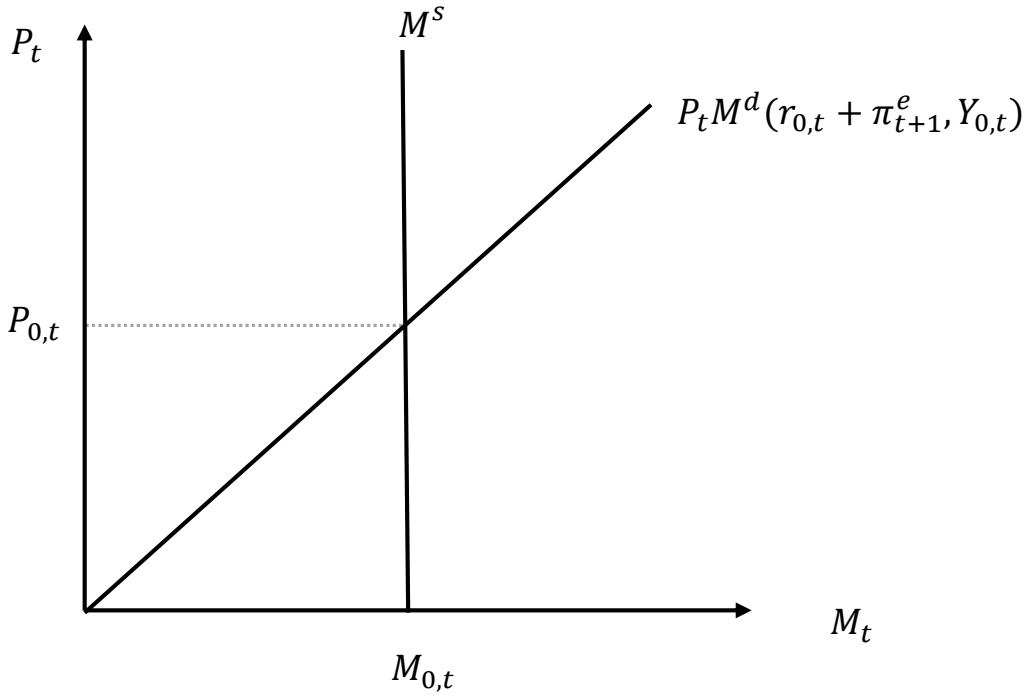
General Equilibrium

$$Y_t^d = C^d(Y_t - G_t, Y_{t+1} - G_{t+1}, r_t) + \mathrm{I}^d(r_t, A_{t+1}, K_t) + G_t$$



The nominal side

- Once we know Y_t and r_t we can plot a money market diagram.
  - Money demand: $P_t M^d(r_t + \pi^e_{t+1}, Y_t)$, Money supply: M_t exogenous
  - The equilibrium price level can be determined at the intersection of the money demand and supply curves. Price level is fully controlled by the central bank.
  - The nominal interest rate can be computed via the Fisher equation.



Monetary Neutrality

- Increase in M_t does not affect first six equations – no effect of change in M_t on any real endogenous variable.
- We say that money is neutral.
- Useful medium run benchmark, but in the short run nominal rigidities may break monetary neutrality.
- Only effect of an increase in M_t is an increase in P_t.

Working Through Effects of Changes in Exogenous Variables

- A_t, θ_t, and K_t affect the Y^s curve
- A_{t+1}, G_t, G_{t+1}, and K_t affect the IS curve
- When doing these, a complication arises: changes in I_t affect K_{t+1}, which affects Y_{t+1}, and hence C_t
- We ignore these effects – size of capital stock is large relative to investment, and in medium run can treat capital stock as approximately fixed (unlike long run where we study capital accumulation)
- Y_{t+1} will therefore only be affected by changes in exogenous variables dated $t + 1$: A_{t+1} and G_{t+1}.

Qualitative Effects of Changes in Exogenous Variables

	Exogenous Shock				
Variable	$\uparrow A_t$	$\uparrow A_{t+1}$	$\uparrow G_t$	$\uparrow M_t$	$\uparrow \pi^e_{t+1}$
Y_t	+	0	0	0	0
C_t	+	?	-	0	0
I_t	+	?	-	0	0
N_t	+	0	0	0	0
w_t	+	0	0	0	0
r_t	-	+	+	0	0
i_t	-	+	+	0	+
P_t	-	+	+	+	+

- Effects of changes in θ_t and G_{t+1} similiar to changes in A_t and G_t
- Do not consider changes in K_t – shifts both Y^s and IS curves

Summary

- Have derived a complete microfounded macroeconomic model.
- Household's optimization yield consumption function and a labor supply function.
- Firm's problem yields the labor demand curve and an investment demand curve .
- Government consumption is financed by lump-sum taxes.
- The demand side is described by the IS-curve: equate total income with desired spending.
- The supply side is described by the Y^s curve: labor market clearing determines labor input, production function determines output. Supplied output is independent of r_t.
- Real variables can be analyzed separately from nominal variables.
- Money demand and supply determine the price level. The Fisher-equation determines the nominal interest rate.
- For each variable it is clearly defined how it is affected by exogenous variables via shifting the IS or the Y^s curve.