Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

The Production Sector in EURACE
EURACE Winter School 2009

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Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Introduction

The Consumption Goods Producer

The Investment Goods Producer

Malls and Households' Consumption Decision

Summary

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

The real side of EURACE

- ▶ The core of the Production Sector: Consumption Goods Market
  - ▶ Production and selling of a homogeneous consumption good.
- ▶ 2 Factor Markets:
  - ▶ Capital Goods Market:
    - ▶ Capital goods are vertically differentiated among their productivity.
  - ▶ Labor Market:
    - ▶ Labor differentiated among general and specific skills.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Agents and their roles

- ▶ Consumption goods producer:
    - ▶ Producer and seller of consumption goods.
    - ▶ Buyer of labor and capital goods.
- ▶ Households:
    - ▶ Consumer on the Consumption Goods Market.
    - ▶ Supplier on the Labor Market.
- ▶ Investment Goods Producer:
    - ▶ Supplier on the Investment Goods Market.
- ▶ Malls (passive agent type):
    - ▶ Market platforms where consumption goods producers store and offer their commodities.
    - ▶ Transfer of information and goods between producers and consumers.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
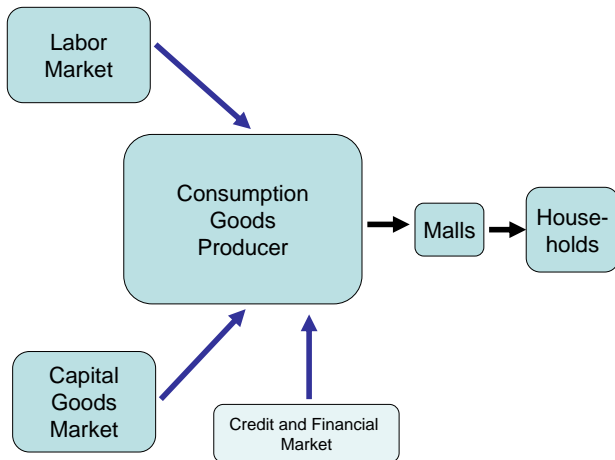Summary

Regional structure

- ▶ Consumption Goods Market: Semi local market
  - ▶ On the supply side the market is global: producers can deliver goods to all malls.
  - ▶ On the demand side the CGM is a local market: consumers shop in their region
- ▶ Investment Goods Market: Global market
  - ▶ All firms have frictionless access to the IG market.
- ▶ Labor Market: Semi local market
  - ▶ Firms can hire workers from their home region and neighboring regions.
  - ▶ Workers have to bear commuting costs if they work for firms in outside regions.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

General modeling philosophy

- Strong micro-foundation of decision rules: firms and households act rule-based using backward looking expectations.
- Operational decisions of firms are modeled using standard decision rules from the Operations Management literature:
  - Pricing (markup)
  - Inventory and production planing (newsboy problem)
- Savings/consumption decisions of HHs are simplified versions of empirically confirmed rules.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

General features

- ▶ The firm uses capital and labor to produce consumption goods.
- ▶ Firms are located in regions.
  - ▶ The commodities are sold at geographically distributed outlet malls.
  - ▶ Goods can be frictionless transfered to all regions/malls.
  - ▶ Firms have access to the (global) Investment Goods Market.
  - ▶ There are barriers to hire workers from outside regions (commuting costs).
- ▶ The firm can finance the production and investments internally and externally.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Technology

- ▶ The production technology of firm i is embedded in firm's capital stock $K_{i,t}$ and is characterized by its technical productivity $A_{i,t}$.
  - ▶ Provided by capital goods producers with a quality that increases over time.
- ▶ Average productivity $A_{i,t}$ of the capital stock depends on past investments.
- ▶ $A_{i,t}$ is updated by depreciation and new physical investments.
- ▶ The firm depreciates its capital stock $K_{i,t}$ at a rate δ, it follows $K_{i,t} = (1 - \delta)K_{i,t-1} + I_{i,t}$.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

The impact of Skills

- ▶ A worker w has two skill dimensions:
  - ▶ General skills: Education and general abilities measured in 5 discrete skill groups $b_w^{gen} = \{1, ...5\}$.
  - ▶ Specific skills: $b_{w,t}$ are experiences and know how obtained on the job.
  - ▶ Specific skills of a worker w employed in firm i evolve through learning by doing etc. according to

  $$b_{w,t} = b_{w,t-1} + \chi(b_w^{gen}) \cdot \max\left[0, (A_{i,t} - b_{w,t-1})\right].$$

    - ▶ Building up specific skills depends on educational level.
    - ▶ Function χ increasing in the general skill level of worker w, $f'(b_w^{gen}) > 0$.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Interaction of Technology and Skills

- ▶ Complementarity between mean specific skills $B_{i,t}$ and technical productivity $A_{i,t}$.
- ▶ Effective productivity $A_{i,t}^{eff} = \min[A_{i,t}, B_{i,t}]$.
- ▶ Productivity of a given technology level is only fully exploited if workers in the firm have sufficiently high specific skills.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production Function

- ▶ Production Function of a Consumption Goods Producer:
  - ▶ Cobb-Douglas production function

$$Q_{i,t} = \min\left[A_{i,t}, B_{i,t}\right] L_{i,t}^{\alpha} K_{i,t}^{\beta}.$$

  - ▶ $L_{i,t}$ current labor stock, $K_{i,t}$ capital stock, α, β input factor intensity with constant returns to scale, $\alpha + \beta = 1$.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Sequence of activities

- ▶ The sequence of decisions and actions
    - ▶ Production planning.
    - ▶ Tentative input factor planning.
    - ▶ Financial planning.
    - ▶ Final production planning and input factor determination.
    - ▶ Labor and Capital Market transactions.
    - ▶ Production and delivery.
    - ▶ Periodic earnings statement.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Timing

- ▶ Timing of production
  - ▶ Length of the production and selling cycle: 1 month.
  - ▶ At the monthly activation day (first day of the cycle): Production planing, financing, production, and delivery to the malls.
  - ▶ Selling during the whole of the month.
  - ▶ Earnings statement at the last day of the production cycle.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production planning

▶ Standard inventory rule with stochastic demand: The firms compute different delivery volumes for all served malls (newsboy problem).

▶ $Y_{i,r,t}$ is the critical stock of firm i in mall r, $SL_{i,r,t}$ is the current mall stock at the activation day.

▶ Desired replenishment quantity:

$$\tilde{D}_{i,r,t} = \begin{cases} 0 & SL_{i,r,t} \geq Y_{i,r,t}, \\ Y_{i,r,t} - SL_{i,r,t} & else. \end{cases}$$

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production planning

▶ Demand is estimated by computing a linear trend from the previous demands.

▶ Demand of the last τ periods for mall r: $\left\{ \hat{D}_{i,r,t-\tau}, ..., \hat{D}_{i,r,t-1} \right\}$.

▶ Determination of the demand (Estimation with a simple adaption rule):

$$\hat{D}_{i,r,t} = \begin{cases} S_{i,r,t} & if SL_{i,r,t} > 0 \\ S_{i,r,t} \cdot (1 + \nu) & if SL_{i,r,t} = 0, \end{cases}$$

where $0 < \nu < 1$ and $S_{i,r,t}$ is the sold quantity in mall r.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
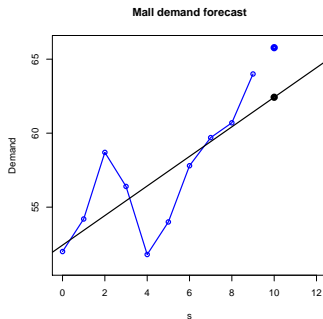Summary

Production planning

- $Y_{i,r,t}$ is chosen such that the firm expects to be able to satisfy the market demand with probability $1 - \chi$ (χ stock-out probability).

- Linear regression model based on previous demands:

$$Y_{i,r,t} = \hat{a}_{i,r,t} + \tau \cdot \hat{b}_{i,r,t} + \bar{q}_{1-\chi} \cdot \sqrt{\hat{\delta}_{i,r,t}}.$$

- $\hat{a}$, $\hat{b}$ linear regression coefficients, $\hat{\delta}$ estimated variance, and $\bar{q}_{1-\chi}$ the $1 - \chi$-quantile of the standard normal distribution.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production planning

- ▶ Illustration: Linear regression of $\hat{D}_{i,r,t-\tau+s}$ with regressor s, and $\tau = 10$ past observations.
- ▶ Estimation of demand for $s = 10 : \hat{D}_{i,r,t} = Y_{i,r,t}$

Mall demand forecast

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production planning

- Desired replenishment quantity:

$$\tilde{D}_{i,r,t} = \begin{cases} 0 & SL_{i,r,t} \geq Y_{i,r,t}, \\ Y_{i,r,t} - SL_{i,r,t} & else. \end{cases}$$

- Sum of all replenishment quantities is $\tilde{D}_{i,t} = \sum_{r=1}^{R} \tilde{D}_{i,r,t}$.
- Smoothing of (planned) production quantity:

$$\tilde{Q}_{i,t} = \xi \tilde{D}_{i,t} + (1 - \xi)\frac{1}{T} \sum_{k=t-T}^{t-1} \tilde{Q}_{i,k}.$$

- Proportional adjustment of delivery volumes: $D_{i,r,t} = \frac{\tilde{D}_{i,r,t}}{\tilde{D}_{i,t}} \tilde{Q}_{i,t}$.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Input factor planning

- The firm aims to realize a capital to labor ratio according to the standard rule for CES production functions:

$$\frac{\tilde{K}_{i,t}}{p^{inv}} / \frac{\tilde{L}_{i,t}}{w_t^e} = \frac{\beta}{\alpha}.$$

- w_t^e expected mean wage, and p^{inv} a calculatory capital goods price.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Input factor planning: Capital

▶ Optimal capital stock

$$\tilde{\tilde{K}}_{i,t} = \frac{(\beta w_t^e)^\alpha \tilde{Q}_{i,t}}{(\alpha p^{inv})^\alpha \min[A_{i,t-1}, B_{i,t-1}]}.$$

▶ In two cases the desired capital stock $\tilde{K}$ deviates from the optimal value $\tilde{\tilde{K}}$:

1. If $\tilde{\tilde{K}}_{i,t} < (1-\delta)K_{i,t-1} \Rightarrow \tilde{K}_{i,t} = (1-\delta)K_{i,t-1}$
   ▶ No exceptional depreciation.

2. If $\tilde{\tilde{K}}_{i,t} \geq (1+\kappa) \cdot K_{i,t-1}, \kappa > 0 \Rightarrow \tilde{K}_{i,t} = (1+\kappa) \cdot K_{i,t-1}$.

   ▶ Inertia of the capital stock.
   ▶ The monthly gross investments are limited:
     $I_{i,t} = (\delta + \kappa)K_{i,t-1}.$

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Input factor planning: Labor

▶ After determining the desired capital stock $\tilde{K}_{i,t}$, the firm computes the required labor input:

$$\tilde{L}_{i,t} = \left(\frac{\tilde{Q}_{i,t}}{(\tilde{K}_{i,t}^{\beta} \min[A_{i,t-1}, B_{i,t-1}]} \right)^{1/\alpha}.$$

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Financial planning

- ▶ Financial needs of a firm :
  - ▶ Expected expenditures for the production:

$$\hat{Exp}_{i,t}^{Prod} = w_t^e \tilde{L}_{i,t} + (\tilde{K}_{i,t} - K_{i,t-1})\bar{p}_t^{Inv}.$$

  - ▶ Financial obligations: $\hat{Exp}_{i,t}^{Fin}$ (Dividends, taxes, interest payments, debt installment payments).
  - ▶ Total financial needs:

$$\hat{Exp}_{i,t}^{Tot} = \hat{Exp}_{i,t}^{Prod} + \hat{Exp}_{i,t}^{Fin}.$$

- ▶ The firm checks how much can be financed internally.
  - ▶ The amount that cannot be financed by internal resources has to be obtained on the Credit or Financial Market.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Financial planning

- ▶ If the firm had to raise external liquidity:
  - ▶ Firm checks if it has obtained the complete external financial needs.
  - ▶ If this is not the case: The firm has to adapt its expenditures.
    - ▶ Priority to serve the financial obligations.
    - ▶ Firm reduces the output quantity as long as the recalculated expected expenditures are covered by the resources.
    - ▶ If the firm is still not able to serve its financial obligations: Bankruptcy.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Production

- ▶ Firm enters the Capital Market and the Labor Market.
- ▶ The capital stock after realized investments is $K_{i,t}$ with a technical productivity of $A_{i,t}$.
- ▶ The number of workers is $L_{i,t}$ with a mean specific skill level of $B_{i,t}$.
- ▶ The realized production quantity $Q_{i,t}$ is then:

$$Q_{i,t} = \min\left[A_{i,t}, B_{i,t}\right] L_{i,t}^{\alpha} K_{i,t}^{\beta}.$$

- ▶ Delivery volumes to malls: $D_{i,r,t} = \tilde{D}_{i,r,t} \frac{Q_{i,t}}{\bar{Q}_{i,t}}$

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Cost accounting

- The production expenditures are:

$$Exp_{i,t}^{Prod} = w_{i,t} \cdot L_{i,t} + I_{i,t} \cdot \bar{p}_t^{Inv}.$$

  - $w_{i,t}$ is the mean wage firm i pays in period t.

- The production costs are:

$$Cost_{i,t}^{Prod} = w_{i,t} \cdot L_{i,t} + Cost_{i,t}^{Cap} + Int_{i,t}.$$

  - $Cost_{i,t}^{Cap}$ calculatory capital costs, $Int_{i,t}$ interest payments.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Cost accounting

- Unit costs:

$$Cost_{i,t}^{Unit} = \frac{Cost_{i,t}^{Prod}}{Q_{i,t}}.$$

- Mark up pricing:

$$p_{i,t} = Cost_{i,t}^{Unit} \cdot \frac{1}{1 + 1/\epsilon_i^e}.$$

  - ϵ_i^e expected demand elasticity.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Earnings statement

▶ At the end of the selling period the mall informs the firm about the sold items $S_{i,r,t}$ and the current mall stock $SL_{i,r,t+1}$.

▶ The firm computes the EBIT:

$$EBIT_{i,t} = \sum_R S_{i,r,t} p_{i,t} - Cost_{i,t}^{Prod}.$$

▶ Determination of taxes, dividends, interests and debt installment payments to be paid in the next production cycle.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

General features

- ▶ The IG sector is in the current model version simplified.
- ▶ One IG firm offers its capital good on a global market.
- ▶ Consumption goods producers order the capital good and get the required amount without rationing.
- ▶ The IG firm produces without input factors.
- ▶ Net earnings (revenues minus taxes) are paid out as dividends.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Technological progress

▶ The IG firm carries out R&D activities to improve the technology.

▶ R&D is successful with a probability $prob^{Inno}$.

   ▶ The productivity increases: $q_t^{Inv} = (1 + \theta)q_{t-1}^{Inv}$.

   ▶ The price of the investment good increases at the same rate: $p_t^{Inv} = (1 + \theta)p_{t-1}^{Inv}$.

▶ Technological progress is driven by innovations in the investment goods sector, diffusion of the technology is induced by consumption good firms' investments in their capital stocks.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Malls

- ▶ The malls are local market platforms where consumption goods producer offer their goods and households purchase consumption goods.

- ▶ One mall per region.

- ▶ The mall informs the consumers about the range of provided goods and the corresponding prices.

- ▶ It receives orders from the household, if the sum of order quantities for a particular good exceeds the local inventory, consumers of that good are rationed.

- ▶ Sales are collected at the mall and transfered to firms.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Household's purchasing decision

▶ Once a week households go to the mall located in their home region.

▶ $CB_{k,week_t}$ is the weekly consumption budget which a household can spend.

▶ $G_{k,week_t}$ is the set of goods, which is available at that day.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Household's purchasing decision

- ▶ The household decides about one good to purchase using a standard discrete choice model.
  - ▶ Logit model based on price differences.
- ▶ The value of consumption good i is given by $v_k(p_{i,t}) = -\ln(p_{i,t})$.
- ▶ Consumer k selects one good where the probability for good i to be selected is

$$Prob_{k,i,t} = \frac{\text{Exp}[\lambda^{cons} v_k(p_{i,t})]}{\sum_{i' \in G_{k,week_t}} \text{Exp}[\lambda_{cons} v_k(p_{i',t})]}$$

- ▶ The intensity of (price) competition is λ^{cons}

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

Household's purchasing decision

- The household orders $\frac{CB_{k,week_t}}{p_{i,t}}$ units of the selected good i.

- If the household cannot spend the complete budget $CB_{k,week_t}$ due to rationing, the household enters a second loop in order to spend the remaining budget for another good.

- If the household is rationed once again, the remaining budget is rolled over to the following week.

Overview
Introduction
The Consumption Goods Producer
The Investment Goods Producer
Malls and Households' Consumption Decision
Summary

- In this lecture presented:
    - Producer role of consumption goods producers.
    - IG firm.
    - Malls.
    - Consumer role of Households.
- Interactions with other EURACE components:
    - Labor Market.
    - Credit and Financial market.
    - Public sector.