



# The Production Sector in EURACE

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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.



# 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.

## 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.



# General modeling philosophy

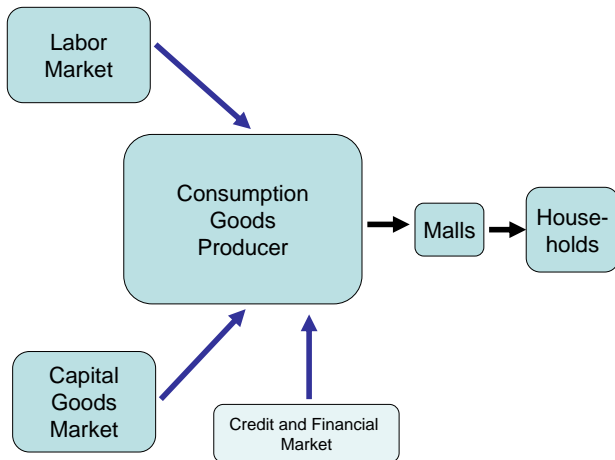
- ▶ Strong micro-foundation of decision rules: firms and households act rule-based using backward looking expectations.
- ▶ Operational decisions of firms are modeled using standard decision rules from the Operations Management literature:
  - ▶ Pricing (markup)
  - ▶ Inventory and production planning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



## 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 transferred 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.







# 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  $\delta$ , it follows  $K_{i,t} = (1 - \delta)K_{i,t-1} + I_{i,t}$ .



## The impact of Skills

- ▶ A worker  $w$  has two skill dimensions:
  - ▶ General skills: Education and general abilities measured in 5 discrete skill groups  $b_w^{gen} = \{1, \dots, 5\}$ .
  - ▶ 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

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

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



# 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.



# Production Function

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

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

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



## 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.



# 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.



## 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:

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



## Production planning

- ▶ Demand is estimated by computing a linear trend from the previous demands.
- ▶ Demand of the last  $\tau$  periods for mall  $r$ :  
 $\{\hat{D}_{i,r,t-\tau}, \dots, \hat{D}_{i,r,t-1}\}.$
- ▶ Determination of the demand (Estimation with a simple adaption rule):

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

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





## Production planning

- ▶  $Y_{i,r,t}$  is chosen such that the firm expects to be able to satisfy the market demand with probability  $1 - \chi$  ( $\chi$  stock-out probability).
- ▶ Linear regression model based on previous demands:

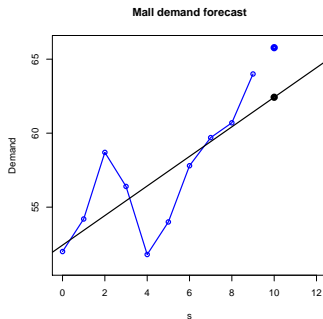
$$Y_{i,r,t} = \hat{a}_{i,r,t} + \tau \cdot \hat{b}_{i,r,t} + \bar{q}_{1-\chi} \cdot \sqrt{\hat{\delta}_{i,r,t}}.$$

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



# 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  $s = 10$  :  $\hat{D}_{i,r,t} = Y_{i,r,t}$



# Production planning

- Desired replenishment quantity:

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

- 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:  $D_{i,r,t} = \frac{\tilde{D}_{i,r,t}}{\tilde{D}_{i,t}} \tilde{Q}_{i,t}$ .



## 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.



# Input factor planning: Capital

## ► Optimal capital stock

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

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

1. If  $\tilde{K}_{i,t} < (1 - \delta)K_{i,t-1} \Rightarrow \tilde{K}_{i,t} = (1 - \delta)K_{i,t-1}$ 
  - No exceptional depreciation.
2. If  $\tilde{K}_{i,t} \geq (1 + \kappa) \cdot K_{i,t-1}, \kappa > 0 \Rightarrow \tilde{K}_{i,t} = (1 + \kappa) \cdot K_{i,t-1}$ .
  - Inertia of the capital stock.
  - The monthly gross investments are limited:  
 $I_{i,t} = (\delta + \kappa)K_{i,t-1}$ .



## Input factor planning: Labor

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

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



## 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.

## 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.





# 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:

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

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



## 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.



# Cost accounting

- ▶ Unit costs:

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

- ▶ Mark up pricing:

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

- ▶  $\epsilon_i^e$  expected demand elasticity.



## 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.



## 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.



## 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.



# 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 transferred to firms.



# 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.





## 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  $\lambda^{cons}$



## 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.



- ▶ 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.

