Project no.
035086
Project acronym
EURACE
Project title
An Agent-Based software platform for European economic policy design with heterogeneous interacting agents: new insights from a bottom up approach to economic modelling and simulation

Instrument STREP

Thematic Priority IST FET PROACTIVE INITIATIVE "SIMULATING EMERGENT PROPERTIES IN COMPLEX SYSTEMS"

Deliverable reference number and title
D7.2: Computational experiments of policy design on skill dynamics and innovation
Due date of deliverable:

Actual submission date:

Start date of project: September 1st 2006 Duration: 36 months

Organisation name of lead contractor for this deliverable
Universitaet Bielefeld - UNIBI

Revision 1

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Computational experiments of policy design on skill dynamics and innovation

EURACE Deliverable D7.2

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Abstract

We report results of economic policy experiments carried out in the framework of the EURACE agent-based macroeconomic model featuring a distinct geographical dimension and heterogeneous workers with respect to skill types. Using a calibrated able to replicate a range of stylized facts of goods and labor markets, it is examined in how far effects differ if policy measures aiming at an improvement of general skills are uniformly spread over all regions in the economy or focused in one particular region. We find that it depends on the level of spatial frictions on the labor market how the spatial distribution of policy measures affects the effects of the policy. Furthermore we show that a reduction in spatial frictions does not necessarily improve the growth of output and household income.

1 Introduction

The aganda of the EURACE project is to highlight that agent-based closed macroeconomic models are not only well suited to reproduce empirically observed regularities but can be usefully applied to evaluate economic policy measures in a way that is infeasible for representative agent models. The focus of WP7 is on an area that has recently received strong attention by policy makers in industrialized countries, namely the question what kind of

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economic policy measures are best suited to facilitate innovation and diffusion of new technologies and productivity increase. Dealing with this question requires to shed more light on the interplay of processes leading to the generation of new technologies and the ability of firms to adopt such new technologies. In order to efficiently use new technologies the workforce of the industrial firms has to be able to build up the required level of specific skills and the ability to do so depends on the general skills levels of the employees. There is strong empirical evidence that the skill distribution in the workforce has substantial influence on the speed of technological change, the employment and wage dynamics and growth in an economy (e.g. Bassanini and Scarpetta (2002), Bassanini (2004)). For example empirical studies initiated by the OECD economics division (see e.g. OECD (2000)) indicate that the lack of the new forces of economic growth and relatively low-skill levels in the labor force have negative effects on employment in Europe. In particular, the U.S. took the lead since the 1990's in creating new knowledge, human capital and innovations accompanied by entrepreneurship and new start-up firms which gave rise to higher employment. Therefore, policies aiming at a change in the local skill distribution play an important role in fostering technological change and growth. Any model designed to evaluate such policies, and more generally any technology and growth policy measures, miss a crucial aspect if they do not incorporate the dynamics of skill and knowledge distribution in the workforce.

To be more concrete, we can address questions concerning the vivid policy debate whether strengthening general or specific skills is more likely to enhance growth and employment. For example in Germany the dual-apprenticeship system is notoriously questioned by firms, unions and policy-makers with regard to its provision of general skills. A common complaint concerning university education in Germany is the high level of the abstraction of the curriculum which provides only limited specific skills. Currently there are no theoretical models that allow to analyze these issues based on thorough macroeconomic analysis. In particular standard analyses conducting cost/benefit analysis of dual apprenticeship systems are based on partial static analysis (Mühlemann et al. (2007)). Obviously, in a world with fast changing technological frontiers this does not fully take into account the full benefits of workers' general skills. Gaining better insights into the effects of increases in both types of skills should have impact on the balance of public spending between primary and secondary education, tertiary eduction, life-long learning measures and dual apprenticeships.

An additional aspect in the policy debate about the optimal design of educational policies fostering innovation and growth is the question in how far such policies should depend on the technological distance of the firms in the economy from the technological frontier. Claims have been made that in regions far from the frontier the main focus should be on primary and secondary education improving the lower end of the skill distribution, whereas regions at the frontier profit more from higher investments in the tertiary sector (see Aghion (2007)). From a dynamic perspective this raises the questions in how far the effectiveness of different policy approaches depends on the speed at which the technological frontier is moving, which itself is influenced by measures in the area of innovation and technology policy. Such measures include among others direct funding of basic and applied research, financial incentives for R&D efforts by firms, providing infrastructure and incentives for R&D cooperation and intensive knowledge exchange between research institutions and firms.

In that respect spatial aspects also play a crucial role. First, in many industrialized countries there are strong regional differences in the skill and knowledge distribution where high-skill employees are strongly concentrated in a few areas. Second, geographic proximity between firms has a crucial impact on the intensity of technological spillovers between them. Both theoretical and empirical studies of innovative activities have demonstrated the importance of technological spillovers for industry development (see e.g. the surveys by Audretsch and Feldman (2004) and Döring and Schnellenbach (2006)). Whereas the main channels through which technological information flows between firms depends heavily on the type of industry considered (see e.g. Geroski (1995)), a considerable role in establishing technological spillovers is typically assigned to direct communication and the flow of skilled and well informed employees. Therefore, the interaction of firms and employees on the (local) labor market is of great importance for the size of technological spillovers and, hence, for innovative activities. Taking into account regional differences and the existence of (*local*) knowledge flows between firms the question arises to what extent economic policy measures should be regionally differentiated. In particular, it has to be explored how the effects of certain skill enhancing policy measures differ when applied in regions with different characteristics. Furthermore, the right allocation of policy measures among all regions in the economy is a difficult problem. Should the activity be centered on the strongest or on the weakest region or should all measures be uniformly distributed across regions? The type of insights about crucial medium and long run effects we can generate using our model allows policy makers to get a broader picture of the implications of different allocations of public funds and therefore provides an important contribution to policy advice.

In previous years the main approach for the analysis of spatial aspects of economic activity has been the use of 'New Economic Geography' (NEG) models introduced by Krugman (1991). These models rely on a number of simplifying assumptions like the restriction to two regions or equidistant multi-regions (see Bosker et al. (2007)), the absence of strategic behavior of firms or the lack of considerations of institutional aspects. These restrictions, which are mainly due to the desire to keep the models tractable, have been acknowledged by NEG researchers. For example in their survey of recent NEG work Ottaviano and Thisse (2004) point out that '*By their very nature, such models are unable to, explain the rich and complex hierarchy that characterizes the space-economy. ... Therefore, one major step on the research agenda is the study of a multi-regional system whose aim is to understand why some regions are more successful than others.*' [p. 2603]. Also some limitations of NEG concerning the study of spatial dynamics on the labor market is acknowledged in Ottaviano and Thisse (2004): '*Another fundamental question is related to the fact that local labor markets are modeled in a very simple way in NEG: operating profits are used to pay skilled workers. In particular, these models do not help understand why unemployment persists in areas included in or adjacent to prosperous regions.*'[p. 2604]. These restrictions of NEG models imply that they are not well suited to address the (spatial) policy questions discussed above. Actually, the work using an NEG approach for normative analysis of economic policy is limited. An indicator in that respect is that the recently published Handbook of Regional and Urban Economics (Henderson and Thisse (2004)), where a lot of attention is dedicated to NEG, does not include any chapters discussing economic policy.

Based on the obvious restrictions imposed by analytical tractability on the spatial analysis of the interplay of technological change and properties of the labor force, the need for an alternative approach for the evaluation of different combinations of economic policy measures seems particularly strong. Agent-based models are well suited to address this need[1].

The work in the second year of the EURACE project reported here builds on the general EURACE modeling framework developed in the first year and in particular on the models of consumption and labor markets described in deliverable D7.1. However, the model has been amended and improved in several respects and therefore we provide a description of the model that was actually implemented in this deliverable although this produces some overlap with D7.1. According to the approach agreed upon in the EURACE consortium the goods and labor market model was stepwise implemented in FLAME as a reduced model where other EURACE parts, like credit and financial markets were not represented in an agent-based way. Based on

[1]See Dawid and Wersching (2006) or Wersching (2007) for agent-based analyses of spatial aspects of industry dynamics.

this version calibration and some steps towards validation of the model were made and the potential of the model for carrying out policy experiments that produce non-trivial and economically meaningful insights was demonstrated. These results are reported in this deliverable. In addition during the second EURACE period all interfaces to the other parts of the EURACE model have been defined and implemented which opens the option to start in the third year to run simulations with the integrated full EURACE model.

We proceed by describing our model which underlies the policy simulation exercises. In section 3 we run the policy experiments. The results of a base run scenario are reported in section 3.1 where we also report on our calibration strategy and refer to several stylized facts which our model is apt to replicate. The policy experiments and the results of these are described and discussed in section 3.4. The last section concludes.

2 The model

2.1 General features

Our model consists of a capital good, a consumption good, and a labor market.[2] Capital goods are provided with infinite supply at exogenously given prices. The quality of the capital good improves over time where technological change is driven by a stochastic (innovation) process. Firms in the consumption goods sector use capital goods combined with labor input to produce consumption goods. The labor market is populated with workers that have a finite number of general skill levels and acquire specific skills on-the-job which they need to fully exploit the technological advantages of the capital employed in the production process. Consumption goods are sold at malls. Malls are not treated as profit-oriented enterprizes but simply as local market platforms where firms store and offer their products and consumers come to buy goods at posted prices.

Thus, two types of active agents and two types of passive agents (in the sense that this type of agent does not take any decisions) are present in the model. Each type of active agent has several 'roles' corresponding to its activities in the different markets. Table 1 summarizes these roles.

The economy consists of $R = 2$ regions and each agent is located in one of these regions. Some actions occur locally, such as the agents' consumption, others occur globally including the sale of the investment good or labor

[2]In the fully fledged EURACE model, a financial and a credit market will be added, and an exogenous energy market will constitute a proxy for the link to the 'rest-of-the-world' by affecting the production costs in the capital goods market.

Active Agents	Households	- Consumption Goods Market: Role of Buyer - Labor Market: Role of Worker
	Consumption Goods Producer	- Investment Goods Market: Role of Buyer - Consumption Goods Market: Role of Seller - Labor Market: Role of Employer
Passive Agents	Malls	- Consumption Goods Market: Information Transfer between Producers and Households
	Capital Goods Producer	- Investment Goods Market: Role of Seller

Table 1: Agents and their role in the model.

supply.

Generally, the minimal unit of time is a day, however almost all the interactions and decisions are repeated on a monthly basis.[3] Therefore, whenever we refer to one time-period by default we mean one month. Some decisions in the consumption goods market are taken on a weekly basis and we will explicitly point out this fact in the text.

2.2 Investment goods market

There exists a single type of technology for investment goods. The investment good is offered with infinite supply. The quality of the investment good q_t^{inv} increases over time due to a stochastic process. Every period the quality is increased with probability $\gamma^{inv} \in (0, 1)$ where with probability $(1 - \gamma^{inv})$ there is no change of quality. In case of an increase the quality of the offered good changes by a fixed percentage Δq^{inv}.

The price of the investment good $p^{inv} > 0$ is assumed to be linked to the level of quality, so that a rise of quality leads to a proportional increase of p^{inv}. Although capital goods producers are not modelled as active agents the amounts paid for investment goods are channeled back into the economy. Revenues accruing with the investment good producer are distributed in equal shares among all households in order to close the model. Put differently, it is assumed that all households own equal shares in the fictitious capital goods producer.

[3]In the model each week consists of 5 days and each month of 4 weeks. Accordingly, each year has 240 days.

2.3 Consumption good producer

2.3.1 Quantity choice

Every consumption goods producer keeps a stock of its products at every regional mall. For simplicity it is assumed that all producers offer their products in both regions. A producer checks once every period whether any of the stocks it keeps at different malls have to be refilled. To that end the firm receives messages from all the malls it serves reporting the current stock level. Taking this information into account, the firm i has to decide whether and on what scale it restocks the supply. According to our approach of using standard managerial methods wherever it is applicable, we employ a standard inventory rule for managing the stock holding. For reasons of simplicity we ignore setup costs that arise for each delivery to a mall. We denote by $C_{i,r}^{inv}$ costs of holding one unit of the good in the inventory for one period and by $\tilde{\Phi}_{i,r,t}(D) : [0,\infty) \mapsto [0,1]$ the estimated distribution function of the demand for the good of firm i at the mall in region r, where the estimation is based on demands reported by the mall in the previous T periods. Furthermore, $SL_{i,r,t}$ is the level of the stock of firm i at the mall in region r at the day in period t when the stock is checked. Then, standard results from inventory theory suggest that the firm should choose its desired replenishment quantity for region r according to the following simple rule (see Hillier and Lieberman (1986)):

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

where $Y_{i,r,t}$ is the smallest value $Y \geq 0$ that satisfies

$$\tilde{\Phi}_{i,r,t}(Y) \geq \frac{p_{i,r,t} - (1-\rho)\bar{c}_{i,t-1}}{p_{i,r,t} + C_{i,r}^{inv}}.$$

Here $\bar{c}_{i,t-1}$ denotes unit costs of production for firm i in the previous period, $p_{i,r,t}$ the prices of the consumption good, and ρ the discount factor. The sum of the orders received by all malls becomes

$$\tilde{D}_{i,t} = \sum_{r=1}^{R} \tilde{D}_{i,r,t}.$$

To avoid excessive oscillations of the quantities $\tilde{Q}_{i,t}$ that the firm desires to produce in period t, the time-series of total quantities required by the different malls ($\tilde{D}_{i,t}$) is smoothed. On this account, the consumption goods producer shows some inertia in adapting the actual production quantity to the quantity requested by the malls. In particular, we have

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

As discussed in more detail below, the realized production volume $Q_{i,t}$ can deviate from the planned output $\tilde{Q}_{i,t}$ due to rationing on the factor markets. The quantities actually delivered to the malls, $D_{i,r,t}$, are adjusted proportional to the intended quantities $\tilde{D}_{i,r,t}$, so that

$$D_{i,r,t} = \frac{\tilde{D}_{i,r,t}}{\sum_{r'=1}^{R} \tilde{D}_{i,r',t}} \cdot Q_{i,t}.$$

Production times of consumption goods are not explicitly taken into account and the produced quantities are delivered on the same day when production takes place. The local stock levels at the malls are updated accordingly.

2.3.2 Factor demand

Consumption good producers, denoted by i, need physical capital and labor to produce the consumption goods. The accumulation of physical capital by a consumption good producer follows

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

where $K_i(0) = 0$ and $I_{i,t} > 0$ is the gross investment.

Every worker w has a level of general skills $b_w^{gen} \in \{1, \ldots, b_{max}^{gen}\}$ and a level of specific skills $b_{w,t}$. The specific skills of worker w indicate how efficiently the corresponding technology is exploited by the individual worker. Building up those specific skills depends on collecting experience by using the technology in the production process. There is vast empirical evidence for such adjustment processes (see e.g. Argote and Epple (1990)). The shape of the evolution of productivity follows a concave curve, the so-called learning curve, when the organizational productivity is recorded after implementing a new production method or introducing a new good. Concavity in this context means that the productivity rises with proceeding use of the production method or production of the new good, but this increase emerges at a decreasing rate. We transfer this pattern of organizational learning on the individual level and assume that the development of individual productivity follows a learning curve. The specific skills are updated once in each production cycle of one month. Further, we assume that updating takes place at the end of the cycle.

A crucial assumption is the positive relationship between the general skills b_w^{gen} of a worker and his ability to utilize his experiences. Building up worker's technology specific skills depends on a worker's level of general skills, i.e. his education and the other abilities which are not directly linked to the particular technology. Taking the relevance of the general skill level into account the specific skills of a worker w for technology j is assumed to evolve according to

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

where we denote with $A_{i,t}$ the average quality of the capital stock. The function χ is increasing in the general skill level of the worker. Note that this formulation captures the fact that in the absence of technology improvements marginal learning curve effects per time unit decrease as experience is accumulated and the specific skills of the worker approaches the current technological frontier.

The production technology in the consumption goods sector is represented by a Cobb-Douglas type production function with complementarities between the quality of the investment good and the specific skills of employees for using that type of technology. Factor productivity is determined by the minimum of the average quality of physical capital and the average level of relevant specific skills of the workers. Capital and labor input is substitutable with a constant elasticity and we assume constant returns to scale. Accordingly, output for a consumption goods producer is given by

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

where $B_{i,t}$ denotes the average specific skill level in firms and $\alpha + \beta = 1$.

Firms aim to realize a capital to labor ratio according to the standard rule for CES production functions. That is a ratio of quantity to price of the two factors proportional to the corresponding intensity parameter. Accordingly,

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

Taking into account the above production function this yields under the assumption of positive investments

$$\begin{aligned} \tilde{\tilde{K}}_{i,t} &= \frac{(\beta w_t^e)^{\alpha} \tilde{Q}_{i,t}}{(\alpha p^{inv})^{\alpha} \min[A_{i,t}, B_{i,t}]} \\ \tilde{\tilde{L}}_{i,t} &= \frac{(\alpha p^{inv})^{\beta} \tilde{Q}_{i,t}}{(\beta w_t^e)^{\beta} \min[A_{i,t}, B_{i,t}]} \end{aligned}$$

and if $\tilde{\tilde{K}}_{i,t} \geq (1-\delta)K_{i,t-1}$ the desired capital and labor stocks read $\tilde{K}_{i,t} = \tilde{\tilde{K}}_{i,t}$ and $\tilde{L}_{i,t} = \tilde{\tilde{L}}_{i,t}$. Otherwise, we have

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

For simplicity credit constraints are not incorporated in this version of the model.[4] All desired investments can be financed.

The monthly realized profit of a consumption goods producer is the difference of sales revenues achieved in the malls during the previous period and costs as well as investments (i.e. labor costs and capital good investments) borne for production in the current period. In cases of positive profits, the firm pays dividends to its stockholders and the remaining profits, as well as losses, are entered on an account $Acc_{i,t}$. Similar to the capital goods producer, we assume that all households hold equal shares in all consumption goods producers, consequently the dividends are equally distributed to the households. In order to avoid exceeding accumulations of savings as well as excessive indebtedness, we employ a simple dividend policy that provides different dividend rates depending on the current balance of saving account $Acc_{i,t}$. The rule states that a firm pays no dividends, if the balance is negative and the debt is on a scale above the last monthly revenue. If the balance is positive and savings are above the monthly revenue, the firm disburses all profits. In the remaining case, if the balance is between these critical levels, a fixed proportion $div \in [0,1]$ of profits is paid out.

Since there are no constraints on the credit market and there is infinite supply of the investment good, the consumption goods producers are never rationed on the investment goods market. Wages for the full month are paid to all workers at the day when the firm updates its labor force. Investment goods are paid at the day when they are delivered.

2.3.3 Pricing

Consumption good producers employ a standard approach from the management literature, the so-called 'break-even analysis' (see Nagle (1987)), to set their prices. The break-even formula determines at what point the change in sales becomes large enough to make a price reduction profitable and at what point the decrease in sales becomes small enough to justify a rise in

[4] In contrast, in the fully fledged EURACE platform, there is an explicit credit market model which can be appropriately linked to the real sectors considered here.

the price. Basically, this managerial pricing rule corresponds to standard elasticity based pricing.

Assuming that all firms have constant expectations $\varepsilon_i^e < -1$ of the elasticity of their demand, they set the price according to the standard rule

$$p_{i,t} = \frac{\bar{c}_{i,t-1}}{1 + 1/\varepsilon_i^e},$$

where $\bar{c}_{i,t-1}$ denotes unit costs in production of firm i in the previous period. Once the firm has determined the updated prices $p_{i,r,t}$ for all regions r where it offers its goods, the new prices are sent to the regional malls and posted there for the following period.

2.4 Households' consumption

Once a month households receive their income. Depending on the available cash, that is the current income from factor markets (i.e. labor income and dividends distributed by capital and consumption goods producers) plus assets carried over from the previous period, the household sets the budget which it will spend for consumption and consequently determines the remaining part which is saved. On a weekly basis, sampling prices at the (regional) mall the consumer decides which goods to buy.

2.4.1 The savings decision

Our decision rule for determining the savings is based on the work of Deaton (1991). Deaton examines the saving behavior of impatient consumers when they are not permitted to borrow. In a scenario with independent and identically distributed income draws, he obtains a consumption function depending on cash on hand, which has the following characteristics: There exists a critical value of cash on hand. When the available liquidity is below this critical value the whole cash on hand will be spent. In the opposite case the agent will save a part of his cash on hand.[5] The assets act like a buffer stock which protect consumption against bad income draws.

We assume a stepwise linear approximation of the consumption rule derived by Deaton (1991, 1992). At the beginning of period t, a consumer k decides about the budget $B_{k,t}^{cons}$ that he will spend. In period t the agent receives an income $Inc_{k,t}$, and holds assets $Ass_{k,t}$. Thus, cash on hand is denoted by $Liq_{k,t}^{Avail} = Ass_{k,t} + Inc_{k,t}$. The assets evolve according to

$$Ass_{k,t} = Liq_{k,t-1}^{Avail} - B_{k,t-1}^{cons}.$$

[5] In a more elaborate version savings will also be made dependent on the uncertainty over income.

Note, that while we do not establish interest rates here, in the fully fledged EURACE framework where financial and credit markets are included, interest rates will be incorporated and become endogenous.

The consumer sets his consumption according to the following consumption rule

$$B^{cons}_{k,t} = \begin{cases} Liq^{Avail}_{k,t} - \kappa(Liq^{Avail}_{k,t} - \Phi \cdot Inc^{Mean}_{k,t}) & \text{for } Liq^{Avail}_{k,t} > \Phi \cdot Inc^{Mean}_{k,t} \\ Liq^{Avail}_{k,t} & \text{else,} \end{cases}$$

where $\Phi \leq 1$ is a parameter, and $Inc^{Mean}_{k,t}$ is the mean individual (labor) income of an agent over the last T periods. By definition the saving propensity fulfills $0 < \kappa < 1$.

The implications of this consumption rule are as follows: if an agent has a current cash on hand that is below the fraction Φ of mean income, he spends all available liquidity and nothing is saved. If cash on hand exceeds $\Phi \cdot Inc^{Mean}_{k,t}$, the agent saves a fixed fraction in order to build up a buffer stock for bad times.

The part of cash at hand that is not saved is used as the consumption budget for that month. Each consumer goes shopping once every week, so the monthly budget is equally split over the four weeks. Parts of the weekly budget that are not spent in a given week are rolled over to the consumption budget of the following week. This yields a consumption budget $B^{cons}_{k,week_t}$ for each week in period t.

2.4.2 Selection of consumption goods

The consumer collects information about the range of goods provided. He receives information about prices and inventories. In the Marketing literature it is standard to describe individual consumption decisions using logit models. These models represent the stochastic influence of factors not explicitly modelled on consumption decisions and the power of these models to explain real market data has been well documented (see e.g. Guadagni and Little (1983)). Therefore, we rely on a model of that kind here. We assume that a consumer's decision which good to buy is random, where purchasing probabilities are based on the values he attaches to the different choices he is aware of. Denote by $G_{k,week_t}$ the set of producers whose goods consumer k has sampled in week $week_t$ of period t and where a positive stock is available at the attended mall. Since in our setup there are no quality differences between consumer goods and we also do not explicitly take account of horizontal product differentiation, choice probabilities depend solely on prices. The value of consumption good $i \in G_{k,week_t}$ is then simply given by

$$v_k(p_{i,t}) = -\ln(p_{i,t}).$$

The consumer selects one good $i \in G_{k,week_t}$, where the selection probability for i reads

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

Thus, consumers prefer cheaper products and the intensity of competition in the market is parameterized by λ_k^{cons}. Once the consumer has selected a good he spends his entire budget $B_{k,week_t}^{cons}$ for that good if the stock at the mall is sufficiently large. In case the consumer cannot spend all his budget on the product selected first, he spends as much as possible, removes that product from the list $G_{k,week_t}$, updates the logit values and selects another product to spend the remaining consumption budget there. If he is rationed again, he spends as much as possible on the second selected product, rolls over the remaining budget to the following week and finishes the visit to the mall.

2.5 Labor market

2.5.1 Labor demand

Labor demand is determined in the consumption goods market. If the firms plan to extend the production they post vacancies and corresponding wage offers. The wage offer $w_{i,t}^O$ keeps unchanged as long as the firm can fill its vacancies, otherwise the firm updates the wage offer by a parameterized fraction. In case of downsizing the incumbent workforce, the firm dismisses workers with lowest general skill levels first.

2.5.2 Labor supply

Job seekers consist of a randomly determined fraction ϕ of employed workers who search on-the-job and the unemployed. A worker k only takes the posted wage offer into consideration and compares it with his reservation wage $w_{k,t}^R$. A worker will not apply at a firm that makes a wage offer which is lower than his reservation wage. The level of the reservation wage is determined by the current wage if the worker is employed, and in case of an unemployed by his adjusted past wage. That is an unemployed worker will reduce his reservation wage with the duration of unemployment. When a worker applies he sends information about his general as well as his specific skill level to the firm.

2.5.3 Matching algorithm

According to the procedures described in the previous sections consumption goods producers review once a month whether to post vacancies for production workers. Job seekers check for vacancies. The matching between vacancies and job seekers works in the following way:

Step 1: The firms post vacancies including wage offers.

Step 2: Every job seeker extracts from the list of vacancies those postings to which he fits in terms of his reservation wage. Job seekers rank the suitable vacancies. The vacancy which offers the highest wage is ranked on position one and so on. If the wage offers that come with the posting are equal, vacancies are ranked by chance.

Step 3: Every firm ranks the applicants. Applicants with higher general skill b^{gen} levels are ranked higher. If there are two or more applicants with equal general skill levels, but different specific skill levels, the applicant with the higher specific skill level is ranked higher. Based on their ranking firms send job offers to as many applicants as they have vacancies to fill.

Step 4: Each worker ranks the incoming job offers according to the wages net of commuting costs ($comm > 0$) that may arise if he was to accept a job in the region where he does not live. Each worker accepts the highest ranked job offer at the advertised wage rate. After acceptance a worker refuses all other job offers and outstanding applications.

Step 5: Vacancies' lists and applications' lists are adjusted for filled jobs. If a firm received refusals, these applicants are dropped from the list of applicants. If all vacancies of a firm have been filled the firm refuses the other applicants and the algorithm for this firm ends.

Step 6: If the number of vacancies not filled exceeds some threshold $\overline{v} > 0$ the firm raises the wage offer by a fraction φ_i such that $w^O_{i,t+1} = (1+\varphi_i)w^O_{i,t}$. If an unemployed job seeker did not find a job he reduces his reservation wage by a fraction ψ_k, that is $(w^R_{k,t+1} = (1-\psi_k)w^R_{k,t})$. There exists a lower bound to the reservation wage w^R_{min} which may be a function of unemployment benefits, opportunities for black market activity or the value of leisure. If a worker finds a job then his new reservation wage is the actual wage, i.e. $w^R_{k,t} = w_{i,t}$. Go to step 1.

This cycle is aborted after two iterations even if not all firms may have satisfied their demand for labor. As indicated above this might lead to rationing of firms on the labor market and therefore to deviations of actual output quantities from the planned quantities. In such a case the quantities delivered by the consumption good producer to the malls it serves is reduced

	General Skill Level				
Region	1	2	3	4	5
Low Skill	0.8	0.05	0.05	0.05	0.05
Medium Skill	0.05	0.05	0.8	0.05	0.05
High Skill	0.05	0.05	0.05	0.05	0.8

Table 2: General skill distributions in the three different types of regions.

proportionally. This results in lower stock levels and therefore increases the expected planned production quantities in the following period.

3 Simulation

3.1 General set-up

The model described in the previous section has been implemented in FLAME and in order to carry out simulation based policy experiments. Before we illustrate the potential of our model for carrying out policy experiments with respect to the spatial distribution of policy measures we show that it generates time series of key economic variables with very plausible features. To that end we consider a base scenario which we will refer to as the *base run scenario*. Throughout the document we assume that there are $b^{gen}_{max} = 5$ levels of general skills. The function $\chi(b^{gen}_w)$, which governs the speed of specific skill improvement, is chosen such that the time workers with general skill 3 need to cut the gap between their specific skill and the firm's technology level in half is the mean of the corresponding time needed by a skill level 1 and a skill level 5 worker. An analogous linear relationship also determines the adjustment speed of workers with general skill levels 2 and 4. In a *low skill* region the skill distribution is such that 80% of workers have the lowest general skill level, whereas the remaining workers are equally distributed across the other four levels of general skills. Analogously, a region is a *medium skill* or *high skill* regions if 80% of workers have general skill level 3 respectively 5.

We summarize the skill distributions in three types of regions in table 2. Although none of these distributions match empirical skill distributions in industrialized countries we still use them to show the qualitative effects of policies influencing the skill distribution.

3.2 Calibration

The parameters of our model as summarized in table 3 were chosen whenever possible to reflect empirical evidence. The ratio of the number of households (workers) and firms that we implemented matches mean firm sizes to be observed in Europe.[6] Estimates of labor intensity of the German Statistical office, see Bundesamt (2004), suggest $\alpha = 0.662$ so that we have $\beta = 0.338$ given our assumption of a constant returns to scale production function. The innovation probability γ^{inv} was chosen to reflect estimates approximating shifts of the technological frontier. We assume that there is a 10% probability of a quality improving innovation in the investment goods sector per month and each innovation on average increases the quality of the investment good by 5%. Thus, comparable to data reported in Aghion et al. (2006) our calibration yields a growth rate of the technological frontier of around 6% per year if skills were sufficient to fully exploit technological innovations. The calibration of the yearly depreciation rate follows what is reported in Bundesamt (2006). Our choice for the markup is based on the empirical evidence reported in Small (1997). We take the estimate for motor cycle production as a guideline for a markup of 20 percent. Wage updates (φ_i) are calibrated to match wage growth in Germany during the decade of full employment in the sixties.[7] The parameter value for the adjustment of the reservation wage (ψ_k) was chosen based on reported wage losses of approximately 17% after spells of unemployment in Germany (see Burda and Mertens (2001)), and an average duration of unemployment of 30 weeks which matches German data. As a proxy for the reservation wage we make use of the net replacement rates of unemployment benefit schemes in OECD countries (OECD (2004)). For the marginal propensity to save we chose $\kappa = 0.1$, which is close to the savings rate in Germany in previous years. The calibrated value for the intensity of the consumer choice stems from estimated multi-nominal logit models of brand selection. Estimates based on market data by, e.g. Krishnamruthi and Raj (1988), provide a lower bound for λ_k^{cons}, which captures choices between brands that are available in the same local mall. These considerations suggest the value of $\lambda_k^{cons} = 8.5$ which we have chosen. Finally, we let 10% of the employed search on-the-job which is in the range of ratios reported in Rosenfeld (1977), Black (1981), or Pissarides and Wadsworth (1994). Simulations are run for 250 months which corresponds to about 20 years.

[6] See http://epp.eurostat.eu.europa.eu.

[7] See, for instance, www.sachverstaendigenrat-wirtschaft.de/timerow/tabdeu.php.

Table 3: Parameter settings

Description	Parameter	Value
Number of households:		400
Number of firms		10
Number of regions	R	2
Labor Intensity of Production	α	0.662
Capital Intensity of Production	β	0.338
Innovation probability	γ^{inv}	0.1
Depreciation rate of capital	δ	0.01
Monthly Discount factor	ρ	0.95
Mark-up factor	$\frac{1}{\lvert\epsilon_i^e\rvert-1}$	0.2
Wage update	φ_i	0.02
Reservation wage update	ψ_k	0.02
Minimal reservation wage	w_{min}^R	1
Marginal saving propensity	κ	0.1
Intensity of choice by consumers	λ_k^{cons}	8.5
Commuting costs	$comm$	0.2
Fraction of on-the-job searchers	ϕ	0.1

3.3 Coping with stylized facts for the base case

There is a range of stylized facts for goods and labor markets and innovation processes. Most of these were already documented in our last year's deliverable D.7.1. On top of these empirical regularities Dosi et al. (2008) present a collection of stylized facts for business cycles. We started to confront the outcomes of our model with these findings. It will be one of the main tasks in the last year of the Eurace project to accomplish coping with an even broader set of stylized facts.

The current outcomes occur to be a promising step towards the achievement of having a model that can deal with stylized behavior to be found in goods and labor markets, for innovation processes, and in the business cycle literature. Taking the case of zero commuting costs and low general skill levels in both regions we are able to generate a yearly real output growth rate of approximately 2.6% which is in the range of what one can typically observe.[8] Real wage growth rates are in the magnitude of 3.8%. The generated wage distribution reflects what one finds empirically. Workers with

[8]All data for the base case refer to the means of 50 batch runs averaged over the last five years of the simulation period.

higher general skills earn higher wages. Furthermore, and in line with empirical observations, the risk of being unemployed is unequally distributed among the worker population. Workers with higher skill levels have lower unemployment rates. Averaging the unemployment rate over all skill levels we get a rate of 23%. The rather high average unemployment rate is driven by the somewhat artificially high share (80% in this scenario) of low skilled workers who have a high risk of unemployment whereas the other skill groups have unemployment rates between 1% and 3%.

The next steps towards coping with a broader set of stylized facts will be to look more closely at the business cycle features of our model. This will include the evaluation of time series properties. Based on preliminary observations we expect to be able to replicate that investment is typically more volatile than consumption and consequently output. Furthermore we will look into cross-relations of our output and labor market series. Features such as pro- or counter-cyclicality and lag structures will be analyzed. The number of agents currently employed does not allow us to address firm-size properties in any meaningful way. Once the software platform is apt to run the model with larger populations size distributions will be looked at as well as diffusion processes of innovations. The aim will be to cover as many of the stylized facts of the goods and labor market, innovation processes and the business cycle as possible with a strong focus on the European economy.

3.4 Policy experiments

In our policy experiment we consider an initial condition where both regions in our economy are low skill regions and a policy maker intends to invest in the upgrading of general skills in the economy. Due to financial constraints it is not possible to upgrade both regions to high-skill regions. Rather the policy maker has to choose between two options. Either both regions can be upgraded to medium skill or efforts are concentrated in region 2 thereby moving this region to high skill whereas the skill distribution in region 1 stays unchanged. We examine the effects of these two types of policies for two different scenarios characterized by the level of commuting cost. On the one hand, we consider the scenario where commuting costs are zero ($comm = 0$) and in the second scenario we set commuting costs to 5% of the initial wage level in the economy ($comm = 0.05$), which we consider as a positive but low level of commuting costs.

In order to address this question we have run batches of 50 simulation runs for the *uniform medium* and *low-high* scenarios and compare them with each other and with the base case of uniform low-skill regions. In figure 1 we compare mean trajectories of output over the 50 runs in the three cases for

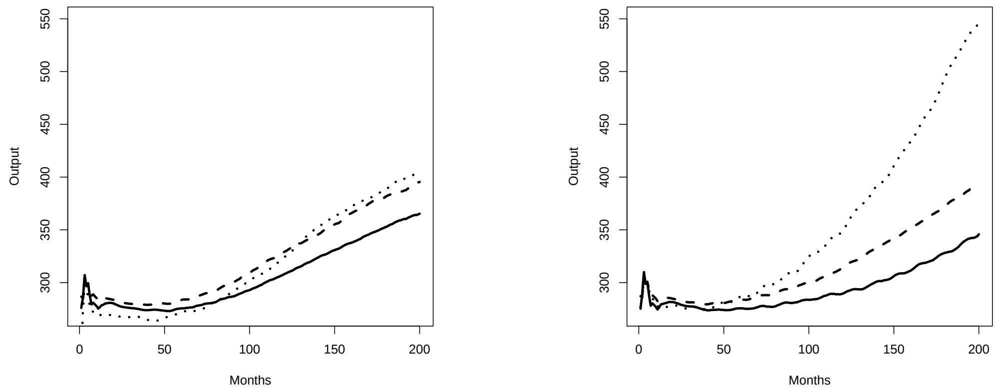

Figure 1: Batch run with zero (left panel) and low (right panel) commuting costs for outputs in uniform low scenario (solid line), uniform medium scenario (dashed line), and low/high scenario (dotted line);

$comm = 0$ and $comm = 0.05$. Each simulation is run for 200 months, which corresponds to about 17 years. The economy consists of two regions where in each region 5 consumption good producers and 200 workers/households are located.

It can be clearly seen that the relative performance of the two different types of policy distributions depends crucially on the level of commuting costs. If commuting costs are zero, which means that there exists a global labor market without spatial frictions, no significant difference in output growth between the uniform medium and the low/high scenario can be detected. In both cases the policy induced increase in general skills leads to an improved growth rate compared to the uniform low scenario. Quite a different picture emerges for low positive commuting costs. Here the growth rate is substantially larger in the low/high scenario than in the uniform medium scenario and also substantially larger than the growth rate in the low/high scenario without commuting costs. This finding is remarkable for two reasons. First, it is qualitatively opposite to the effects of the different policy types if commuting costs are large. As discussed in Dawid et al. (2008) for large commuting costs a uniform distribution of skill upgrading measures leads to higher growth than a spatially concentrated policy. Second, if the spatially concentrated policy is implemented the introduction of small spatial frictions on the labor market actually improves performance compared to a frictionless global labor market. Both observations are at first sight surprising and demonstrate the non-linear and path-dependent nature of the

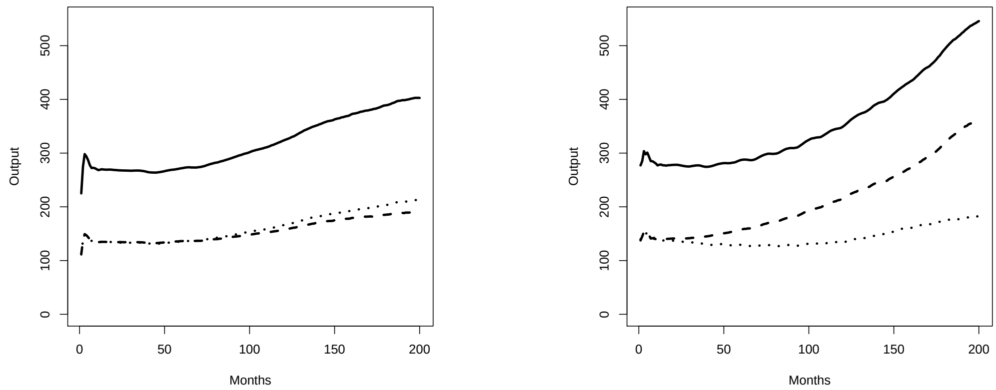

Figure 2: Batch runs for zero (left panel) and low (right panel) commuting costs; total outputs (solid line), output in the low skill region (dashed line), output in the high skill region (dotted line);

relevant economic processes.

In order to get a better understanding of the economic mechanisms responsible for relative performance of the two policy types we examine in more detail the features of the dynamics of several key variables in the low/high scenario. We always simultaneously consider the cases $comm = 0$ and $comm = 0.05$, since such a comparison highlights the mechanisms that are driving the results.

Figure 2 shows the dynamics of the aggregate output of producers in the low skill region 1 and the high skill region 2. Whereas with no commuting costs both regions produce about the same output, in case of low commuting costs the low skill region exhibits a strong growth in output over time and at the end of the considered time interval of 200 months produces about double the output of the high–skill region. To understand why the output of the high skill region is not larger than that of the low skill region, it has to be kept in mind that the terms high and low skill regions refers to the skills of the workers living in a certain region rather than to the skills of workers working in a certain region. As can be seen in figure 3 in both scenarios a substantial number of high-skill workers commute to the low-skill region and work for producers located there. In case of no commuting costs almost half of the high skill workers commute throughout the entire time interval of 200 periods, so the number of high-skill employees in both regions is almost identical which also explains the relatively homogeneous output quantities across the two regions. Also, without commuting costs there is a substantial

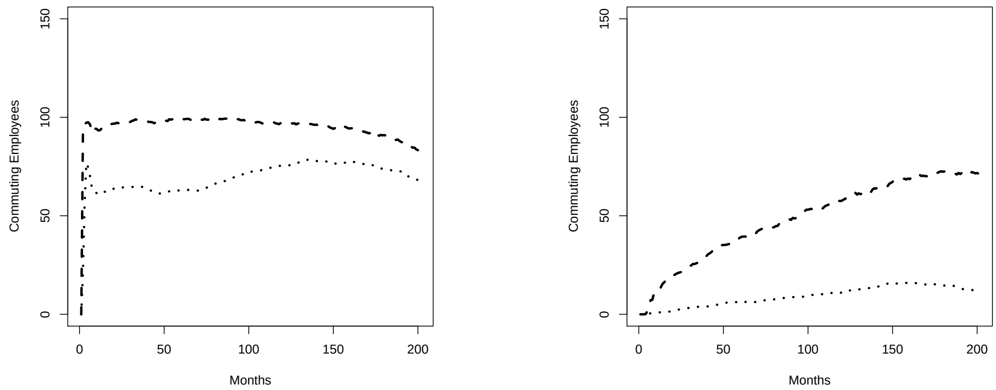

Figure 3: Batch runs for zero (left panel) and low (right panel) commuting costs; number of commuters from low to high skill region (dotted line), number of commuters from high to low skill region (dashed line);

number of commuters from the low-skill to the high-skill region. As has to be expected the introduction of small commuting costs reduces the flow of commuters in both directions, where the number of commuters from the high- to the low-skill region is still substantial and increasing over time. On the other hand, the flow from the low- to the high-skill region becomes very small. So, a first observation to be made is that as well with zero as with small commuting costs substantial transregional spillovers through the labor markets emerge and both regions profit from the general skill level of workers in the high skill region.

The fact that these spillovers have a much more positive effect in the low skill region if commuting costs are positive is due to the different demand dynamics emerging for different commuting costs. Differences in demand for goods produced in the two regions are triggered by price differences which again are driven by wage differences in the two regions. In case of a global labor market no systematic wage differences between the two regions emerge and as can be seen in figure 4 there are no significant price difference between the goods produced in the two regions. In the case of positive commuting costs systematic price differences emerge after a short initial phase, where products from the low-skill region are cheaper than those from the high-skill region. The reason is that initially the number of commuters from the high- to the low-skill region is small and therefore the vast majority of workers with high general skills work for producers in the high-skill region. On the one hand, this leads to a faster wage dynamic in that region because employers

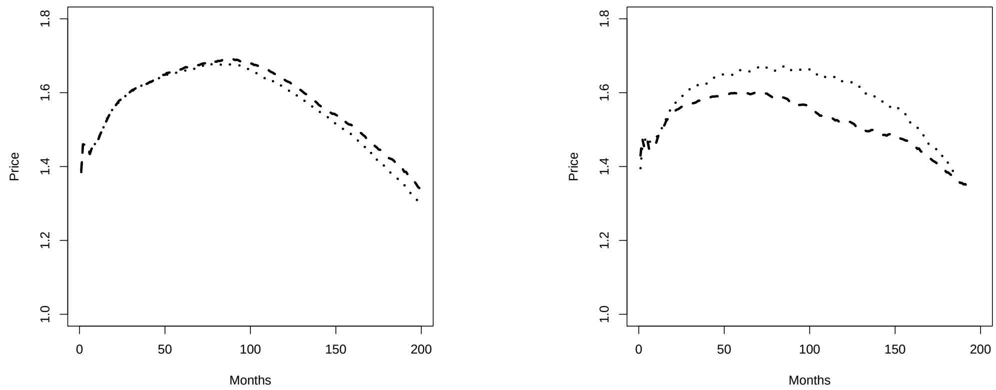

Figure 4: Batch runs for zero (left panel) and low (right panel) commuting costs; prices in the low skill region (dashed line), prices in the high skill region (dotted line);

have preferences to hire high-skilled workers and therefore these workers are more likely to carry out successful on-the-job searches, thereby increasing their wages[9]. On the other hand, initially the difference in specific skills between workers with different levels of general skills are small and therefore producers in the high-skill region have higher unit-costs than those in the low-skill region. This translates to the observed price difference and due to this price difference demand shifts towards the goods produced in the low skill region. Producers in that region react to the increasing demand by investing in new capital stock (see figure 5, which due to the assumed technological progress in the investment good sector also improves the quality of their capital stock and increase their productivity. This is a self-reinforcing process because improvements in productivity reinforces the price advantages of producers from the low-skill region and generates additional positive demand effects. At the same time the output expansion of producers from the low skill region leads to a transfer of high-skilled workers from the high- to the low-skill region (see figure 3). The reason that we can see a flow of high-skilled workers from the high- to the low-skill region despite of the fact that the average wage level in the high-skill region is higher, is that due to the falling demand for goods produced in the high-skill region labor demand goes down there and high-skilled workers become unemployed. Indeed the capital and labor investment process triggered by the price heterogeneity is

[9]Due to space constraints we do not present the graph that demonstrates the wage differences between the regions.

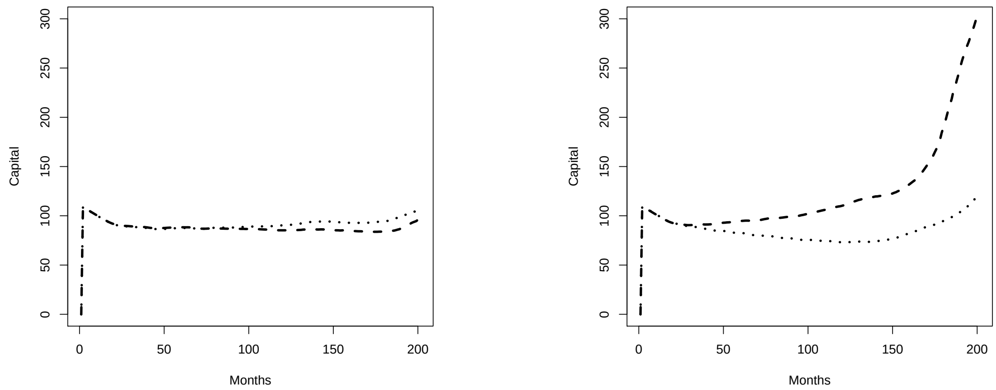

Figure 5: Batch runs for zero (left panel) and low (right panel) commuting costs; capital stock in the low skill region (dashed line), capital stock in the high skill region (dotted line);

the crucial mechanism responsible for the high growth of the low-skill region output. As can be seen in figure 5 no net investment of capital emerges in the case without commuting costs where price stay almost homogeneous throughout the run.

The chain of effects we have discussed above implies that with positive but low commuting costs a self-reinforcing cycle of capital and labor investments by producers from the low-skill region arises which implies that output in that region grows fast and is larger than output in the high-skill region. This however does not imply that in such a scenario the low-skill region also has an advantage with respect to regional income and consumption. As can be seen in figure 6 labor income is in both scenarios larger in the high-skill than in the low skill region, where the difference is smaller in the presence of small positive commuting costs. This of course is due to the fact that high-skilled workers earn higher wages than low-skilled ones regardless of where they are employed. An interesting observation to be made in figure 6 is that labor income in both regions goes up as the commuting costs increase from zero to a positive level. Accordingly, for $comm = 0.05$ total output in the economy and labor income in both regions are larger than in the absence of spatial frictions in the labor market.

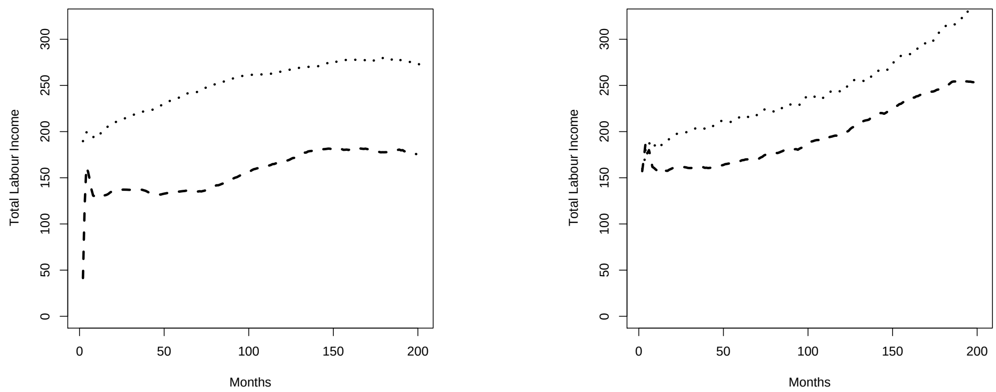

Figure 6: Batch runs for zero (left panel) and low (right panel) commuting costs; total labor income of workers in the low skill region (dashed line) and the high skill region (dotted line);

4 Conclusions

Following the agenda of the second year of EURACE WP 7 we have in this document used the part of the EURACE model describing the interaction between goods and labor markets to examine the question how the effects of different spatial concentrations of economic policy measures depend on spatial frictions in the labor market. In particular, we have compared scenarios where general skills of workers are upgraded uniformly across regions with regionally concentrated upgrading. It has been shown that in the absence of commuting costs the spatial distribution of the policy measures does not significantly affect their impact. However, if commuting costs are positive but low than a spatially concentrated policy performs better than a uniform approach. In case such a policy is applied the existence of spatial frictions has positive effects on total output in the economy and on labor income in both regions. These positive effects are due to the combination of technological spillovers to the low-skill region through the labor market and demand induced investment incentives for producers in that region. As has been shown in Dawid et al. (2008) the advantages of the spatially concentrated policy disappear if commuting costs become larger and the technological spillovers are reduced.

These insights have several policy implications. First, they clearly demonstrate that the optimal spatial distribution of policy measures depends crucially on the spatial frictions in different markets. As our results demonstrate the effect of an increase in a parameter like the commuting costs is not always monotonous and therefore a good estimate of such frictions is needed to give sound policy advise. Second, if we take the spatial skill distribution as given and consider policy measures aiming at the reduction of spatial frictions on the labor market, our findings suggest that in cases where skill distributions differ between regions it is desirable to reduce commuting costs to a level where substantial spillovers between regions through the labor market can arise, but it is not necessarily desirable to completely eliminate the spatial frictions. The finding that the existence of frictions can have positive macroeconomic effects is to our knowledge an innovative observation in this type of literature. As has been demonstrated in our discussion above it is due to the combination of the explicit consideration of agents' heterogeneities and of the path dependencies of transient dynamics on the goods and labor market. In that respect we feel that these observation very well illustrate the potential of agent-based models to produce innovative insights into economic dynamics and policy design.

Future work using the fully integrated EURACE framework will allow to examine in how far the qualitative effects pointed out in this document interact with important other aspects of economic processes like financing issues and credit constraints.

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