Labor market integration policies and the convergence of regions: the role of skills and technology diffusion

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Abstract

We study the role of different labor market integration policies on economic performance and convergence of two distinct regions in an agent-based model. Production is characterized by a complementarity between the quality of the capital stock and the specific skills of workers using the capital stock. Hence, productivity changes in a region are influenced both by the investment of local firms in high quality capital goods and by the evolution of the specific skill distribution of workers employed in the region. We show that various labor market integration policies yield via differing regional worker flows to distinct regional distributions of specific skills. Through this mechanism relative regional prices are affected determining the shares that the regions can capture from overall consumption good demand. There occurs to be a trade-off between aggregate output and convergence of regions with closed labor markets resulting in relatively high convergence but low output, and more integrated labor markets yielding higher output but lower convergence. Furthermore, results differ substantially in several respects as distinct labor market opening policies are applied.

Keywords: labor market integration, convergence, skill complementarity, agent-based model, regional economics

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1 Introduction

An important challenge faced by the European Union (EU) is the integration of several Eastern European countries that became EU members at the eastward enlargement in 2004. Ten new countries joined the EU then, 8 of which formerly were under communist rule. From the fall of the Iron Curtain to present these countries have faced similar structural problems that can be considered as an inheritance of the communist planned economy: a quantitatively and qualitatively worse endowment of physical capital as well as less skilled human capital compared to established member states like France, Germany or the UK.

In this paper we ask (and try to answer) the questions to which extent different policies of opening up labor markets accompanying the integration process affect output and consumption in regions that start(ed) from different levels of economic development, and how these policies impact the convergence processes in general.

Prior to the eastward enlargement of the EU a long-lasting and fierce debate emerged concerning the extent to which integration should also cover labor markets. The European Commission had to take into account in its decision that there was the fear in the general public that an opening up of labor markets would lead through massive flows of labor from the east to the west to labor market tensions, social imbalances, and crime. In an influential policy paper Boeri et al. (2002) argued that estimates on to be expected labor flows were showing a high degree of uncertainty which would warrant a postponement of full liberalization of labor migration until more accurate numbers were available but by the same time would strongly suggest to start opening up labor markets, and phase out the transition period at a preannounced date. Finally it was agreed upon that after accession countries became part of the EU in May 2004 there should be a transition phase of up to seven years where member countries would be allowed to impose restrictions on labor mobility of workers. Along the "2+3+2" formula restrictions had to be reviewed after two and another three years. Only the UK, Ireland and Sweden opened up their labor markets already in 2004. After the first review seven members lifted their restrictions, some simplified their procedures while others like Austria and Germany even after the second revision maintained their rigorous stance requiring working permits for workers from former communist states.

Five years after the accession it occurs to be still to early to evaluate how economies of the old and new members states unfolded as a response to these particular labor market policy choices. Ultimately, it will be an empirical question to assess to which extent per capita growth on both sides of the former Iron Curtain, and convergence of the two so distinct European regions were affected.

In fact, these policies as they were implemented and in some cases changed in the meantime accompanying the integration process of EU countries raise important and so far not well understood research questions. In particular, it is an unresolved issue to which extent spatial frictions with respect to labor mobility may have positive or detrimental effects on overall and region specific variables related to the well-being of their citizens in the medium and long run. It is a non-trivial task to take into account the most likely consequences of various labor market integration policies in a world where there is complementarity between technologies used in a country and the specific skills needed to fully exploit the merits of these technologies, and where the speed of adoption of the necessary specific skills is driven by general skills, whose distribution differs between countries[1]. Moreover, important feedback processes through wage dynamics, accompanying productivity growth and demand shifts driven by changes in households' consumption and investment behavior of firms, interplay with the mobility of workers.

Our work relates to the growth literature on convergence, which according to the neoclassical approach (see, e.g., Solow, 1956; Mankiw et al., 1992; Barro und Sala-i-Martin, 1992)) is the result of decreasing returns to physical or human capital. Among others, empirically the speed of convergence was investigated by Islam (1995) based on cross country data and by Canova und Marcet (1995) drawing on regional data. Howitt (2000) explains convergence taking cross-country knowledge spill-overs as a starting point, and Keller (2004) puts geographic proximity at the forefront.

We contribute to the convergence literature by studying the dynamic linkages between inter-regional spillovers through labor mobility and technological diffusion driven by demand induced investment of firms. All firms have access to latest technology provided by an investment good producer. However, regions differ in their initial current productivity which is a central distinguishing feature between new and old member states of the EU, or the West and former East Germany. In particular there are different endowments with respect to the current technology used, the specific skills necessary to operate the capital stock, and the distribution of general skills. Although the latest technology can be bought by any firm in any region there are restrictions to use this technology because of the constraining factor of specific skills. This brings into the picture a so far not well studied channel (see, e.g.,

[1]There is ample empirical evidence that in many cases the diffusion of innovations requires adequate skills of the workforce at the firms adopting the innovation (see e.g. Bassanini und Scarpetta (2002), Griffith et al. (2004)).

Acemoglu, 2009, Ch. 18) for the diffusion of technology and convergence of regions. Labor movement between the regions changes the allocation of specific and general human capital and thus the exploitability of the current technological level and the speed of adjustment to the current technological level. Choices of workers to offer labor in one of the regions is restricted by an exogenous and politically determined level of labor market integration. And thus different policies on labor market integration may have non-trivial repercussions on productivity growth in the regions. Under particular consideration of the dynamic effects discussed above we will address the following policy questions:

- How does the timing of the opening up of labor flows between (technological) leader and laggard regions affect growth and productivity development in both regions?
- Which differences arise in short-term and long-term effects of different labor market opening policies?
- In how far are technological spillovers induced by labor flows essential for the convergence between the regions?

There is little work on knowledge spillovers driven by migrating workers. Among the few suggestions elaborating that particular channel are Wong und Yip (1999) and a very recent study by Aghion et al. (2009). This investigates the spillovers occurring between regions in terms of human capital endowments by letting workers migrate. In that sense our set-up is similar. We, too, look into the effects of different allocations of workers and therefore human capital across the regions by studying distinct scenarios of opening up regions for labor commuting. However, in terms of modeling choices we look into a different role of human capital for the growth mechanics as opposed to Aghion et al. (2009). In particular, they make a distinction between "high brow" and "low brow" educational endowments with the former fostering innovation and the latter imitation of existing technologies. The role which we assign to human capital endowments is different. Our distinction is between general and specific skills, with general skills driving the speed of specific skill adoption which are necessary to run the current capital stock. And consequently, labor movements from one region to another have an effect on the specific and general skill levels in the regions thus affecting the speed of adoption of the current level of productivity to the technological frontier.

Agent-based models have been developed in many areas of economics. Among others, they have been used to study the emergence of trading behavior on goods-markets and on financial markets, bidding behavior in auctions, numerous issues concerning innovation and industry evolution or the emergence of cooperative behavior in economic systems. A large part of this work is surveyed in Tesfatsion und Judd (2006). Agent-based work in the area of macroeconomic modeling is however sparse. Closed macroeconomic models using an ACE approach have been provided for example by Chiaromonte und Dosi (1993), Silverberg und Verspagen (1993), Delli Gatti et al. (2005), Dosi et al. (2010) or Haber (2008) but these models do neither focus on spatial aspects nor on the effects of labor flows. Closest to this work are the preceding studies by Dawid et al. (2008, 2009), where the effects of different skill upgrading policies on technological change and growth were analyzed in the EURACE macroeconomic model, which is also the basis for this paper. The research focus of this paper on the comparison of labor market opening strategies, however, is quite distinct from the questions addressed in these previous studies. Also, in this paper we deal with the interaction between regions which differ in several important aspects, whereas in Dawid et al. (2008, 2009) scenarios were considered where regions differ only with respect to the general skills distribution among workers.

On a more general level the discussion of the policy experiments highlight the fact that an agent-based approach, namely to evaluate single or combined policy measures in the framework of a closed macroeconomic model with micro foundations that encompasses the interaction between different sectors, allows insights that go beyond the current economic literature. In particular, in the policy area considered here we extend the literature reviewed above quite fundamentally by incorporating the feedback effects arising from technology and skills development through (regional) demand dynamics on consumption and investment goods markets and by discussing the way frictions on different markets influence policy effects. Furthermore, we can explicitly distinguish between short and long run implications of policies.

Finally, our work is in several respects closely related to the literature in Evolutionary Economics. First, the driving factor of (regional) economic growth in our model is technological change brought about by a combination of investment by firms in new technologies and skill acquisition by workers. Second, our work is related to evolutionary industry life cycle models (e.g. Dosi et al. (1995)) in a sense that the industry structure is endogenous and its evolution is driven by the relative competitiveness of firms caused by their investment in new technologies and by their ability to use these technologies. Third, our rule-based approach to capture firm behavior builds strongly on the rich evolutionary literature in this area like e.g. Nelson und Winter (1982) or Malerba et al. (2001).

We proceed by describing the core modeling assumptions, the parametrization of the agent-based model and the set-up of the experiments. In section

4 we present and discuss our results from the various policy scenarios. In the last section we conclude and sketch some directions for future analysis.

2 The model

We conduct our analysis in an agent-based macroeconomic model that has a distinct regional dimension. Rather than fully describing in detail the various elaborate features of our framework we stick here to a description of the core assumptions that are necessary for an understanding of our results. The model, already used for other policy analysis on the role of fostering human capital endowments in a spatial context, is explained in detail in the Online-Appendix A (see also Dawid et al. (2008, 2009)).

The focus in our experiments on labor market policy integration is on the interaction of three markets namely the labor, the consumption goods, and the capital goods market in a regional context, i.e. each firm and each household is located in one of the regions. The spatial extensions of the markets differ. The capital goods market is global meaning that firms in both regions buy from the same capital good producer and therefore have access to the same technology. On the consumption good market demand is determined locally in the sense that all consumers buy at a regional market located in their region, but supply is global because every firm might sell its products in all regional markets of the economy. Labor markets are characterized by spatial frictions determined by commuting costs that arise if workers accept jobs outside their own region. We model commuting costs as a proxy for the various degrees of labor market integration, where these costs may be inhibitive so that no worker flows occur, or may be at more moderate levels where workers decide to accept jobs in the other region if the wage difference nets out the costs from commuting. The basic time unit in the model is one day, where many decisions, like production choice or hiring of firms, are take monthly.

The consumption goods producer uses labor (L) and capital (K) as input factors. Both are vertically differentiated. The production quantity $Q_{i,t}$ of firm i in period t is given by

$$Q_{i,t} = \min[B_{i,t}, A_{i,t}] \times L_{i,t}^{\alpha} K_{i,t}^{\beta}, \tag{1}$$

where $B_{i,t}$ denotes the average specific skill level in the firms, $L_{i,t}$ is the number of workers and $\alpha + \beta = 1$. The variable $A_{i,t}$ measures the average quality of the capital stock of firm i at time t. Note, that due to $\min[B_{i,t}, A_{i,t}]$ there is complementarity between the quality of capital goods and the specific skill level of the workers. The average quality of the capital stock of a firm increases over time as due to investments of the firm the most recent vintages of the capital good are added to the stock. The technological quality of the capital good sold by the capital good producer increases over time following a random process and the quality of the capital good sold at time t is referred to as the 'technological frontier' at time t.

Workers' human capital endowments have two dimensions. They embody an exogenously given level of general skills and an endogenously level of specific skills which changes on-the-job with the operation of the currently employed technology. The acquisition of specific skills in the production is faster for higher general skill levels. The specific skills can be interpreted as capabilities and experiences obtained on the job. These skills are associated to the technology being used by the employer. Formally, the workers increase the specific skills over time by a learning process. The speed of learning depends on the general skill level b_w^{gen} of the worker w and the quality of the technology $A_{i,t}$ used by employer i.

$$b_{w,t+1} = b_{w,t} + \chi(b_w^{gen})(A_{i,t} - b_{w,t}) \tag{2}$$

Here $b_{w,t}$ are the specific skills of worker w in period t and $\chi(b_w^{gen})$ increases with b_w^{gen}. The average specific skills $B_{i,t+1}$ in firm i is given by the values of $b_{w,t+1}$ averaged over all workers employed by firm i at $t+1$.

The wage offer has two constituent parts. The first part is the market driven base wage $w_{i,t}^{base}$. The base wage is paid per unit of specific skill. If the firm can not fill its vacancies it increases the base wage to attract more workers. The second part is related to the specific skills. Since the specific skills represent the productivity of the workers the wage $w_{i,t}$ is higher for higher specific skills. For each of the general-skill groups the firm i offers different wages $w_{i,t,g}$ in period t. The wage offers are given by

$$w_{i,t,g} = w_{i,t}^{base} \times \bar{b}_{i,t,g} \tag{3}$$

where $\bar{b}_{i,t,g}$ are the average specific skills of all workers with general skill g in the firm. The underlying assumption of this determination of wage offers is that firms can observe general but not specific skills of job applicants.

The price of the capital good increases with its rising quality and finally the price of the consumption good sold by any of the firms in the market is determined by a standard elasticity based pricing rule. Assuming that all firms have constant expectations $\varepsilon_i^e < -1$ of the elasticity of their demand, they set the price according to the rule

$$p_{i,t} = \frac{\bar{c}_{i,t-1}}{1 + 1/\varepsilon_i^e}, \tag{4}$$

where $\bar{c}_{i,t-1}$ denotes unit costs in production of firm i in the previous period. As indicated above, producers distribute their goods by offering them at the posted price $p_{i,t}$ at the regional markets located in each region. The quantities they deliver to each of these markets every month (and hence the total production quantity in that month) are determined by production planning heuristics applied to demand estimations based on past data. Consumers regularly visit their regional market and make purchasing decisions described by a standard logit-choice model. For these and numerous additional decisions not mentioned here (detailed explanations are in the Online-Appendix A), the general modeling approach is to find rules which are backed by managerial decision rules documented in the corresponding management literature, or empirically based results on consumer choices that can be found in the corresponding marketing literature. Overall, the modeling choices are when feasible, empirically based, as is the parametrization to which we turn now.

3 Parametrization and set-up of experiment

Table 1 summarizes the general set up in terms of the numbers and types of agents and regions involved. There are two regions, each region hosts 800 households, 40 consumption good producers, and a regional market denoted as mall. There is a single capital goods producer.

Table 1: General set up

Description	Value
Regions	2
Households	1600
Consumption goods producers	80
Capital goods producers	1
Malls	2

We model the two regions featuring distinct total factor productivity. It is not our intention to focus on two particular regions when choosing parameters and initializations of the simulations, as we want to make a more general point on the role of labor market integration policies on economic performance and convergence of two regions with different endowments with physical and human capital. However, to have a solid empirical grounding of the experiment we choose values which are reflecting differences between Germany and Poland that are particularly relevant for the aspects of the integration dynamics we want to study. To that end we rely on institutional and OECD data as well as on empirical findings reported in Growiec (2008). In this paper the distance to the world technological frontier is determined for OECD and new EU member countries based on Data Envelopment Analysis. Furthermore, Growiec (2008) uses the resulting estimates of relative efficiency levels to decompose the ratios of per capita output into ratios of several factors including physical capital per capita and human capital. We approximate the estimated ratios of physical capital stocks and of total factor productivity between Germany and Poland reported in Growiec (2008) by initializing the per capita stock of physical capital in the high income region 1 as three times higher than that in region 2 and both specific skill levels and average capital quality in region 1 at 150% of that in region 2. Furthermore, it is assumed that at $t = 0$ the technology used in the region 1 corresponds to the technological frontier, and wages in region 1 are 1.8 times higher than in region 2.

Table 2: Experiment design with initial values for different variables for the high income region 1 and low income region 2

	Region 1	Region 2
Technological Frontier	1.5	1.5
Per Capita Capital Stock	3600	1200
Productivity Capital Stock	1.5	1.0
Specific Skill Level	1.5	1.0
Wage	1.8	1.0

In addition to the differences in the initialization of key variables in the two regions we also capture institutional respectively more persistent regional differences by setting (constant) parameters differently in the two regions. In particular, we incorporate differences in general skills of workers between the regions as measured in the International Adult Literacy Survey (IALS) and represent differences between the social security systems by setting the wage replacement rate in case of unemployment to 70% in region 1 and 60% in region 2[2]. All other parameters were chosen as in previous calibrations of the corresponding simulation model (see Dawid et al., 2008, 2009) combining what the relevant literature reports on empirical estimates relating to the various parameters of the model with considerations of viability of the model

[2]Again these numbers were motivated by empirical observations in Germany and Poland.

and its ability to reproduce standard stylized facts.

After choosing the parameters for the model we compare in our experiments four policies, which read the following:

> **"closed"**: Workers can only work in their domestic region.
>
> **"closed-1000-open-c"**: Workers can work in both regions after the first 1000 periods (50 months) and have to bear commuting costs.
>
> **"open-c"**: Workers can work in both regions but face commuting costs.
>
> **"open"**: Workers can work in both regions but do not face commuting costs.

These experiments are thought to address the policy question formulated in the Introduction.

For each scenario we run 38 single runs. Each single run represents 6000 periods (days), which corresponds to 300 months since we assume that each month has 20 (working) days. We allow for a transient phase of 2000 periods (100 months) before policies are applied in order to let the economy develop and to avoid starting effects. The transient phase is not part of the economic analysis in the following and consequently not shown in the figures. During the transient phase the technological progress is switched off, no worker flows occur and consumption goods are only delivered to the regional malls where production took place. After 2000 periods consumption and capital good markets are opened between the regions and results are shown from 60 periods later onwards to let firms adjust their delivery volumes of consumption goods to the other region after the regional goods market were opened.

Before we discuss the findings of our simulation analysis, it is useful to explicitly point out why a simulation approach is needed to study the effects we are interested in. A meaningful examination of the dynamics of the agent-based model per se, which in a mathematical sense can be interpreted as a Markov process in a high-dimensional state-space, by analytical means is prevented by the complexity of the involved transition functions. So, any analytical treatment would have to rely on a mean-field approach, where only the dynamics of the first few moments of the distribution of variables, like the specific skill level of workers is captured. Given our approach to describe individual decision process by means of empricially founded and partly quite complex rule-based heuristics, a closed form formulation of such a mean-field model would already be quite challenging. But even if such a model could be formulated, it is quite obvious that important aspects of our model, that will be crucial for the mechanisms driving our results, could not be captured in such a model. Consider for example the interplay of the movement of workers between regions and the dynamics of skill acquisition. The decisions of workers to accept a job in a different region depends on their reservation wage, which again depends on their (general) skills and their job history. These two aspects influence the specific skill levels of the considered workers, which means that the micro-structure of the interaction leads to a systematic bias in the specific skill levels of commuting workers relative to the average specific skills in that region. Furthermore, the acquistion of specific skills by workers commuting from an ex-ante low-tech to an ex-ante high-tech region will be systemtically different from the average speed of skill acquisition in that region due to their larger skill gap. Since these workers are more likely to move back to firms in the low-tech regions once these firms have closed the wage gap, another systematic bias with respect to skill transfer between the regions occurs when these workers move back to firms in their home region. To capture such effects an explicit representation of the micro-interactions is needed and hence mean-field models or even more so representative agent models, that are analytically tractable, are no feasible alternatives.

4 Simulation results

We are interested in how different policies targeting the integration of the two distinct regions fare. As a measure of performance we consider (regional) output of the consumption good for most of our analysis. However, at the end of the section we will also comment on the effects the different policies have on regional consumption. Figure 1 displays output using box plots that represent the distribution across 38 batch-runs for each policy scenario, where output is given by the average over the last twenty monthly observations. The four scenarios are ordered in a way that from left to right the amount of spatial labor market frictions go down. From the aggregate point of view we observe that opening labor markets increases total output, but the particular way the labor market is opened has little long-run impact. Total output is lowest for the policy option of never allowing labor flows between the regions ("closed"). For all other three scenarios which are opening up the labor market delayed by 50 months and some commuting costs ("closed-open-1000-c"), opening up immediately imposing some commuting costs ("open-c"), and full integration right away ("open"), no output differences occur. Applying Wilcoxon rank test the only statistically significant differences occur if we compare the closed scenario with any of the integration scenarios.

Interestingly, the aggregated point of view hides regional differences oc-

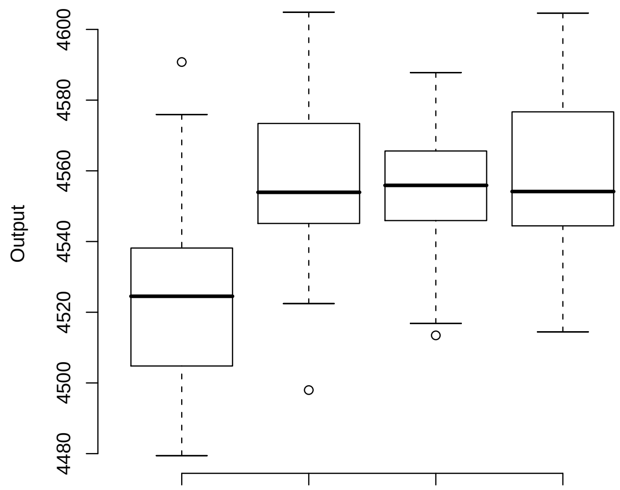

Figure 1: Output (from left to right) for scenarios: “closed”, “closed-open-1000-c”, “open-c”, and “open”.

curring along the policy scenarios again taking output as the performance measure. Figure 2 summarizes the outcomes, now, showing box plots by policy scenario and by region. While output leveled off at the aggregate it shows quite striking regional differences along the different policy options. For the high income region, as we start allowing for regional labor market flows going from the “closed” scenario to the “closed-open-1000-c” and the “open-c” scenario, output increases, again measured as the mean of the last 20 months of the simulated time series. Going for the full integration policy with no commuting costs involved yields an outcome somewhere located between the output levels of a closed and delayed opening of the regional labor markets.

An inverse ranking along the policy experiments can be observed for the low income region 2. For the first three policy scenarios output becomes lower and lower as we integrate regional labor markets. And going to the extreme of imposing no commuting costs we get, again, an output level somewhere located between the output associated with a closed and regional labor markets opened after 50 months. Thus, looking at convergence of the two regions as a function of the various policy options, we are confronted with the least unequal distribution of output across regions if labor markets are closed, where, however, recalling the result from figure 1 total output was lowest, too. As among all the remaining polices total output is equal, a ranking of the other three policies based on an objective which is to reduce regional inequality, would be "open" followed by "closed-open-1000-c", and "open-c". Two sided Wilcoxon signed rank tests were carried out for each pairwise comparison of policies in each region and it was established that all in figure 2 observed output differences are statistically significant at a 99% level.

In the Online-Appendix B we show that the qualitative features of figures 1 and 2 stay intact for variations of key parameters, like the general skill levels in the two regions, the initial quality of the capital stock in the two regions and the location of the technological frontier. The crucial point is that the two regions differ with respect to the initial distributions of specific skill levels of workers and the initial quality of the capital stock such that there is a low income and a high income region. Accordingly, the mechanisms discussed below are relevant not only for the particular parametrization discussed here, but for a larger set of scenarios.

Figure 2 illustrates the long run effects of the different policies in the different regions, but as can be seen in figure 3, where the dynamics of output produced in each region (averaged over the batch runs carried out for each scenario) is depicted, short run effects do not fully coincide with these observations. In particular, for the scenario where labor markets stay closed the short run effects differ significantly from the long run effects. Short-run output in region 1 under closed labor markets is relatively high compared to the scenarios with labor market opening, whereas in region 2 for the first 100 months output in the closed scenario is below that of the three scenarios with labor flows. The relative advantage of a closed labor market compared to an open one for region 2 emerges more than 100 months after the introduction of the different policies.

The remainder of the section will trace the mechanisms causing the regionally dispersive effects of the various labor market integration policies. Using the possibilities offered by micro-founded agent-based modeling we will thereby illustrate that the effects of the policies are determined by particular feedbacks between price driven demand effects and flows of workers, know-how and capital. Essentially, what we are going to show by looking into the evolution of various region specific variables is that due to cost and price differences between producers located in the two regions, demand in both regions shifts toward goods produced in one of the regions. This induces an increased demand for labor in that region, which under closed labor markets results in increasing wages in that region thereby reducing the local cost ad-

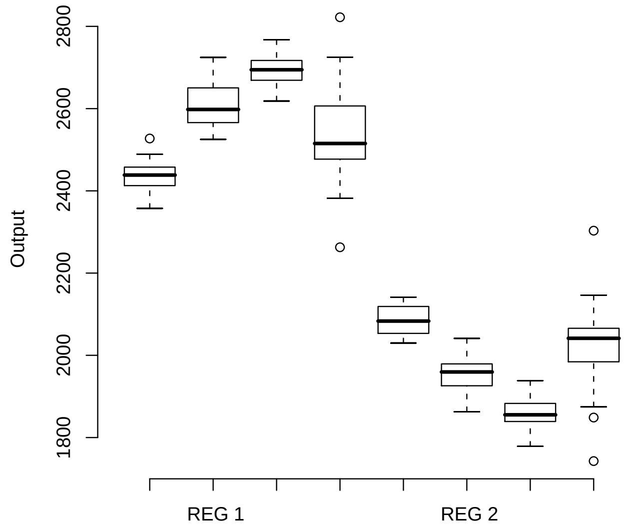

Figure 2: Output by regions (from left to right within high income region 1 and low income region 2, respectively) for scenarios: “closed”, “closed-open-1000-c”, “open-c”, and “open”.

vantage. At the same time investment in that region goes up at least in the short run. Under open labor market scenarios the increased labor demand in the region with initial cost advantages leads to labor flows which on the one hand induce technological spillovers between the regions and on the other hand alter the tightness of the two regional labor markets and imply quite different wage dynamics compared to the closed scenario. These countervailing effects drive region specific production costs and ultimately the relative prices, which in turn determine future worker flows.

Figure 4 shows the relative prices relating the price level of goods in region 2 to the price level of goods in region 1. Focusing on the last months of the time series one sees how the convergence results coincide with the relative prices. As figure 4 reveals the “closed scenario” which is related to the solid line has the lowest relative price levels by the end of the simulation period. The other relative price levels rank across the policy scenarios in accordance with the output levels across the two regions (see figure 2), with the “open-c” policy featuring the highest relative price and consequently the largest output gap between the two regions. Furthermore, it can be clearly seen that the

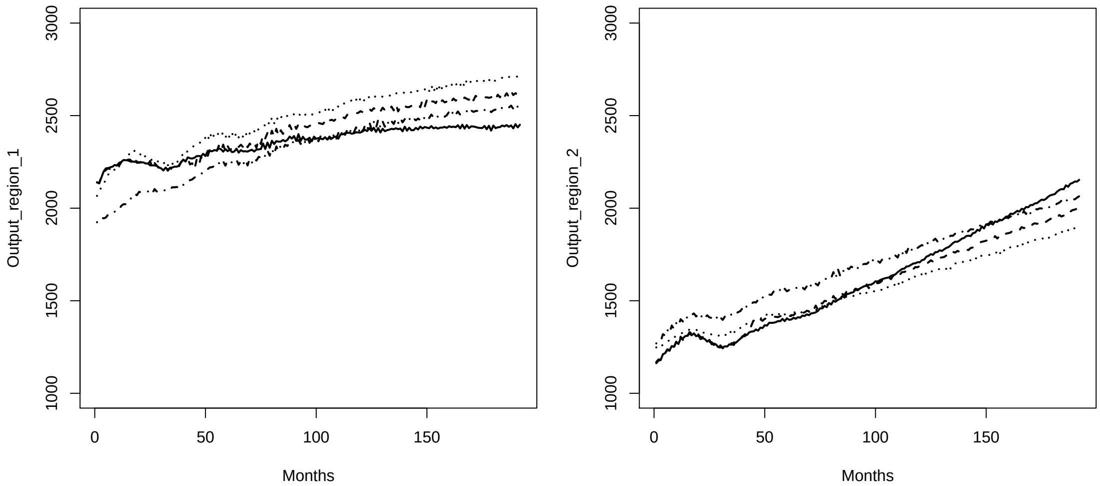

Figure 3: Dynamics of output in region 1 (left panel) and region 2 (right panel) for scenarios: "closed" (solid line), "closed-open-1000-c" (dashed line), "open-c" (dotted line), and "open" (dashed-dotted line).

difference between short- and long-run output effects of the closed policy is based on the fact that in the short run relative prices of goods produced in region 2 compared to those from region 1 go up before they start declining.

Digging deeper trying to understand what is driving the relative regional price levels, one has to recall first, that firms set prices as a mark-up on the average costs with labor costs making a large share. Figure 5 illustrates the role of labor costs per output by showing the relative wages between the two regions for the various policy scenarios and the relative specific skills, respectively. Specific skills constrain the firm using the available technology, and thus higher specific skills allow for higher production by making use of the qualitatively better capital stock. A first observation based on these two figures is that in the open scenario, where the two labor markets are completely integrated without commuting costs at the same time when goods markets open up, the convergence between the two regions with respect to productivity and wages of workers employed in each region is almost perfect after 200 months. If labor flows are inhibited by spatial frictions the degree of convergence is substantially reduced but still larger than in the case of closed labor markets. The "closed" policy yields the lowest relative wages measured as the wage level in region 2 to the wage level in region 1. Although one finds also the lowest relative skill level for that same policy scenario comparing the

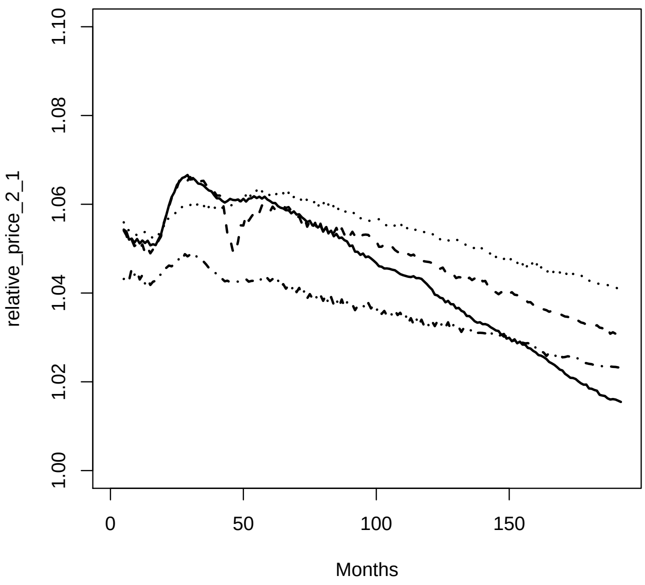

Figure 4: Relative prices region 2 to region 1 for scenarios: “closed” (solid line), “closed-open-1000-c” (dashed line), “open-c” (dotted line), and “open” (dashed-dotted line).

two figures makes clear that in terms of relative specific skills region 2 under the closed scenario comes close to the level it would reach under the open scenario, whereas the gap with respect to wages between these two policy scenarios stays much larger. The reason for this difference is highlighted in figure 6 where the “base wage” offer, i.e. the wage a firm pays per expected unit of specific skills of a worker, in the region 2 relative to that in region 1 is shown. Initially base wages in region 1 are larger, due to tighter labor markets in that region prior to the opening of goods markets, but in all three scenarios where labor markets are opened the relative base wages in region 2 go up over time and for “open” and “open-c” policies base wage offers in region 2 eventually exceed those in region 1. Only in the case of a closed labor market the base wage offers in region 2 consistently decrease compared to those in region 1. These observations show that an important explanatory factor of the differences in relative prices under the four scenarios is the development of relative base wage offers. Comparing figures 4 and 6 shows, however, that also other effects must be relevant, since for a large time interval relative prices in the open scenario are below those in the closed scenario although

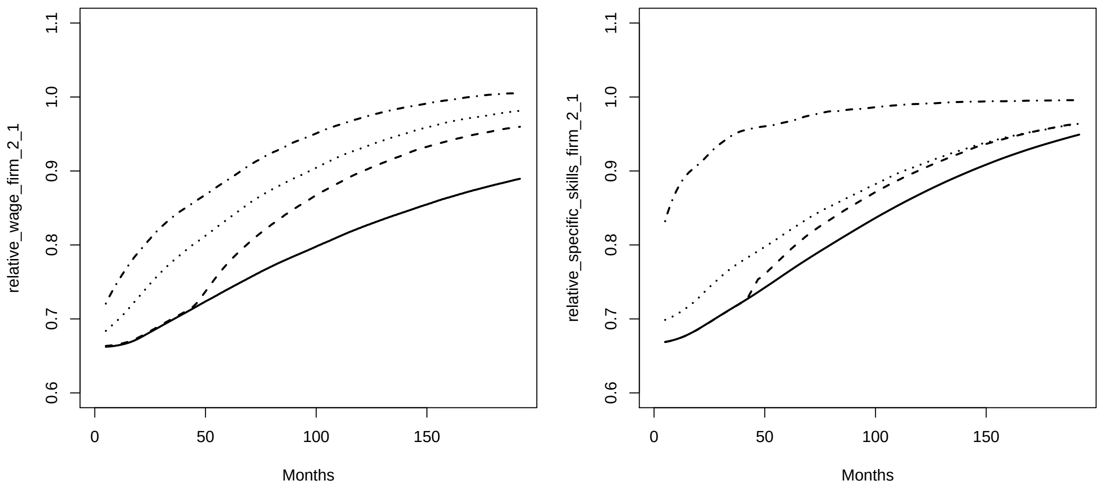

Figure 5: Relative wages (left panel) and relative specific skills (right panel) of region 2 compared to region 1 for scenarios: “closed” (solid line), “closed-open-1000-c” (dashed line), “open-c” (dotted line), and “open” (dashed-dotted line).

relative base wage offers in the open scenario always stay above the relative base wage offers under the closed policy. Before we return to that issue we further investigate the reasons for the diverging dynamics of relative base wage offers in the four scenarios.

Obviously, both the dynamics of the base wage offers as well as the distributions of the specific skills by region and differentiated along the policy scenarios are strongly linked to the flows of workers between the regions. The two panels in figure 7 illustrate this feature. Again the solid line refers to the policy scenario of closed regional labor markets where no commuting takes place. As one chooses the policy option of opening up labor markets after a transition period and still imposing commuting costs afterwards (“closed-open-1000-c”) one generates an immediate increase in commuters from low income region 2 to the high income region 1 (see dashed line). As wages paid in region 1 are higher than wages in region 2 it pays off for the workers in region 2 to accept job offers from firms in region 1 even taking into account costs from commuting. Worker flows from region 1 to region 2 only slowly increase as the wage levels of the two regions get closer. The only striking qualitative difference between the “closed-open-1000-c” scenario and opening up labor markets immediately but imposing commuting costs (“open-c”) is

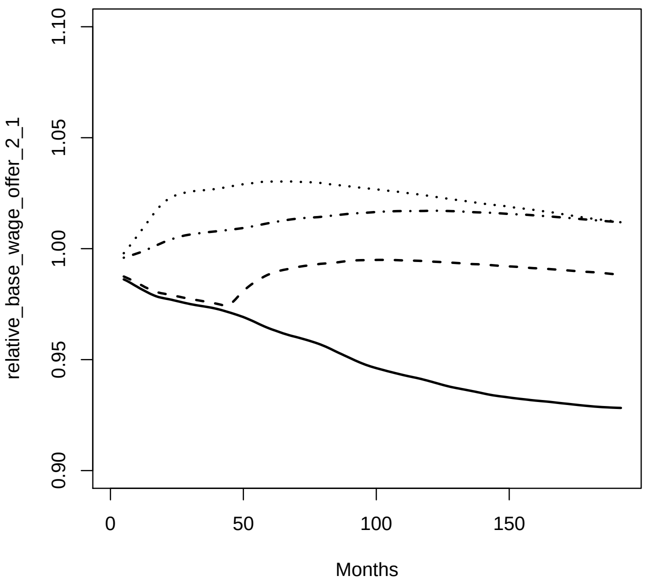

Figure 6: Ratio of base wage offers in region 2 and region 1 for scenarios: “closed” (solid line), “closed-open-1000-c” (dashed line), “open-c” (dotted line), and “open” (dashed-dotted line).

the immediate onset of commuter flows from region 2 to region 1 as depicted with the dotted line in the right panel of figure 7. Otherwise worker flows between the regions behave similarly in these two policy scenarios. Combining the flows in both directions to compute net worker flows between the regions, it can be easily seen that in all three open scenarios there are net worker flows from region 2 to region 1 and that these net flows are largest under the ”open-c” policy. It is now easy to understand that the worker flows are the driving force underneath the differences in base wage offer dynamics between the four policy scenarios. In the ”closed” scenario the increased demand for labor in region 1 triggered by the additional demand faced by region 1 producers after the opening of the labor market cannot be met by workers commuting from region 2. Therefore, producers in region 1 often have to deal with unfilled vacancies and accordingly increase their base wage offer more frequently than producers in region 2. Quite the contrary holds true for the “open” scenario, where producers in region 1 can easily attract workers from region 2. The resulting outflow of workers from region 2 increases the labor market tightness in that region thereby generating an upward trend of base wage offers in that region.

As discussed above, in terms of the regional distribution of specific skills the low income region 2 profits most from opening up the labor markets completely. Given the commuting patters the explanation for this observation is straight forward. In the open scenario a large number of workers from region 1, who on average have higher specific skills than those in region 2, commute to region 2, whereas an even larger number of region 2 workers with relatively low specific skills commute to region 1, thereby lowering the average specific skill level of firms in region 1. Similar considerations explain the dynamics of specific skills in the other policy scenarios. An additional implication of the worker flows depicted in figure 7 is that the labor intensity of production in the two regions is affected by the applied policy, which in turn influences production costs and prices. Focusing again on region 2, due to the worker flows, the capital intensity of production under the “open” policy is larger than under the “closed” policy[3]. This implies that per worker with a given specific skill level more output is produced in the open than in the closed scenario, which explains our previous observation that relative prices in region 2 are lower in the ”open” than in the “closed” scenario in many periods although the relative base wage offers are always lower in the “closed” scenario.

Thus, the commuter flows induced by the different policies have intricate implications for specific skill distributions, wages and capital intensity which influences prices thereby generating demand shifts which feed back on commuter flows and investments. As the relative prices finally determine the market share which a region can ultimately capture they explain the output and convergence patterns over the policies which we analyzed.

To finish our analysis, we like to point out that the ranking of the different policies from the perspectives of the two regions was carried out with a focus on output produced by all firms located in that regions. A different perspective is to focus on the dynamics of the consumption of all households in a particular region. In scenarios with open labor markets, where many workers are employed outside their home region but still consume at home, the two perspectives might differ. Indeed figure 8, which shows box-plots of consumption in both regions in the final 20 months, demonstrates that for both regions the policies that yield largest local production do not lead to highest local consumption. From the perspective of consumption in region 1 the best option is to keep labor markets closed, whereas for region 2 the

[3]This observation has been checked considering the dynamics of capital/output ratios, but we abstain from presenting the corresponding figure here.

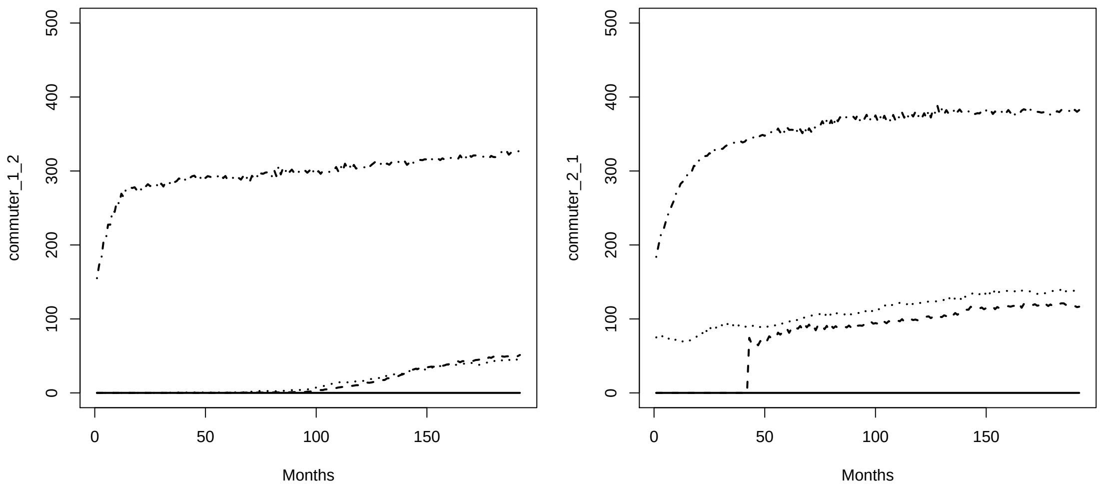

Figure 7: Commuters from region 1 to region 2 (left panel) and commuters from region 2 to region 1 (right panel) for scenarios: "closed" (solid line), "closed-open-1000-c" (dashed line), "open-c" (dotted line), and "open" (dashed-dotted line).

three scenarios where labor markets are opened give higher consumption than the "closed" policy although the ranking was exactly the opposite with resepct to local production. The reason for these differences is the interplay of commuter flows and relative wages in the two regions. Under the "open" policy the large number of region 2 workers that commute to region 1 earn higher (real) wages than they would earn in their own region under the "closed" policy. This increases the overall consumption budgets of households in region 2 and therefore has positive effects on total consumption there. On the other hand, workers in region 1 profit from the larger real wages they earn in the "closed" scenarios compared to the three policies with labor market opening. Hence, total consumption in that region is largest in the "closed" scenario.

5 Policy Implications and Conclusions

The policy experiments on labor market integration yield strikingly different outcomes depending on the variable of interest, the regional level of analysis, and the time horizon. Therefore, policy implications on what labor market policies to choose will differ with the various objectives that one may impose

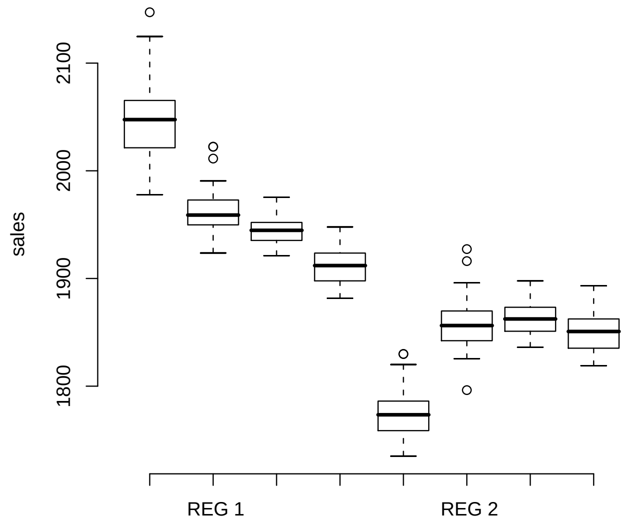

Figure 8: Total consumption by regions (from left to right within region 1 and 2, respectively) for scenarios: “closed”, “closed-open-1000-c”, “open-c”, and “open”.

accordingly. We show that while overall output is lowest for the closed scenario and equally higher for all policies that open up labor markets, output differs along all four policies if we look into the regional effects. Thus, while the policy advice is, when the objective is to maximize overall output, to choose either of the policies that at least gradually opens up labor markets, the advice to a policymaker who cares about convergence of regions would go differently. A policymaker that is willing to trade-off some output on the aggregate for more convergence should rather not integrate labor markets. If, however, a policymaker is not willing to give up overall output, then the advice is to fully open up labor markets as among all the policies that promote labor market integration, this is the policy which results in the least inequality between regions with respect to output levels (c.f. figures 1 and 2). In a world in which there are considerable flows of workers who work abroad but still consume in their domestic region results in terms of convergence effects of the various labor market integration policies differ, and so will policy advice if a policymakers objective is to reduce between region inequality regarding per-capita consumption (c.f. figure 8). With consumption as an argument in a policymakers objective function, no trade-off between convergence of the regions and overall performance arises. Consequently, it is advisable to open up labor markets as this policy yields better results in terms of overall consumption and convergence of regions than not allowing workers to commute between regions. Finishing up on the policy implications of our analysis we want to remark that the implications drawn so far, differentiating along output or consumption, and the overall effects of policies as well as the effects on convergence, are implied by long-run outcomes. However, as illustrated in figure 3 the evolution of output differs with respect to the various policies by region. In particular, the high productivity region fares better initially in terms of output with a policy of closed labor markets. Thus, contrary to an advice which relates to the long-run consequences, for a policymaker in that region who discounts the future heavily it would rather be advisable not to open up labor markets.

Although the current model is already quite comprehensive, potentially interesting features are left out. This is, for example, endogenous technological change which would provide a richer model of productivity progress than our approach of using the standard assumption of an exogenously given process that eventually increases the quality of the capital good. A second feature that we will expand on in the future is the commuting behavior of the workers. So far it is a very stylized approach based on a comparison of labor income net of some exogenously given costs for commuting. It would be a rewarding extension to put more structure on this particular decision of the workers, extending the framework to migration where workers actually reside in the region where they chose to accept work. The framework which we are using is sufficiently flexible to allow for these extensions, but they define a worthwhile agenda for future work.

Acknowledgment

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References

ACEMOGLU, D. (2009): *Introduction to modern economic growth*, Princeton University Press.

AGHION, P., L. BOUSTAN, C. HOXBY, UND J. VANDENBUSSCHE (2009): "The causal impact of education on economic growth: evidence from U.S." Harvard University, mimeo.

BARRO, R. J. UND X. SALA-I-MARTIN (1992): "Convergence," *Journal of Political Economy*, 100, 223–251.

BASSANINI, A. UND S. SCARPETTA (2002): "Does Human Capital Matter for Growth in OECD countries?: A Pooled Mean Group Approach," *Economics Letters*, 74, 399–405.

BOERI, T., G. BERTOLA, H. BRÜCKER, F. CORICELLI, J. DOLADO, J. FITZGERALD, A. DE LA FUENTE, P. GARIBALDI, G. HANSON, J. JIMENO, R. PORTES, G. SAINT-PAUL, UND A. SPILIMBERGO (2002): "Who's afraid of the big enlargement? Economic and social implications of the European Union's prospective eastern expansion," CEPR policy paper no. 7, CEPR London.

CANOVA, F. UND A. MARCET (1995): "The poor stay poor: non-convergence across countries and regions," CEPR discussion paper no. 1265.

CHIAROMONTE, F. UND G. DOSI (1993): "Heterogeneity, competition and macroeconomic dynamics," *Structural Change and Economic Dynamics*, 4, 39–63.

DAWID, H., S. GEMKOW, P. HARTING, UND M. NEUGART (2009): "On the effects of skill upgrading in the presence of spatial labor market frictions: an agent-based analysis of spatial policy design," *Journal of Artifical Societies and Social Simulation – JASSS*, 12, 4.

DAWID, H., S. GEMKOW, P. HARTING, M. NEUGART, UND K. WERSCHING (2008): "Skills, innovation and growth: an agent-based policy analysis," *Jahrbücher für Nationalökonomie und Statistik/Journal of Economics and Statistics*, 228, 251–275.

DELLI GATTI, D., C. GUILMI, E. GAFFEO, G. GIULIONI, M. GALLEGATI, UND A. PALESTRINI (2005): "A new approach to business fluctuations: heterogeneous interacting agents, scaling laws and financial fragility," *Journal of Economic Behavior and Organization*, 56, 489–512.

Dosi, G., G. Fagiolo, und A. Roventini (2010): “Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles,” *Journal of Economics and Control*, 34, 1748–1767.

Dosi, G., O. Marsili, L. Orsenigo, und R. Salvatore (1995): “Learning, market selection and the evolution of industrial structures,” *Small Business Economics*, 7, 411–436.

Griffith, R., S. Redding, und J. van Reenen (2004): “Mapping the two faces of R&D: Productivity growth in a panel of OECD industries,” *Review of Economics and Statistics*, 86, 883–895.

Growiec, J. (2008): “Productivity differences across OECD countries, 1970-2000: the world technology frontier revisited,” IBS Working Paper No.1/2008, Institute for Structural Research.

Haber, G. (2008): “Monetary and Fiscal Policy Analysis With an Agent-Based Macroeconomic Model,” *Jahrbücher für Nationalökonomie und Statistik/Journal of Economics and Statistics*, 228, 276–295.

Howitt, P. (2000): “Endogenous growth and cross-country differences,” *American Economic Review*, 90, 829–846.

Islam, N. (1995): “Growth empirics: a panel data approach,” *Quarterly Journal of Economics*, 110, 1127–1170.

Keller, W. (2004): “International technology diffusion,” *Journal of Economic Literature*, 42, 752–782.

Malerba, F., R. Nelson, L. Orsenigo, und S. Winter (2001): “Competition and Industrial Policies in a ’History-Friendly’ Model of the Evolution of the Computer Industry,” *Journal of Industrial Organization*, 19, 635–664.

Mankiw, G. N., P. Romer, und D. N. Weil (1992): “A contribution to the empirics of economic growth,” *Quarterly Journal of Economics*, 107, 407–437.

Nelson, R. R. und S. G. Winter (1982): *An Evolutionary Theory of Economic Change*, Cambridge, Mass. and London: Harvard University Press.

Silverberg, G. und B. Verspagen (1993): “Collective learning, innovation and growth in a boundedly rational, evolutionary world,” *Journal of Evolutionary Economics*, 4, 207–226.

Solow, R. (1956): "A contribution to the theory of economic growth," *Quarterly Journal of Economics*, 70, 65–94.

Tesfatsion, L. und K. E. Judd (2006): *Handbook of Computational Economics II: Agent-Based Computational Economics*, North-Holland.

Wong, K. und K. C. Yip (1999): "Education, economic growth, and brain drain," *Journal of Economic Dynamics and Control*, 23, 699–726.

Online Appendix to

Labor market integration policies and the convergence of regions: the role of skills and technology diffusion

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A: Details of the Model

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 among the households in order to close the model.

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Consumption good producer

Quantity choice

Every consumption goods producer keeps a stock of its products at every regional mall. 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 has to decide whether and on what scale it restocks the supply.

The vector $\left\{\hat{D}_{i,r,t-\tau}, ..., \hat{D}_{i,r,t-1}\right\}$ gives the estimated demand of firm i in mall r during the last τ periods. Furthermore, $SL_{i,r,t}$ is firm's current mall stock 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 rule:

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

where $Y_{i,r,t}$ is chosen such that the firm expects to be able to satisfy the market demand with some probability $1-X$. Demand in the current period is estimated using a linear regression based on previous demands. Put formally,

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

where $\bar{q}_{1-X}$ is the $1-X$ quantile of the standard normal distribution and the regression coefficients $\hat{a}_{i,r,t}$ and $\hat{b}_{i,r,t}$ as well as the variance $\hat{\delta}_{i,r,t}$ are estimated using standard linear regression methods.

The sum of the planed quantities to be 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

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

As discussed in more detail below, the realized production volume $Q_{,t}$ 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

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

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.

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 $K_i(0)$ is given by the initialization 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. 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. 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.

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 parameters. 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. 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 households hold shares of consumption goods producers, consequently the dividends are distributed to the households.

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.

Pricing

The 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.

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.

The savings decision

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

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

The consumer sets his consumption according to the following consumption rule

$$B_{k,t}^{cons} = \begin{cases} Liq_{k,t}^{Avail} - \kappa(Liq_{k,t}^{Avail} - \Phi \cdot Inc_{k,t}^{Mean}) & \text{for } Liq_{k,t}^{Avail} > \Phi \cdot Inc_{k,t}^{Mean} \\ Liq_{k,t}^{Avail} & \text{else,} \end{cases}$$

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

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 $B_{k,week_t}^{cons}$ for each week in period t.

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. 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

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

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.

Labor market

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 offers $w^O_{i,t,g}$ for each general skill group g 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.

Labor supply

Labor supply is generated by the unemployed. An unemployed k only takes the posted wage offer into consideration and compares it with his reservation wage $w^R_{k,t}$. 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.

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. He sends an exogenous determined number of applications to randomly chosen firms.

Step 3: If the number of applicants is smaller or equal to the number of vacancies the firms send job offers to every applicant. If the number of applicants is higher than the number of vacancies firms send job offers to as many applicants as they have vacancies to fill. Applicants with higher general skill levels b^{gen}_w are more likely to receive a job offer.

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.

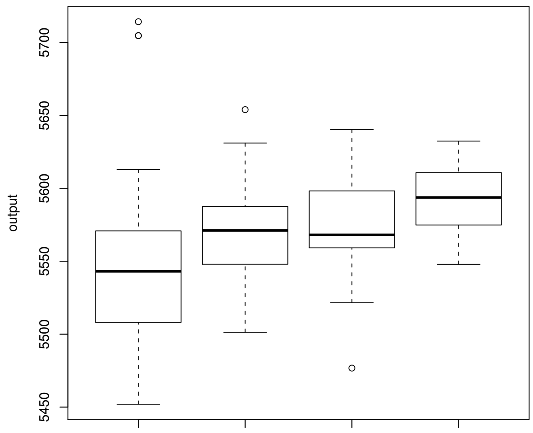
Step 5: Vacancies' lists are adjusted for filled jobs and the labor force is adjusted for new employees.

Step 6: If the number of vacancies not filled exceeds some threshold $\overline{v} > 0$ the firm raises the base wage offer which is paid per unit of specific skills by a fraction φ_i such that $w^{base}_{i,t+1} = (1 + \varphi_i)w^O_{i,t}$. 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.

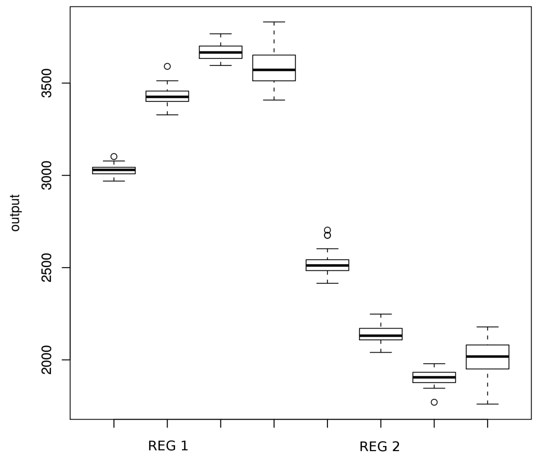
This cycle is aborted after two iterations even if not all firms may have satisfied their demand for labor. As indicated above this might lead to rationing of firms on the labor market and therefore to deviations of actual output quantities from the planned quantities. In such a case the quantities delivered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

B: Robustness Checks

In this Appendix we demonstrate that changes of key parameters within certain ranges do not alter the qualitative features of the patterns of total and regional output distributions under the four considered labor market policies. We focus here on variations of characteristics of the high income region 1 and keep characteristics of region 2 according to the specifications in the main body of the paper. In figure B1 we depict total output and regional output under the considered four policy options in a scenario where specific skills and the quality of the capital stock in region 1 as well as the technological frontier are initialzed at a value of 1.75. As in the paper, initial wages in region 1 are always 20% above initial productivity. Panels (a) and (b) of figure B1 should be compared to figures 1 and 2 in the paper, where the same distributions are shown for the default productivity value of 1.5 in region 1. It can be seen that also with a larger initial gap between the two regions the (relative) effects of the four polices stays the same. In particular, the different policies corresponding to an opening of the labor market yield higher expected total output than the 'closed' policy. Considering regional output we observe the same inverse U-shape for region 1 and U-shape for region 2 that appears in figure 2. Figure B2 illustrates results for a scenario where the initial gap is smaller than in the default case and again we observe the same patterns.



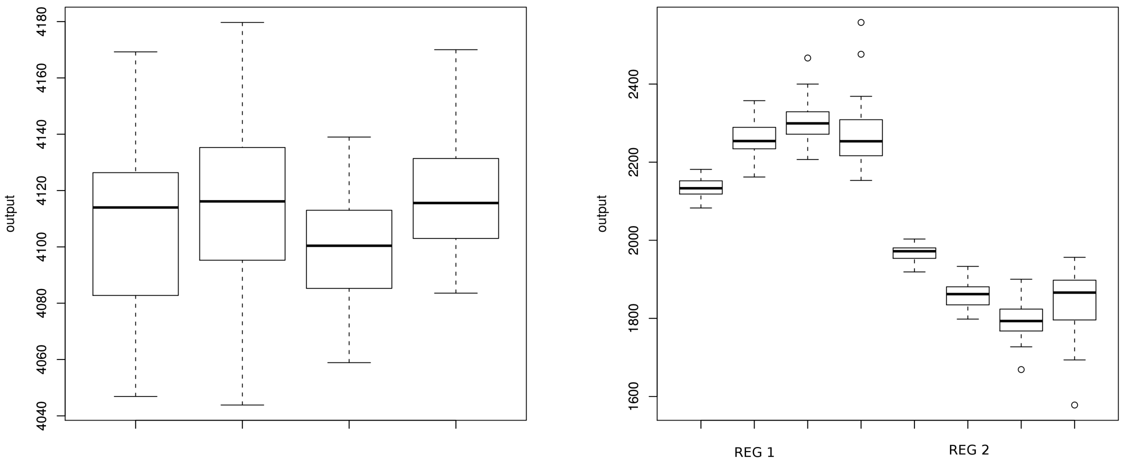
(a)



(b)

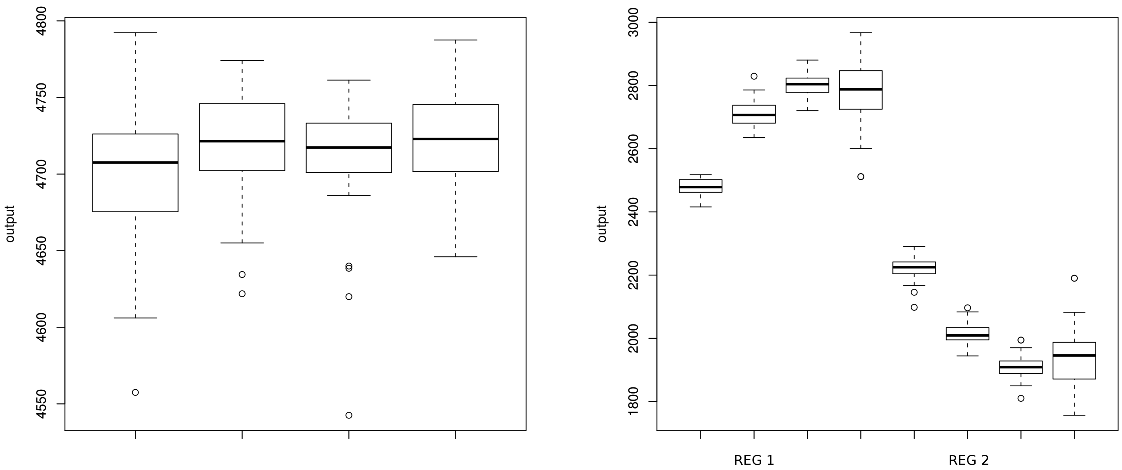
Figure B1: Total output (a) and output by regions (b) after 200 months for scenarios (from left to right): "closed", "closed-open-1000-c", "open-c", and "open". Specific skills in region 1, the quality of the capital stock in region 1 and the technological frontier are initialzed at a value of 1.75.

In figures B3 and B4 we vary the distribution of general skills in region 1 und region 2. In figure B3 it is assumed that all workers in both regions have identical general skills of 3. Hence there exists no general skill gap between the regions. Compared to the default scenario where the distribution of general skills across the five general skill levels in region 1 is given by $(0.1, 0.3, 0.4, 0.15, 0.05)$ and in region 2 by $(0.42, 0.33, 0.2, 0.04, 0.01)$, this corresponds to a slight increase in average general skills in region 1 and a larger increase in average general skills in region 2. Again, we observe qualitativey similar patterns to those in figures 1 and 2. This observation also holds if we reduce the general skills of all workers to a value of 2. In these scenarios without a general skill level gap between the regions the observed implications of the policies nevertheless correspond to those discussed in the paper.



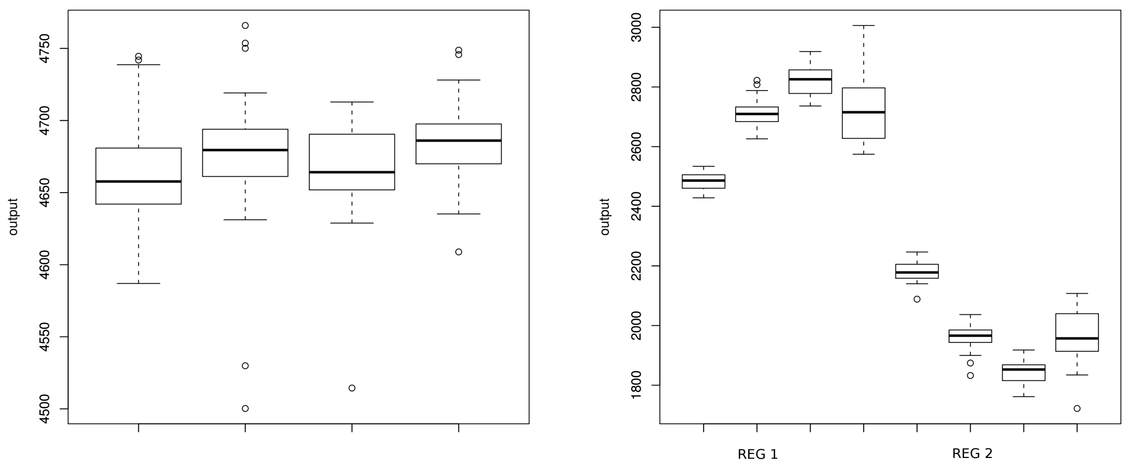
(a) (b)

Figure B2: Total output (a) and output by regions (b) after 200 months for scenarios (from left to right): “closed”, “closed-open-1000-c”, “open-c”, and “open”. Specific skills in region 1, the quality of the capital stock in region 1 and the technological frontier are initialzed at a value of 1.25.



(a) (b)

Figure B3: Total output (a) and output by regions (b) after 200 months for scenarios (from left to right): “closed”, “closed-open-1000-c”, “open-c”, and “open”. All workers in region 1 have general skills of 3.



(a) (b)

Figure B4: Total output (a) and output by regions (b) after 200 months for scenarios (from left to right): "closed", "closed-open-1000-c", "open-c", and "open". All workers in region 1 have general skills of 2.

References

DEATON, A. (1991): "Saving and Liquidity Constraints," *Econometrica*, 59, 1221–1248.

——— (1992): "Household Saving in LDCs: Credit Markets, Insurance and Welfare," *Scandinavian Journal of Economics*, 94, 253–273.