Lecture 3: Key Theories of Structural Transformation

STEG Lecture Series on
Key Concepts in Macro Development

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Tutorial Session

- Monday, February 22, 4:00 pm UK time.
- Send questions by Sunday 8:00 pm UK time.
- Problem set, which is at the end of the slides.

Key Background Paper

- Herrendorf, Rogerson & Valentinyi:

  "Growth and Structural Transformation" (Handbook of Economic Growth 2014)

Outline

1. Introduction
2. The Stylized Facts of Structural Transformation
3. Background: A Two–Sector Version of the Growth Model
4. A Benchmark Model of Structural Transformation
5. Conclusion

1 Introduction

Structural Transformation (ST)

- ST is the reallocation of economic activity across broad sectors.
- Kuznets listed ST as a key feature of modern economic growth.
- Typical sector split
  - agriculture: tangible edible output;
  - manufacturing: tangible non-edible output (exception processed food);
  - services: intangible output.
- ST has important aggregate implications when sectoral composition matters: labor market outcomes, productivity, skill premium, urbanization etc.

Models with Balanced Growth and Structural Transformation

- I first present the stylized facts of structural transformation.
- I then develop a multi–sector extension of the one-sector growth model that
  - is consistent with the stylized facts;
  - serves as a natural benchmark model to study structural transformation.
- Lastly, I ask whether it is possible to simultaneously deliver balanced growth and ST.

2 The Stylized Facts of ST

2.1 How to Measure ST

- The three most common measures of sectoral economic activity are:
  employment, value added, and final expenditures.

- Employment shares are calculated either by using workers or hours worked by sector, depending on data availability.

- Value added shares and final consumption expenditure shares are typically expressed in current prices ("nominal shares").

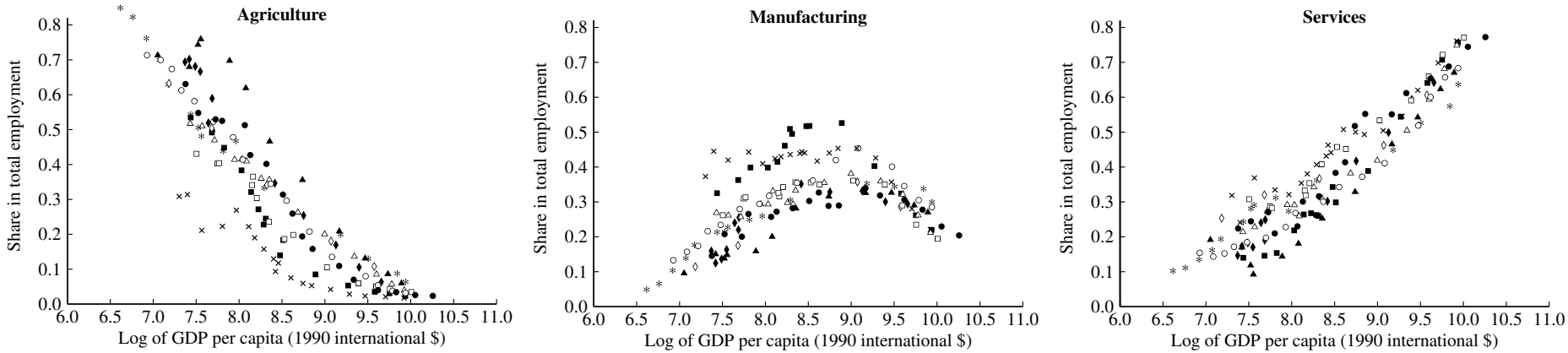
- There are at least two reasons for differences among these measures:
  - investment and trade imply that production and consumption measures differ;
  - value added is a distinct concept from final expenditure.

Background: Some Basic Concepts

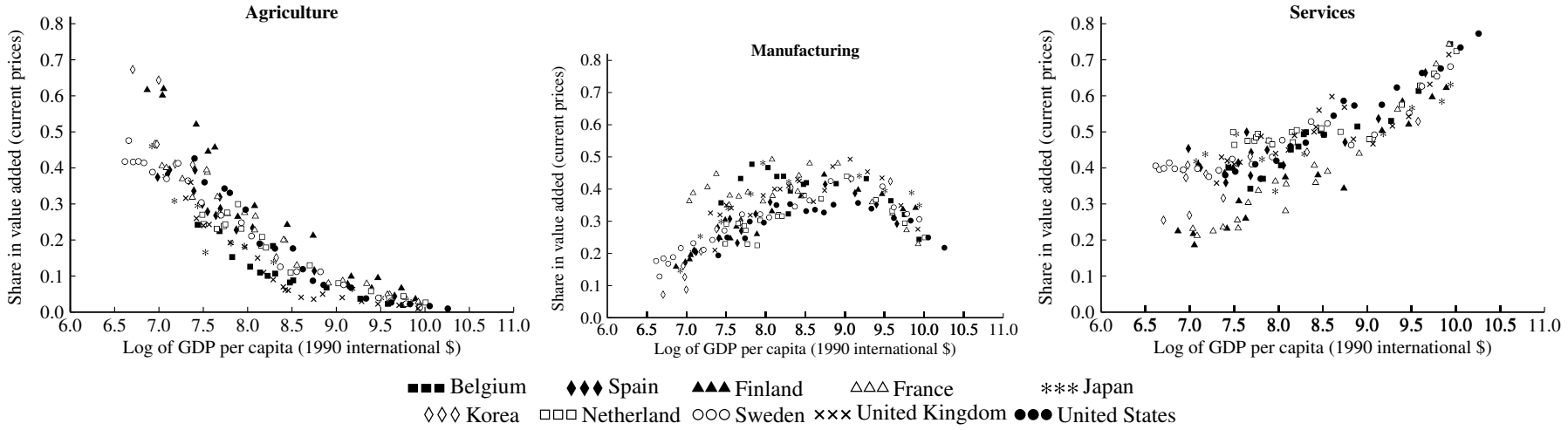
- **Industries:** collections of establishments that produce similar goods or services.
  - Establishments produce (gross) output from capital, labor and intermediate goods.
  - Establishments sell output to final uses, other establishments, or themselves.
- **Sectors:** aggregates of industries with similar characteristics.
- **Value added:** value of gross output minus value of intermediate inputs.
- **Final expenditures:** gross output delivered to final uses.
  - Final expenditure are a composite of value added from different sectors.
  - Total requirement matrix gives the composition
    (like in Herrendorf, Rogerson & Valentinyi, AER, 2013).

2.2 Production Measures of ST

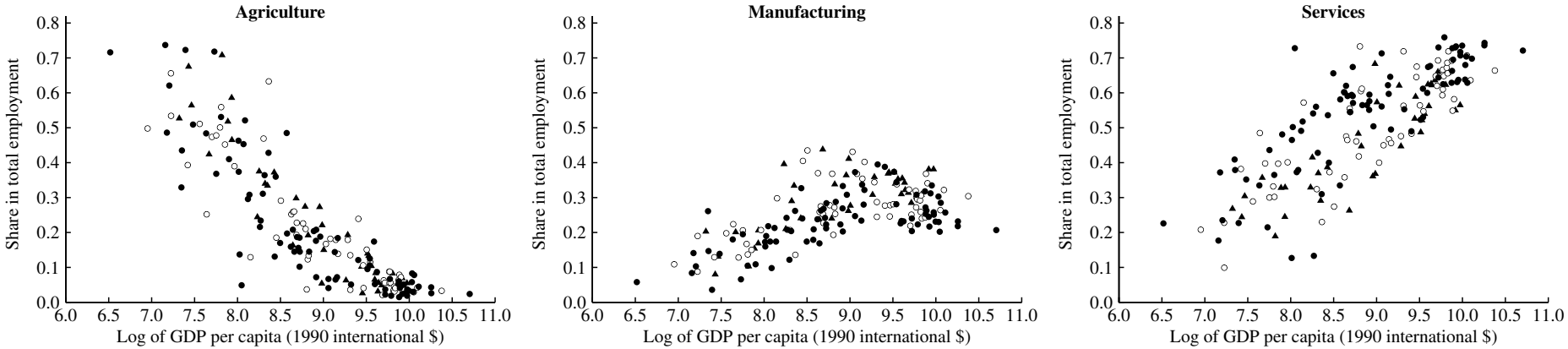
Sectoral Employment Shares – Currently Rich Countries 1800–2000



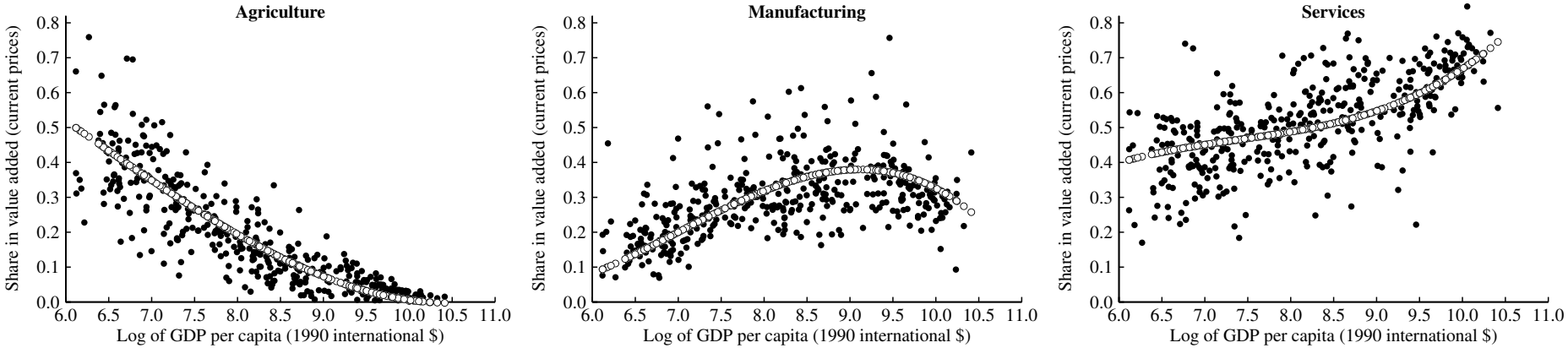
Sectoral Value-Added Shares – Currently Rich Countries 1800–2000



Sectoral Employment Shares – Cross Sections of WDI 1980–2000



Sectoral Value-Added Shares – Cross Sections of UN National Accounts 1975–2005



Summary: Stylized Facts

- When GDP per capita increases, the shares of employment and nominal value added
  - decrease in agriculture;
  - increase in services;
  - follow a hump shape in manufacturing.

- For low levels of development the value added share in agriculture is considerably lower than the employment share (i.e., agriculture is relatively unproductive).

- The employment share and the nominal value added share for the service sector are bounded away from zero even at very low levels of development.

- For a log of GDP per capita around 9
  - the increase in the nominal value added share in services accelerates;
  - the nominal value added share for manufacturing peaks.

3 Background: A Two–Sector Version of the Growth Model

- We start by developing the standard two–sector model with consumption and investment.
- This model goes back to Uzawa (REStud, 1963).
- We present a version building on Greenwood, Hercowitz & Krusell (AER, 1997).

3.1 Environment

Preferences and Endowments

- Infinitely lived representative household.
- Preferences over consumption sequences are described by the utility function

$$\sum_{t=0}^{\infty} \beta^t \log C_t \tag{1}$$

  where $0 < \beta < 1$ is the discount factor.

- Endowments: one unit of time in each period; positive initial stock of capital, $K_0 > 0$.

Technology

- Consumption (C) and investment (X) are produced from capital (k) and labor (n).
- We use upper–case (lower–case) letters to refer to aggregate (sectoral) variables.
- Production takes place in two separate sectors.
- The production functions are Cobb–Douglas with the same exponents:

$$C_t = k_{ct}^{\theta}(A_{ct}n_{ct})^{1-\theta}$$
$$X_t = k_{xt}^{\theta}(A_{xt}n_{xt})^{1-\theta}$$

- Changes in A_{it} represent exogenous labor–augmenting technological progress in sector i.

Capital Accumulation and Feasibility

- Capital accumulates as usual:

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

  where $0 < \delta < 1$ is the depreciation rate.

- We assume capital and labor can be used in both sectors, implying that feasibility requires:

$$K_t \geq k_{ct} + k_{xt}$$
$$1 \geq n_{ct} + n_{xt}$$

3.2 Competitive Equilibrium

- We want to emphasize the role of relative prices.
  Therefore we consider a sequence-of-markets competitive equilibrium.

- The investment good is the numeraire (i.e., it's price equals one in each period).

- The price of the consumption good relative to the investment good is denoted by P_t.

- The rental rates for capital and labor are denoted by R_t and W_t.

- We assume that the household accumulates capital and rents it to firms.

Characterization of Equilibrium

- Capital–to–labor ratios are equalized across sectors at each point in time:

$$\frac{k_{ct}}{n_{ct}} = \frac{k_{xt}}{n_{xt}} = \frac{K_t}{N_t} = K_t$$

- The equilibrium value of the relative price is pinned down by technology:

$$P_t = \left(\frac{A_{xt}}{A_{ct}}\right)^{1-\theta}$$

- The model aggregates on the production side:

$$Y_t = X_t + P_t C_t = K_t^{\theta} A_{xt}^{1-\theta}$$

- The sectoral expenditure shares equal the sectoral employment shares:

$$\frac{P_t C_t}{Y_t} = \frac{n_{ct}}{N_t}$$

- The Euler equation results from the household problem:

$$\frac{P_t C_t}{P_{t-1} C_{t-1}} = \beta(1 - \delta + R_{t+1})$$

- Aggregate Balanced Growth Path (ABGP):
  The Kaldor facts hold for aggregate variables, that is,
  - constant growth of GDP pc and capital pc
  - constant capital-GDP ratio, real interest rate, capital share

- Assume constant sectoral TFP growth

$$\frac{A_{it+1}}{A_{it}} = 1 + \gamma_i, \quad i = c, x$$

Proposition 1. *A unique ABGP exists.*

4 A Benchmark Model of Structural Transformation

4.1 Preferences

- I will present three classes of preferences that generate ST.
- I will then assess whether they are consistent with ABGP.

Generalized Stone-Geary from Herrendorf, Rogerson & Valentinyi (AER, 2013)

$$C_t = \left[\omega_a^{\frac{1}{\varepsilon}} (c_{at} - \bar{c}_a)^{\frac{\varepsilon-1}{\varepsilon}} + \omega_m^{\frac{1}{\varepsilon}} (c_{mt})^{\frac{\varepsilon-1}{\varepsilon}} + \omega_s^{\frac{1}{\varepsilon}} (c_{st} + \bar{c}_s)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

- Implied demand system:

$$\frac{p_{at}c_{at}}{p_{mt}c_{mt}} = \frac{\omega_a}{\omega_m}\left(\frac{p_{at}}{p_{mt}}\right)^{1-\varepsilon} + \frac{p_{at}\bar{c}_a}{p_{mt}c_{mt}}$$

$$\frac{p_{st}c_{st}}{p_{mt}c_{mt}} = \frac{\omega_s}{\omega_m}\left(\frac{p_{st}}{p_{mt}}\right)^{1-\varepsilon} - \frac{p_{st}\bar{c}_s}{p_{mt}c_{mt}}$$

Non-homothetic CES from Comin, Lashkari & Mestieri (R&R[4] ECTRA, 2020)

$$C_t = \left[\omega_a^{\frac{1}{\varepsilon}} C_t^{\frac{\sigma_a+(\varepsilon-1)}{\varepsilon}} (c_{at})^{\frac{\varepsilon-1}{\varepsilon}} + \omega_m^{\frac{1}{\varepsilon}} (c_{mt})^{\frac{\varepsilon-1}{\varepsilon}} + \omega_s^{\frac{1}{\varepsilon}} C_t^{\frac{\sigma_s+(\varepsilon-1)}{\varepsilon}} (c_{st})^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

- Implied demand system:

$$\frac{p_{it}c_{it}}{p_{jt}c_{jt}} = \frac{\omega_i}{\omega_j} \left(\frac{p_{it}}{p_{jt}} \right)^{1-\varepsilon} C_t^{\sigma_i-\sigma_j}$$

PIGL preferences from Boppart (ECTRA, 2014)

- PIGL stands for Price-independent-generalized-linearity:

$$V(E_t, P_{gt}, P_{st}) = \frac{1}{\chi}\left(\frac{E_t}{P_{st}}\right)^{\chi} - \frac{\nu}{\gamma}\left(\frac{P_{gt}}{P_{st}}\right)^{\gamma} - \frac{1}{\chi} + \frac{\nu}{\gamma}$$

  where E_t is expenditures.

- Implied demand system:

$$\frac{P_{gt}C_{gt}}{E_t} = \nu\left(\frac{P_{gt}}{P_{st}}\right)^{\gamma}\left(\frac{E_t}{P_{st}}\right)^{-\chi}$$

- Alder, Mueller & Boppart (AEJ: Macro, 2021) generalize PIGL to many goods.

4.2 Technology

- Cobb–Douglas production functions with equal exponents:

$$c_{it} = k_{it}^{\theta}(A_{it}n_{it})^{1-\theta}, \quad i \in \{a, m, s\}$$
$$X_t = k_{xt}^{\theta}(A_{xt}n_{xt})^{1-\theta}$$

- Generalizations
  - Acemoglu & Guerrieri (JPE, 2008):
    generate ST with Cobb-Douglas production functions with different exponents.
  - Herrendorf, Herrington & Valentinyi (AEJ: Macro, 2015):
    estimate CES production functions when substitution elasticity is not one.
  - Alvarez-Cuadrado & Poschke (TE, 2017):
    generate ST with CES production functions.

Remarks

- The literature often works with only three production functions, assuming all investment is produced by the manufacturing sector.
- This specification is not supported by the data; e.g., U.S. investment exceeds value added of U.S. manufacturing.
- I have therefore left investment separate so that ST happens only within *consumption*.
- Recent work on ST within *investment*:
  - Herrendorf, Rogerson & Valentinyi (REStud, 2021): along ABGP.
  - Garcia, Pijoan-Mas & Villacorta (R&R[3] Econometrica, 2020): along transitions.

4.3 Feasibility Conditions

$$K_t \geq k_{at} + k_{mt} + k_{st} + k_{xt}$$

$$1 \geq n_{at} + n_{mt} + n_{st} + n_{xt}$$

4.4 Equilibrium Properties of the Benchmark Model

Key properties from before also hold in the four–sector model

- The capital–to–labor ratios equal the aggregate capital–to–labor ratio.
- Relative prices are determined by technology.
- The four–sector model aggregates on the production side.
- The sectoral employment shares equal the sectoral expenditure shares.

Breaking the household's problem into two subproblems

$$\max_{\{c_{at},c_{mt},c_{st},K_{t+1}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \log C(c_{at}, c_{mt}, c_{st})$$

$$\text{s.t.} \quad p_{at}c_{at} + p_{mt}c_{mt} + p_{st}c_{st} + K_{t+1} = (1 - \delta + R_t)K_t + W_t$$

(i) Intertemporal Problem
Allocate total income among the composite consumption good and savings

(ii) Static Problem
Allocate the period t consumption expenditure P_tC_t among the consumption goods

4.5 Key Results

Proposition 2. (Kongsamut, Rebelo & Xie, REStud 2001 – "Income Effects")

- *Suppose that* $\gamma_i = \gamma > 0$ *and that utility is Stone-Geary* ($\varepsilon = 1$)*:*

$$C_t = \omega_a \log(c_{at} - \bar{c}_a) + \omega_m \log(c_{mt}) + \omega_s \log(c_{st} + \bar{c}_s)$$

- *There is an ABGP along which the employment and expenditure shares*
  - *are constant for investment;*
  - *decrease for agriculture; increase for services; are constant for manufacturing.*

Proposition 3. (Ngai & Pissarides, AER 2007 – "Relative-Price Effects")

- *Suppose that* $\gamma_a > \gamma_m > \gamma_s$, $\bar{c}_a = \bar{c}_s = 0$, *and* $\varepsilon \in [0, 1)$*:*

$$C_t = \left[\omega_a^{\frac{1}{\varepsilon}} c_{at}^{\frac{\varepsilon-1}{\varepsilon}} + \omega_m^{\frac{1}{\varepsilon}} c_{mt}^{\frac{\varepsilon-1}{\varepsilon}} + \omega_s^{\frac{1}{\varepsilon}} c_{st}^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

- *There is an ABGP along which the employment and expenditure shares*
  - *are constant for investment;*
  - *decrease for agriculture; increase for services*
    lie between the other two shares for manufacturing.

4.6 Additional Results

Non-homothetic CES from Comin, Lashkari & Mestieri (R&R[4] ECTRA, 2021)

- Persistent income effects and usual relative-price effects.
- Replicates agricultural and services shares over long horizons.
- Asymptotic ABGP.

Generalized PIGL from Alder, Mueller & Boppart (AEJ: Macro 2021)

- Persistent income effects and usual relative-price effects.
- Replicates all shares (including hump shape of manufacturing) over long horizons.
- ABGP.

5. Conclusion

- There are clear stylized facts of structural transformation:
  - agriculture shrinks;
  - manufacturing follows a hump shape;
  - services expand.

- There are two main forces behind structural transformation:
  - relative prices change with low elasticity of substitution:
    sector with low (high) productivity growth expands (contracts);
  - income changes with different income elasticities:
    luxuries expand and necessities contract.

- CES and PIGL utility generate these forces and are consistent with ABGP.

Problem Set

Kongsamut-Rebelo-Xie Economy

- Intertemporal utility over total consumption:

$$\sum_{t=0}^{\infty} \beta^t \log C_t \tag{2}$$

  where $\beta \in (0, 1)$ is the discount factor.

- Intratemporal utility over agriculture, manufacturing, and services consumption:

$$C_t = \omega_a \log (c_{at} - \bar{c}_a) + \omega_m \log (c_{mt}) + \omega_s \log (c_{st} + \bar{c}_s) \tag{3}$$

  where $\omega_i > 0$, $\omega_a + \omega_m + \omega_s = 1$, and $\bar{c}_a, \bar{c}_s > 0$.

- Endowments in each period:
  - one unit of time;
  - a positive initial stock of capital, $K_0 > 0$.

- Capital accumulation:

$$K_{t+1} = (1 - \delta)K_t + X_t \tag{4}$$

  where $\delta \in [0, 1]$ is the depreciation rate and $X_t \geq 0$ is investment.

- Cobb–Douglas production functions for each good:

$$c_{it} = k_{it}^{\theta}(A_{it}n_{it})^{1-\theta}, \quad i \in \{a, m, s\} \tag{5}$$

$$X_t = k_{xt}^{\theta}(A_{xt}n_{xt})^{1-\theta} \tag{6}$$

- Capital and labor can be used in both sectors.

- Feasibility:

$$K_t \geq k_{at} + k_{mt} + k_{st} + k_{xt} \tag{7}$$

$$1 \geq n_{at} + n_{mt} + n_{st} + n_{xt} \tag{8}$$

Solve the Following Problems

- Define a sequence-of-markets equilibrium in this economy.
- Define an aggregate balanced growth path (ABGP) in this economy.
- Show that there is an ABGP.
- Show that along the ABGP the employment and expenditure shares
  - are constant for investment
  - decrease for agriculture
  - are constant for manufacturing
  - increase for services