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**History, Spatial Structure, and Regional Growth:
Lessons for Policy Making**

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History, Spatial Structure, and Regional Growth: Lessons for Policy Making

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1. Introduction

In recent years, we have seen some fundamental developments in economic theory concerning the understanding of economic growth. The traditional growth theory, which is based on the famous Solow-model (Solow, 1956), was replaced by a set of models and arguments that are commonly known as „new growth theory“. These developments are fundamental in the sense that they demonstrate that some of the basic assumptions of the traditional growth theory – and most of neo-classical economic theory in general – are inconsistent with basic phenomena of the modern economy, and that they attempt to overcome these assumptions.

In regional economics these advances in economic theory received a mixed reception (Innserman, 1996). On the one hand, they were welcomed because they are bound to reintroduce a spatial dimension into economic theory and thus may move regional economics out of its marginal position within the realm of economic sub-disciplines. On the other hand, many of the arguments that are brought forward and of the conclusions that are derived by the new growth theory have been known and discussed in regional economics for decades so that they appear to be old wine in new bottles to many regional economists.

Despite our long tradition in regional economics of discussing the seemingly new arguments of new growth theory, it seems that we have still missed some of their fundamental implications. This is probably due to the lack of a consistent framework. The recent advances in growth theory provide such a framework and they allow us to investigate more thoroughly the consequences and policy implications of our traditional regional economic argument.

This paper intends to make a step in this direction. It will look at the implications for our understanding of regional growth and of regional growth policy that we get when we allow for scale effects and externalities. The discussion will show that this seemingly minor change in the set of assumptions has major consequences on policy and also brings into play factors like the spatial structure or the history of a region that are of no importance at all in traditional neo-classical (regional) growth theory. We will use a very simple model to make and illustrate our argument.

In the next section, we will briefly discuss the basic structure of the new growth theory and its relationship to traditional neo-classical growth theory and to the polarization argument of regional economics. Section 3 will discuss externalities and their relationship to growth processes and to spatial structure. Section 4 will present the model and use it to illustrate the main arguments that were made in the previous sections. The paper closes with a concluding section.

2. New growth theory, traditional growth theory, and polarization theory

Since the polarization model of regional economics as well as new growth theory have been developed in response to the traditional neo-classical growth model, let us begin our discussion with a brief review of the latter model. In order to avoid unnecessary complications, we will use a very simple version of the model. This version, however, represents all the crucial elements of traditional neo-classical growth theory.

Let us start with a Cobb-Douglas-production-function

$$Y = K^{\alpha}L^{1-\alpha}$$

where Y is the total level of production, K is the capital stock and L is labor input. This production function is linearly homogeneous and has positive but decreasing marginal products of labor and capital. Let us assume a constant input of labor ($L' = 0$). Capital increases through investment and decreases through depreciation. We assume a constant share s of Y to be saved and invested, and a constant proportion δ of the capital stock to be depreciated. Therefore, the temporal change in capital can be written as

$$K' = sY - \delta K.$$

From this set of equations we find that production per unit of labor input changes according to the following time path:

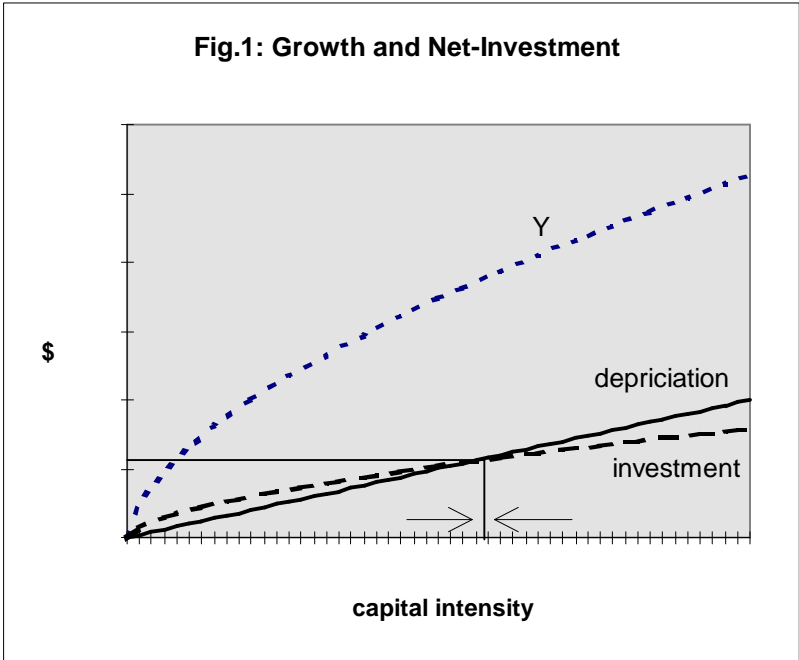
$$Y/L = [A \exp((\alpha-1)\delta t) + s/\delta]^{\alpha/(1-\alpha)}$$

where A is a constant representing the initial conditions. Since α is between zero and one, production per unit of labor converges toward a long run equilibrium that is characterised by

$$[s/\delta]^{\alpha/(1-\alpha)}.$$

Note that this equilibrium is determined only by exogenously given parameters. Therefore, it can be said that the traditional neo-classical growth theory is a theory that „explains“ long term growth only through external factors.

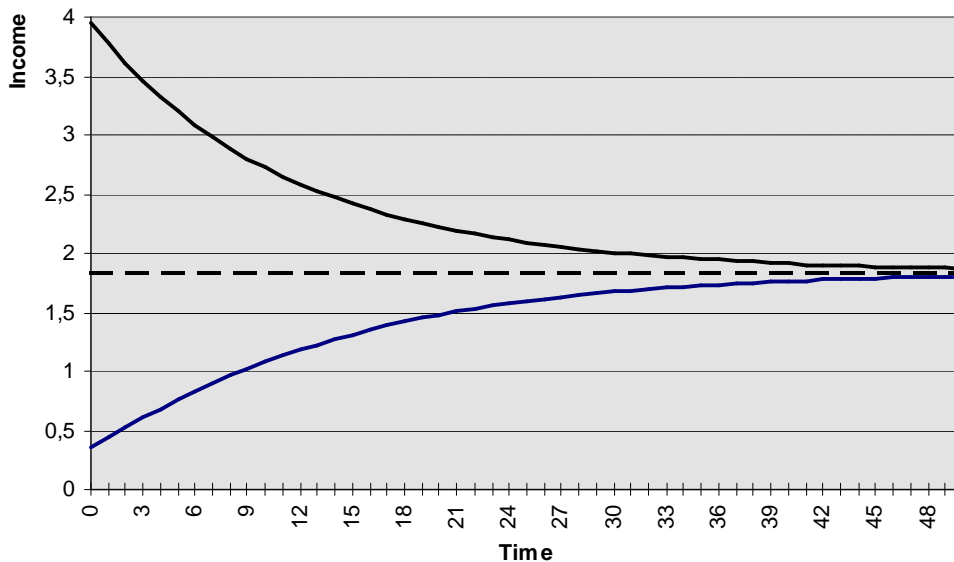
Figure 1 shows the basic relationships of the model. On the horizontal axis we have capital intensity, i.e. the amount of capital relative to the constant labor input, the vertical axis represents monetary units. The curve marked Y is the production function for different levels of capital and a constant level of labor, the other two curves represent depreciation (δK) and Investment (sY). The equilibrium is characterized by the intersection of the latter two curves.



It is easy to see from figure 1 that the system will converge to the equilibrium point. To the left of the equilibrium investment exceeds depreciation, therefore the capital intensity increases. To the right of the equilibrium, depreciation is higher than investment, and the capital stock declines. This can also be seen when we plot the corresponding time path. When we start from

a point above equilibrium, production per labor input declines, when we start below the equilibrium, it increases toward the long term equilibrium value.

Growth of Income per Worker



It is easy to see that even in this simple form the model predicts convergent regional growth.

When we have two regions with identical parameters α , δ , and s , both starting from below the equilibrium value, but one of the regions being more advanced than the other, than the less advanced region will grow more rapidly than the advanced one so that the gap in production per unit of labor diminishes over time and finally disappears. Note that this is the case even when there is no interaction at all between the regions. This convergence results solely from capital accumulation.

This convergence process can also be seen in another way. Suppose that a region is pushed off of its growth path by some historical event (a war, for example). Because of the convergence process, the impact of this event is only temporary. It is „washed away“ over time by the growth process. The time path after the shock asymptotically approaches the original path over time.

In the version of the model that we have discussed so far the growth process comes to a halt once the equilibrium level of capital intensity is reached. Therefore, the production function is usually augmented by a term that represents technical progress. The production function then becomes

$$Y = K^{\alpha} L^{1-\alpha} e^{\tau t}$$

where t represents time and τ the rate of growth of technical knowledge. With this alternative formulation the production function and the investment function are continuously shifted up and the equilibrium point therefore moves further and further to the right. Therefore, the long run steady state growth of the system is determined solely by the growth rate of technical knowledge – another parameter that is external to the model.

Although our simple version already allowed us to derive regional implications, the regional economic version of the neo-classical growth model (Borts and Stein, 1964, Richardson, 1969) often puts particular emphasis on factor mobility. Because of the basic assumptions of neo-classical economics, capital and labor are paid their marginal product. Therefore, when capital is relatively scarce in region I as compared to region II the rate of interest will be higher in region I, the wage rate higher in region II. When the production factors are mobile, capital will flow from region II to region I and labor in the opposite direction until the marginal products are equated between the regions. This mechanism supports the convergence that was described above.

Summarizing our discussion of traditional neo-classical growth theory, we can conclude that according to the model the price mechanism and the process of capital accumulation lead to convergence and thus eliminate interregional differences over time. Neither spatial structure nor historical events have any implication on the long term growth path of a region. The latter is determined only by exogenous parameters.

It is not surprising that regional economists felt quite uneasy about these implications.

Therefore, many counter-arguments to traditional neo-classical growth theory have been formulated in the discipline. This set of arguments is often referred to as „polarization theory“, although it is by no means a consistent theory. Early representatives are Myrdal (1957) and Hirschman (1958), more recent versions can be found in the literature on industrial districts and on business clusters. Since Ed Feser (1998) has provided an excellent review of this literature, we can keep our discussion of polarization theory very brief.

Contrary to traditional neo-classical growth theory the advocates of polarization theory argue that production factors are non-homogeneous, that markets are imperfect, and that the price mechanism is disturbed by externalities and economies of scale. Therefore, it is argued, deviations from equilibrium are not corrected by counter effects, but may set off a circular,

cumulative process of growth or decline. A complex set of positive and negative feedback loops accumulates to a growth process whose direction is fundamentally undetermined. In a spatial context these feedback processes generate spread and backwash effects that transfer impulses from one region to another.

It is quite clear that spatial structure is an important element in such a growth process. It generates leading and lagging regions that depend upon one another in many ways. Polarization theory often argues not only economically, but brings forward also social, political, cultural, etc. arguments when it explains why some regions are more prosperous than others. Because of this rich and interdisciplinary set of arguments, polarization theory has never been able to express its arguments in a consistent economic model and was therefore largely ignored by mainstream economics.

New growth theory, on the other hand, originated in the heartland of economic theory. Economists like Romer, Barro, Helpman, and Grossman were disappointed with the fact that the long term source of growth remains exogenous in traditional neo-classical growth theory. Therefore, they tried to explain technical progress endogenously in their models. As it turned out soon, there is no incentive for economically rational agents to invest resources into the production of technical progress in the standard neo-classical growth model. Production of technical progress can only be explained when we deviate from the basic neo-classical assumptions. Therefore, the models of new growth theory allow for either agglomeration effects (economies of scale and externalities) or for market imperfections. They can now explain economic growth – therefore they are also referred to as „endogenous growth models“ – but the implications of this change in the basic set of assumptions is quite dramatic. New growth theory leads to outcomes that are quite similar to those that polarization theory has claimed decades before:

1. In a model with agglomeration effects or imperfect markets the price mechanism does not necessarily generate an optimal outcome. Depending on the structure of the model, there are either too few (e.g. Barro, 1990, Rebelo, 1991, Romer, 1986, 1990) or too many (e.g., Aghion and Howitt, 1990, Segerstrom et al., 1990, Grossman and Helpman, 1992) resources invested in the production of technical progress in the free-market solution. The market mechanism by itself does not lead to an efficient allocation of resources.
2. The process of capital accumulation and free trade do not necessarily lead to convergence between regions. With positive agglomeration effects the concentration of economic

activities in one region will be self enforcing because this region will become more attractive for new investments. This generates a circular, cumulative process as in polarization theory. While the traditional neo-classical growth theory can demonstrate that under its set of assumptions capital accumulation will lead to convergence, the models of the new growth theory allow for both, convergence and divergence. What type of situation is prevalent becomes an empirical question. Therefore, we could see numerous studies analyzing the convergence or divergence of growth processes in the last years (e.g., Barro, 1991, Barro and Sala-i-Martin, 1991).

3. The most important implication in our context is that in an economy with agglomeration effects or imperfect markets spatial structure and historical events become important. While they are washed away quickly in the traditional theory, in the new growth theory they may trigger long term growth differentials. In the case of positive agglomeration effects, for example, a randomly occurring concentration of economic activity may attract outside investment that will make this region even more attractive (Arthur, 1994, David, 1985). Because of the positive effects between the various economic agents, the process will yield an unequal distribution of economic activity between regions that is stable in the long run. To repeat an argument from above, this outcome may not be optimal or even desirable in any way.

3. Agglomeration effects, growth, and regional structure

Polarization theory as well as new growth theory see economies of scale and externalities as a major source of cumulative effects in the economy. Therefore, in this section we will investigate these factors more closely. Since economies of scale and externalities both result from the concentration of economic activities, we will subsume them under the term „agglomeration effects“.

While economies of scale occur within an economic unit, externalities happen between economic units. In regional economics it is quite common (Hoover, 1937, Carlino, 1978) to subdivide externalities into localization effects and urbanization effects. Localization effects occur between firms of the same sector, urbanization effects between firms from different sectors or even different types of economic actors like firms and households. Obviously, this distinction is not very precise, because it depends on the definition of sectors and economic

units. In a macroeconomic context, for example, when all the firms of a region are aggregated into one producing unit, agglomeration effects can only show up in terms of economies of scale.

The justification for agglomeration effects differs substantially between polarization theory and new growth theory. While polarization theory states them as empirical phenomenon, new growth theory shows that a perfect-market model without agglomeration effects is inconsistent with the production of technical progress. With this theoretical justification, agglomeration effects have to be taken into account when we are talking about dynamic aspects of the economy (Bröcker, 1994).

However, agglomeration effects are directly related to spatial structure. As will be argued below, spatial structure and agglomeration effects are actually two sides of the same coin. On the one hand, agglomeration effects lead to a spatially differentiated structure of the economy, while on the other hand spatial structure produces agglomeration effects.

Because it does not allow for agglomeration effects, the traditional neo-classical model implies a peculiar spatial structure. Mills (1972, p.113) summarizes it in the following way: *„Consider a general equilibrium model in which an arbitrary number of goods is produced either as inputs or for final consumption. The only nonproduced goods are land and labor, each of which is assumed to be homogeneous. Assume that each production function has constant returns to scale and that all input and output markets are competitive. Utility functions have the usual properties and have as arguments amounts of inputs supplied and products consumed. Under these circumstances, consumers would spread themselves over the land at a uniform density to avoid bidding up the price of land above that of land available elsewhere. Adjacent to each consumer would be all the industries necessary – directly or indirectly – to satisfy the demands of that consumer. Constant returns assures us that production could take place at an arbitrarily small scale without loss of efficiency. In this way, all transportation costs could be avoided without any need to agglomerate economic activity.“*

One of the key assumptions is that of production functions with constant returns to scale, i.e. the assumptions that there are no agglomeration factors. If only one industry of this economy had a production function with positive agglomeration factors, the spatial structure of the economy would differ markedly. Because of positive returns to scale this industry could

produce in a more efficient way when it concentrates production in one or a few locations. When it does so, however, not „all the industries necessary“ would be adjacent to each consumer any longer. Some consumers or sectors would need to buy the products of the agglomerated sector or to sell their products to this sector and would therefore have to overcome the spatial distance to this sector. Those who are located closer to the location of the agglomerated sector would have an advantage over their colleagues further away. They could either save transportation costs or produce larger quantities.

In the traditional model as described by Mills, each consumer provides labor inputs to all the industries at her location. But, when one of the sectors is agglomerated, it produces at a larger scale and therefore needs more labor input than is available at this location. It has to attract additional workers who either will have to commute or to migrate to this location. In the first case the agglomerated industry will have to pay higher wages in order to compensate the workers for the costs of commuting, in the second case the sector will have to pay higher wages because with increasing density the costs for land will increase. As a consequence, we will get interregional differences in wages and land prices and in the density of economic activity. The location of the agglomerated industry turns into a market center.

Because of the increasing wages and land prices, those industries who cannot afford those would move away from the locations where the industry with economies of scale is concentrated. The result would be a specialized pattern of land use. Some of the industries that are forced out would try to locate in the vicinity of the market center because they need to sell their products there. However, as has been shown already by von Thünen (1826), they will not locate randomly but according to their bid-rent functions. Those industries whose products are more sensitive to transportation will locate closer to the market than those whose products can be transported more cheaply.

Note that we have argued within the framework of the traditional neo-classical model and have allowed only one industry to have a production function with increasing returns to scale. The result, however, is a structure with spatial differentiation in land use, prices, and densities and with the need to transport products and production factors from one location to another. When we allow other industries to show increasing returns to scale as well, or add location or urbanization effects, the results that were described above will be strengthened further, but qualitatively they will not change. Agglomeration effects in one industry is sufficient for producing spatial structure and spatial differentiation.

Starrett (1978) analyzes the relationship between spatial structure and agglomeration effects in a more rigorous way. He finds that in a system with spatial structure „the usual types of competitive equilibria will never exist“ (Starrett, 1978, p.21). Whenever there are transportation costs in the system and all agents are price takers in competitive markets, all possible allocations are instable. „That is, for any set of prices and location allocation, some agents will want to move to the other location“ (p. 25). The reason for this result is quite simple. Because of transportation costs, and in the absence of any counter forces every economic actor sees an incentive to move closer to his suppliers and/or his markets. In a system of perfect competition this tendency pulls related actors closer together until the system collapses to the structure described by Mills, where all transportation costs are eliminated.

Market imperfections like agglomeration effects or monopoly power counteract this tendency and can stabilize a system with transportation costs. A company with economies of scale, for example, would trade off these economies of scale against potential transportation cost savings and find a location and size of production that balances these counteracting forces.

That these forces are closely related to transportation costs also shows up in Starrett's work. In addition to the above mentioned non-existence result he demonstrates the following: „The monetary incentive to move is on the order of magnitude of transport costs. The degree of market imperfection which is required in order that a location allocation be stable is also related to transport costs“ (Starrett, 1978, p.25).

These arguments show that a stable spatial structure, i.e. an allocation of economic activities where the type and amount of economic activity differs between locations and where goods and production factors are exchanged between locations, and agglomeration factors are two sides of the same coin. One requires and implies the other.

To some extent our discussion in this section parallels the arguments of the new growth theory that we have discussed in the previous section. While new growth theory shows that the production of technical innovations is incompatible with the standard assumptions of neo-classical theory, our arguments show that spatial structure is incompatible with these assumptions as well. Allowing for agglomeration factors can overcome both these problems. However, when we allow for agglomeration factors the model will generate much more

complex dynamic processes and a diversified spatial structure. Agglomeration factors constitute a theoretical link between spatial structure of an economy and its growth dynamics.

In order to illustrate the relationship between agglomeration effects, spatial structure and growth dynamics, let us use a simple model by Arthur et al. (1987). Suppose we have two regions and a process that generates one new company per time period. In each period this new company is assigned to one of the two regions at random. Once a company is assigned to a region it stays there. There is no interregional mobility of companies.

We will distinguish two assignment processes:

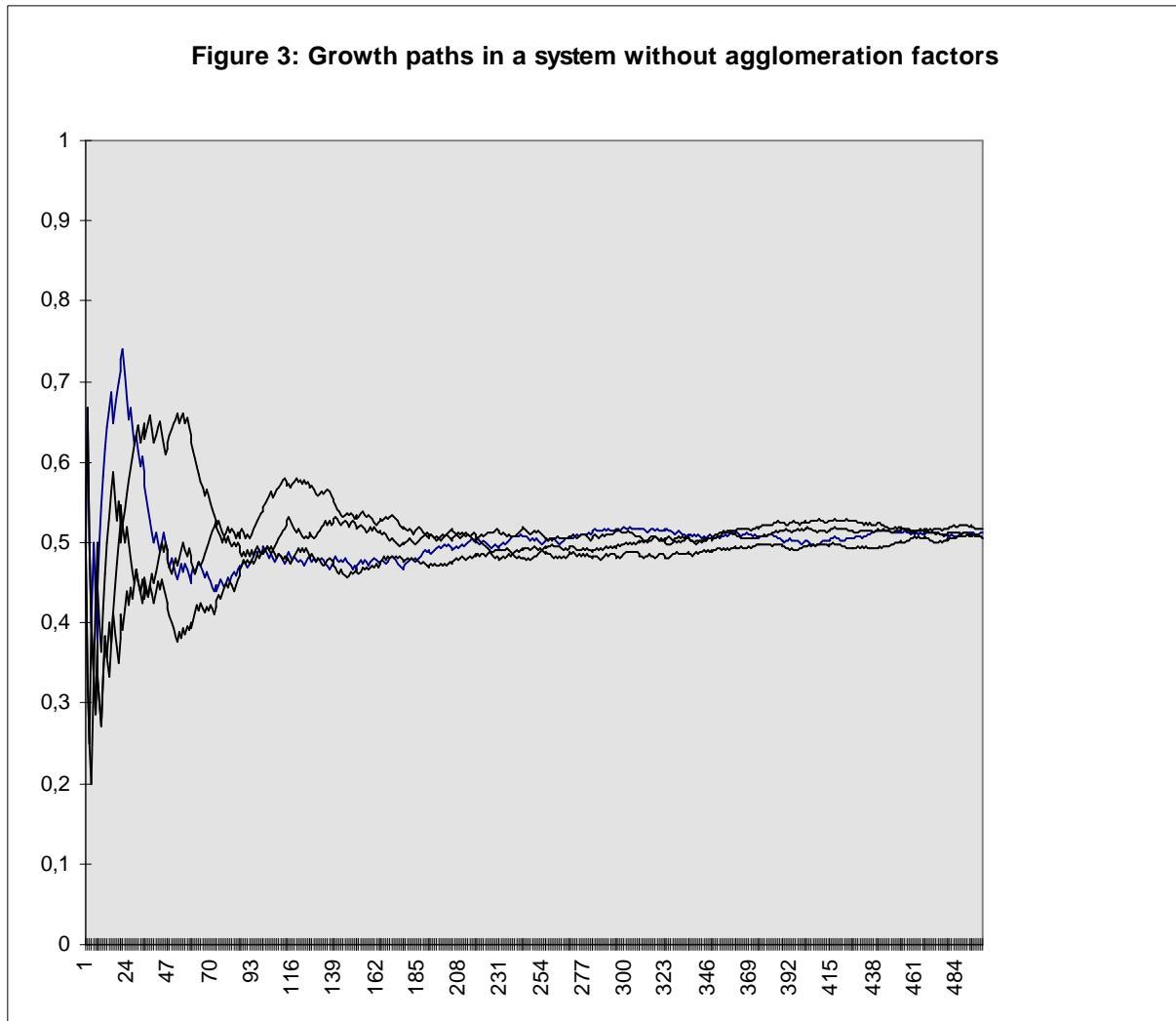
1. The probability that a new company is assigned to a region is exogenously given. For simplicity we will assume that both regions have probability 0.5.
2. The probability that a new company is assigned to a region is proportional to the region's share of companies. For obvious reasons we will start with an initial endowment of one company per region.

The two assignment processes differ as far as agglomeration factors are concerned. While in the first version each assignment is independent of earlier assignments and the existing concentration of companies, in the second assignment process there is a positive feedback between a region's share of companies and its chance for the next new company. This is clearly a positive agglomeration factor.

Despite this seemingly small difference, the long term outcomes of the models as far as spatial structure and growth dynamics is concerned differ dramatically. Figures 3 and 4 show the development of the shares of companies in the two regions. Figure 3 illustrates the case without agglomeration effects, figure 4 the case with agglomeration effects.

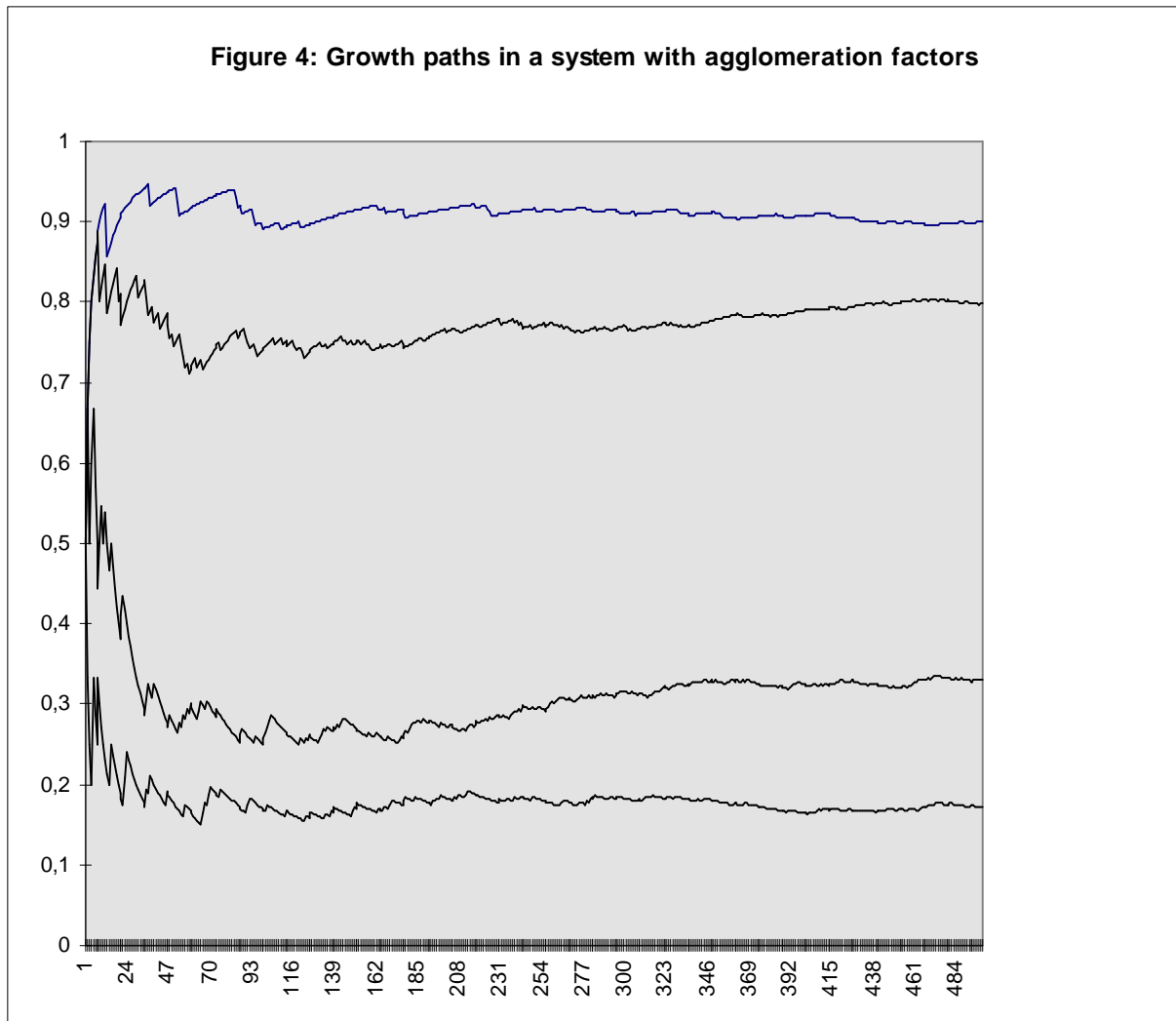
The long term behavior of the model version without agglomeration effects (fig. 3) is quite clear. Since the random assignments in each period are independent from one another the law of large numbers applies and a region's share of companies has to converge toward the constant assignment probability for this region (0.5 in our example). The four time paths that we have plotted in fig. 3 all show some major fluctuations in the early phase of the process and then converge toward the long term share of 0.5. The fluctuations result from the fact that adding one company has a larger impact on the share with a small total number of companies than with a larger one. However, these fluctuations die out over time. Any

advantages in the share that a region gains because of early success in the random assignment process is eliminated quickly by later random assignments. This corresponds to the typical growth process of the traditional neo-classical theory.



From fig. 4 we see that in the second case the regional shares do not converge toward a single value. Each of the four runs that we have plotted seems to tend toward a different value in the long run. This is in fact the case. In mathematical terms the process that we have used for our second example, where the assignment probabilities at a certain point in time are equal to the shares at that time, is known as a Polya-process (Polya and Eggenberger, 1923). From Polya-theory it is known (Polya, 1931) that such a process converges to a stable set of proportions in the long run. „But although this vector of proportions settles down and becomes constant, surprisingly it settles to a constant vector that is *selected randomly* from a uniform distribution over all possible shares that sum to 1.0“ (Arthur, 1994, p. 102). So, although we know that the process will settle down to a certain regional distribution of

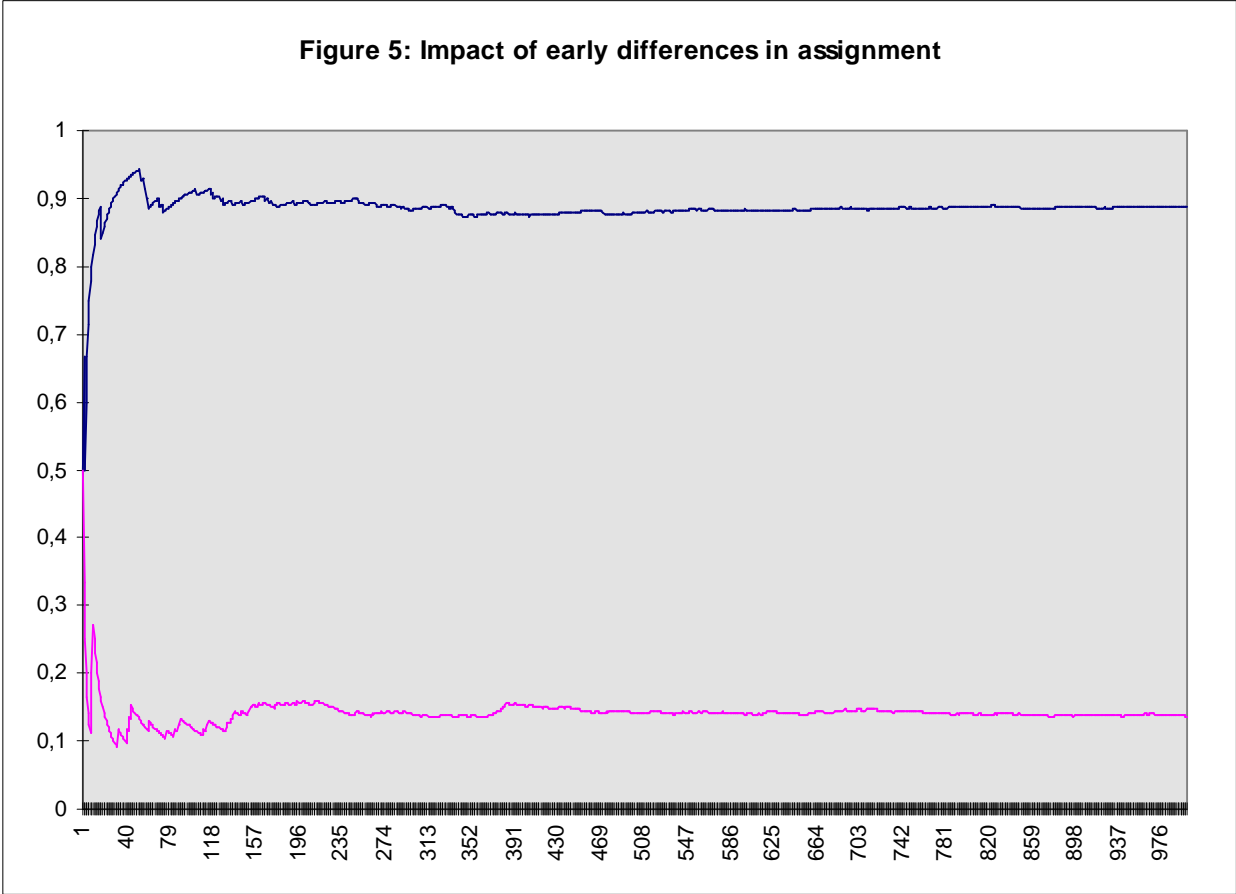
companies that will then remain constant over time, each possible outcome is equally likely. Formulated differently: We know that this process will produce a stable spatial structure, but we do not know a-priorily what this structure will be. Each possible structure is equally likely.



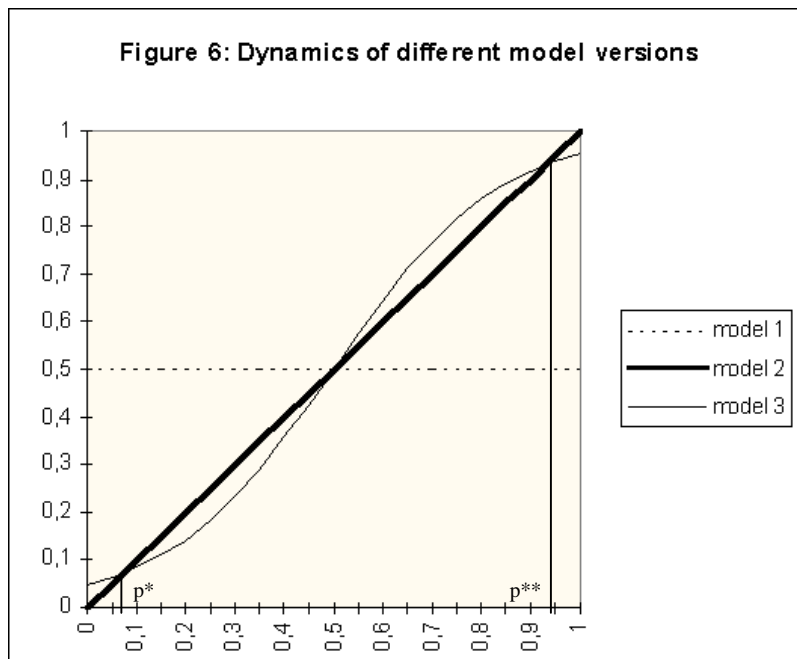
As in the case without agglomeration effects, we see strong fluctuations early on. But now these fluctuations are not just temporary phenomena, but determine the long term result of the process. A region that accumulates companies early on in the process because of good luck will end up with a high share of companies in the long run. Similarly, a region that loses early on in the growth process will also lose in the long run in the sense that it will reach only a low share of companies.

This process with agglomeration effects clearly shows path dependence. The long term fate of the process is determined early on in the process. Because of the relationship between share

and assignment probability seemingly small events in the early process accumulate over time to differences in the long term outcome. The importance of early events is illustrated in figure 5. The top path has been generated according to the mechanism described above by use of a series of random numbers. The first time a company is assigned it is assigned by chance to region I. After one thousand repetitions of the assignment process the share of companies of region I has settled down at 88.8%. The bottom path of fig. 5 has been generated from the same series of random numbers. Only for the first round the company was manually assigned to region II. As a result, the long run share of region I reaches only 13.7%. The difference between these two shares results only from whether the first company is assigned to region I or region II. Because of the impact this assignment has on future assignment probabilities, it results in a long term difference of about 75 percentage points. Depending on whether the first company is assigned to it or not, a region will develop into a dominant location of economic activity or just a marginal one.



The two types of dynamic random processes that we have discussed—a process with constant assignment probabilities and a process with assignment probabilities proportional to shares – are just two out of a number of possible variants. These variants may show different long



term behavior. For example, they may possess a number of fixed points to which the process may converge in the long run. However, when there are agglomeration effects the process is path dependent and events in its early phase determine to which fixed point it will converge in the long run. It can be shown (Arthur, 1986) that if the benefits from agglomeration increase without ceiling as companies are added to the system then one of the regions will eventually gain enough attractivity to capture all the subsequent allocations. This region will dominate the allocation of economic activity in the long run and shut out all the other regions.

We can gain additional insights into the dynamics of the process when we plot the assignment probability of a region against the share of this region. Figure 6 gives some typical examples. The broken line marked „model 1“ represents the model without agglomeration effects. Since this model had a constant assignment probability it is represented by a horizontal line (in our case at a probability of 0.5). We can see the long term behavior of the model directly from this graph. Whatever the share of the region, the assignment probability is always 0.5. Therefore, when the share is below 0.5, it will tend to increase, whereas when it is higher than 0.5 it will tend to decrease. The fixed point of this process is at the intersection of the line with the 45°-line, the share will tend toward 0.5.

The line that represents model 3 intersects the 45°-line three times. However, the fixed point at 0.5 is instable because the slope of the line at this point is higher than 1. Therefore, when the share of the region is slightly higher than 0.5 the region's chance to get the next assigned company is higher than its current share and the share will grow. When the share is slightly below 0.5 it will tend to decrease. The other two intersections of the curve with the 45°-line

represent stable fixed points. Therefore, in the long run the share will tend to a value either close to zero (r^*) or close to one (r^{**}).

For the Polya-model (model 2) the assignment probability always equals the share. Therefore, it is represented by the 45°-line. As a consequence, the Polya-model has an infinite number of stable fixed points. This implies the results that we have discussed above.

A few points are of particular importance in our discussion of dynamic processes with agglomeration effects:

1. Path dependence implies that „historical events“ – represented by random influence in our discussion – may play a decisive role in the development of a region. When they occur early in the process they may set the process off in a certain direction. Later on in the process, however, they may influence it only marginally.
2. Path dependence is paralleled by the phenomenon of „lock in“. Once the process has been set off on a certain path it becomes more and more difficult to move it away from this path. Since the famous results of welfare economics about the Pareto optimal outcome of the market allocation process do not apply in the case of agglomeration effect, there is no guarantee that the path the process takes is in any form desirable. The process may be locked in to a very unfavorable path but cannot depart from it even with substantial political intervention because of the stabilizing role of the agglomeration effects.
3. It should be noted that the model produces not only interesting dynamic trajectories, but also spatial structures that are stable in the long run. In a system with agglomeration effects there are typically two or more paths that the system can take and correspondingly two or more spatial structures that may emerge from the system. Since the spatial structures are just the cross-sectional view of the paths of the system, „lock in“ of the path implies high stability of the corresponding spatial structure.

4. Path Dependence and Lock-in in Regional Economic Growth

Our discussion of the impacts of agglomeration effects in the last section was highly stylized. We used the simplest model structure possible in order to concentrate the discussion on the main points. Therefore, we ignored all the economic mechanisms that were discussed in section

2 of the paper. Now, the question arises what will be the result if we reintroduce these economic mechanisms. Will the qualitative results of the previous section prevail?

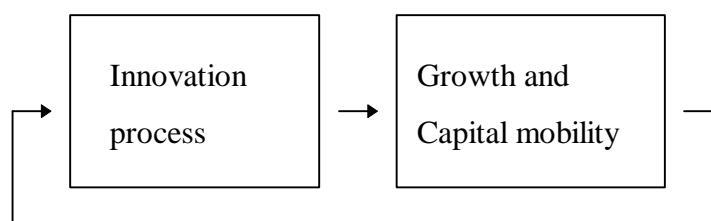
In this section we will analyze a model that combines components from section 2 and section 3. More specifically, we will use the neoclassical growth model from section 2 and augment it with an innovation process that is modelled according to Arthur's model with agglomeration effects that we have discussed above (see figure 7).

4.1. Model structure

The basic model structure is as follows:

- Suppose we have two regional economies that each can be modeled by the neoclassical model. In order to avoid unnecessary disturbances and adjustment processes each regional economy is assumed to have reached its long term equilibrium. The capital stock grows according to savings and depreciation. Capital is assumed to be perfectly mobile between the two regions, labor on the other hand is assumed to be regionally immobile.
- In each time period there is one unit of innovation added to the system. This additional unit is allocated to one of the regions at random. The probability for a region to receive this additional unit of innovation is assumed to be equal to its share of production in this period.

Figure 7: Basic structure of the model

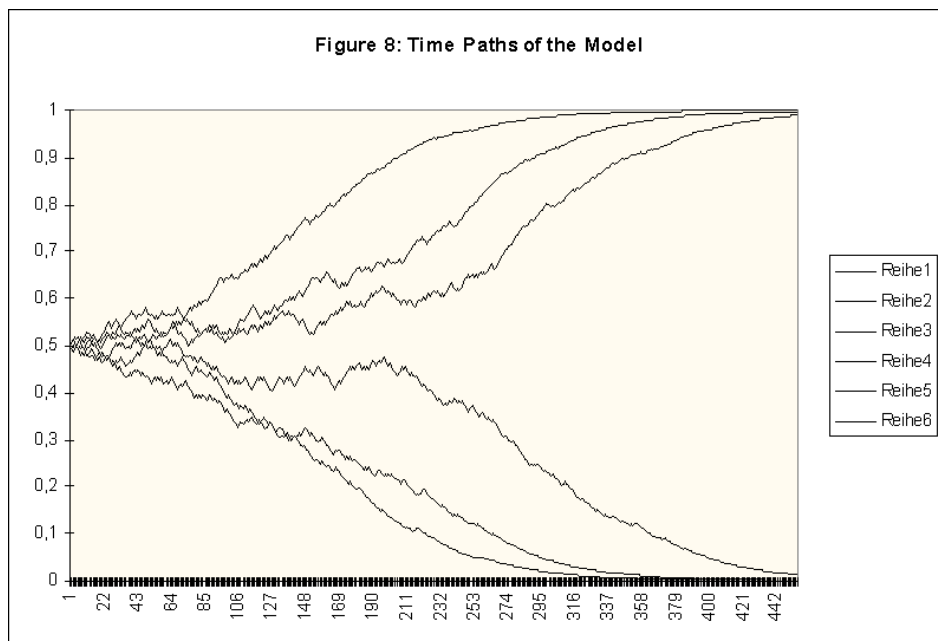


Note that this is basically a neo-classical model. It differs from the traditional neo-classical model only in the way how innovation is allocated. While in the traditional neo-classical model one unit of innovation per time period is added to every region, in our model the additional unit of innovation is allocated at random. The generation of innovation is still exogenous to the model as it is in the traditional neo-classical model.

4.2. Dynamic behavior of the model

In our model we combine two components that display quite different dynamic behavior. While the neo-classical growth model tends toward equilibrium and interregional convergence, the innovation model produces path dependence and may tend to different fixed points (see fig. 6). The question arises which type of dynamic behavior we will get when we combine these two types.

Before we look for an analytic answer to this question let us look at some simulation results. Figure 8 shows the production share of one of the regions for six simulation runs of the model. As we can see quite clearly, the model does not tend toward convergence. It seems that in the long run the region's share of production tends to either one or zero. The dynamic behavior of the total model seems to be different from that of both of its components.



In order to analyze the dynamic behavior of the model, let us look at it in more detail. First, note that we can divide the generation of capital into its two components: the accumulation of capital for the system as a whole and the allocation of capital according to its marginal productivity in the region. Second, note that we have assumed labor to be immobile. This is necessary because without keeping one of the production factors fixed all capital and labor would always immediately move to the region that has a temporary innovative advantage. Additionally we assume that labor is the same in both regions.

Therefore, we can write the production function for region i as

$$Y_i = (\mu_i K)^\alpha L^{1-\alpha} \exp(\tau I_i)$$

where μ_i is the region's share of capital and I_i is the number of units of innovation it has accumulated so far. K is the capital in the system as a whole, L is the constant amount of labor in the region. The other variables have the same meaning as in section 2.

The share of capital is determined by setting the marginal productivities of capital equal in both regions. This yields the following condition for μ (we set $\mu_1 = \mu$ and $\mu_2 = 1-\mu$):

$$[\mu/(1-\mu)]^{\alpha-1} = \exp[\tau(I_2-I_1)].$$

In order to find the results about the dynamic behavior of the system we need to find the relationship between the region's share in innovation units – $i_1 = I_1/N$ with $N = I_1+I_2$ – and the probability that it will receive the next unit of innovation. We call this probability for region 1 P_1 and write it as

$$P_1 = Y_1 / (Y_1 + Y_2)$$

When we substitute the equation of the production function and the condition for μ after some simplification we get the following result:

$$P_1 = 1 / \{1 + \exp[\tau N(1-2i_1)/(1-\alpha)]\}.$$

Note first that the assignment probability takes the form of a logit-model. Second, the assignment probability depends not only on the share and externally given parameters, but also on N , the number of units of innovation in the system. Since N changes over time we must expect the fixed points to change over time as well.

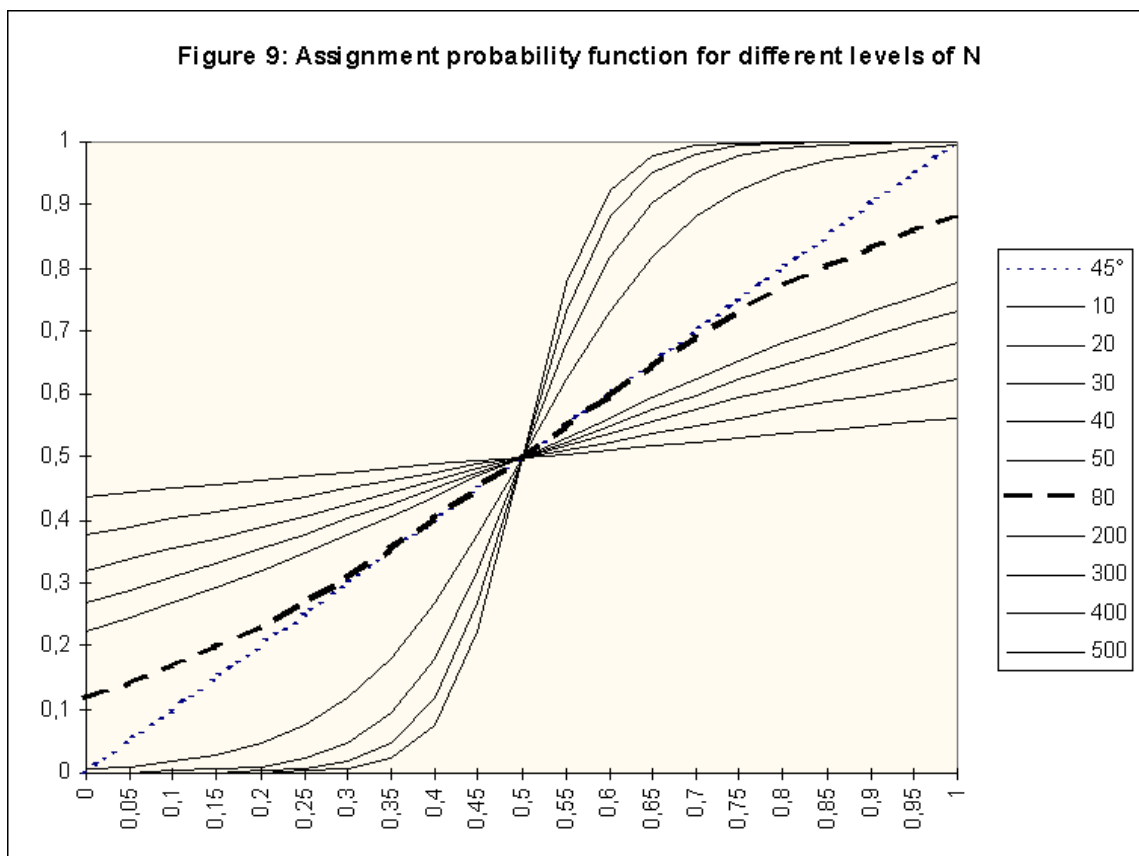
It is easy to see that the function increases monotonically in i_1 . Moreover, it has a fixed point at $i_1 = 0.5$ irrespective of the values of τ , N and α . Whether this fixed point is stable or not we find by looking at the slope of the function at this point. When the slope is equal or less than 1 the fixed point is stable. When we do the respective calculations we find that the fixed point at 0.5 is stable only for

$$N \leq 2(1-\alpha)/\tau.$$

This shows that for given parameters the fixed point at 0.5 is stable only up to a certain point in time represented by N . Up to this period the system will tend toward an equal distribution of innovations and production, after this period it will tend toward another fixed point.

Figure 9 plots the function of the assignment probability for different values of N (τ has been set to 0.01, α to 0.6). The dotted line represents the 45°-line, the thick broken line represents the line for $N = 80$, in this example the value when the fixed point at 0.5 becomes instable.

So, for the first 80 periods the system will tend toward an even distribution of innovation and consequently also of production. But, starting with period 80 small deviations from this distribution will imply that the assignment probability for this region will change in the same direction by more than the deviation in the share. Therefore, the share will tend to either increase or decrease depending on the direction of the deviation. After period 80 the system has two stable fixed points, one at a value above 0.5 and the other the same distance below 0.5. But, as the share tends toward one of these new fixed points with every period the fixed points move further away from 0.5. Since the fixed points tend toward zero and one as N increases, also the share of innovation (and consequently the share of production) will eventually end up in this extreme situation.



In the neo-classical model capital mobility is an important equilibrating factor. In our model, however, it amplifies the random fluctuations in innovation and therefore adds to instability. In order to see this, assume that we fix μ exogenously at 0.5. In this case it drops out of the equation for the assignment probability and this one simplifies to

$$P_1 = 1 / \{1 + \exp[\tau N(1-2i_1)]\}.$$

The condition for a stable fixed point at 0.5 becomes

$$N \leq 2/\tau.$$

But, this threshold is obviously higher than the one we had above for the model with capital mobility. Therefore, when we allow for capital mobility the model is stable (in the sense that it has a stable fixed point at 0.5) for a shorter period than when capital is immobile.

4.3. Policy considerations

Initially the two regions that we distinguish in our model are identical. They start off with the same amount of capital and labor, identical production functions and the same probability for getting assigned the first unit of innovation. Therefore, a development path that keeps the level of economic activity balanced between the two regions seems like a reasonable goal for regional policy. However, in the previous discussion of the dynamic properties of our model we have seen that after an initial period where balanced growth is a likely pattern the model tends to concentrate economic activity and thus also economic growth in one of the regions. In the long run there will always be one region that eventually reaches a sufficient concentration of economic activities that it attracts practically all future innovation and therefore all growth. The other region will stagnate and because of the growth in the system as a whole constantly lose share of economic activity. Taking into account that we have assumed labor to be interregionally immobile this implies that half of the population of the system is confined to a stagnating economy and shut out from future economic gains. Obviously, because of the social and political tensions this must generate, such a situation is not sustainable.

The question arises whether regional policy can save the system from this fate. Can regional policy keep the economic activity balanced between the two regions?

When we look at figure 9 we see immediately that the chances for this are slim. With growing levels of N the logit function that describes the assignment probability tends more and more toward a step function with assignment probabilities being zero for shares below one half, 0.5 when the share is exactly one half, and assignment probabilities being one for shares higher than one half. Therefore, the forces that pull the system away from a balanced distribution of economic activity become stronger and stronger over time. In this range, whenever the system departs from a balanced distribution because of some random influence it will be sucked into a state with almost all economic activity concentrated in one region. Policy's only chances to avoid this are either

- to eliminate the influence of innovation on the economic system or
- to perfectly assign innovations to the regions.

Neither of these alternatives is very practical. The first one would eliminate all growth from the system and both regions would fall into stagnation. The second alternative would require excessive authority and probably a centrally planned economy.

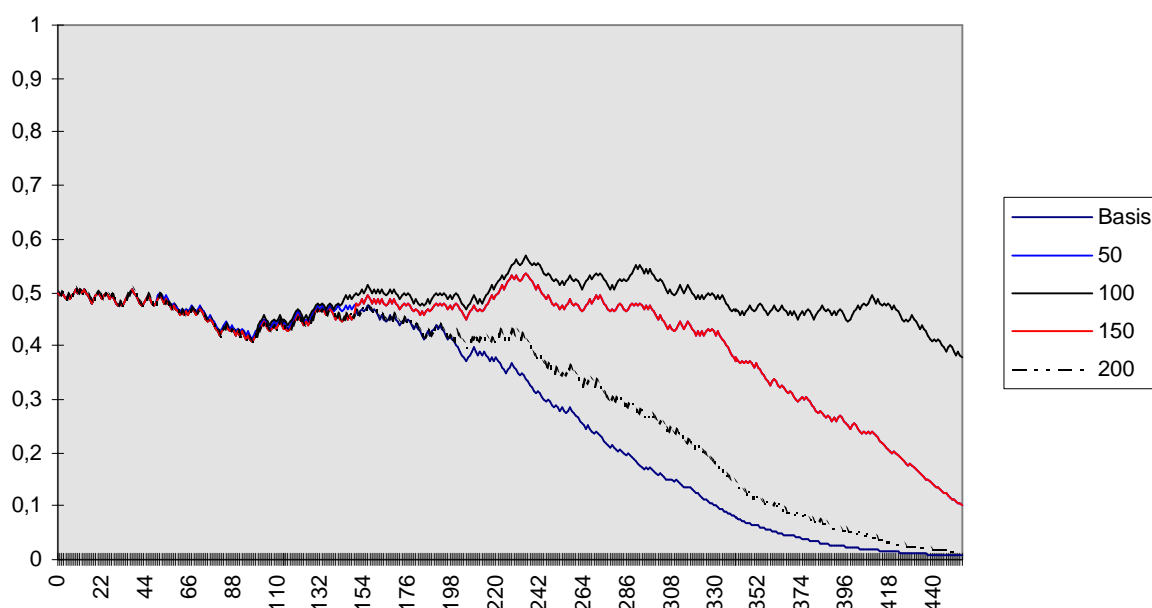
A particular problem for regional policy lies in the initial period of „stability“. In this period the shares fluctuate around the desired value of 0.5. When we observe the behavior of the system during this period, we will not see that after a few more time periods it will reach a state of instability. Once the system has reached this state, it does not switch immediately into the final state of instability. Since the fixed points move away from the value 0.5 gradually over time, the final implications of instability do not become apparent immediately. Therefore, it will probably take some time before regional policy even identifies the problem. During this time the system will most likely have reached a state where it is already locked into a path toward its final fate.

The path dependency of the system suggests that the timing of a policy is important. However, we have to distinguish the timing of a policy from its relative weight. Reassigning one unit of innovation, for example is a much more important policy measure in the fifth period (with $N = 5$) than in period 50. Because of the simplicity of the model only two types of policy can be analyzed, namely

1. exogenous assignment of units of innovation either as the assignment of additional units or as reassignment from one region to the other, and
2. transfer of capital from one region to the other.

Figure 10 shows the effect of the first type of policy at different points in the growth process. The graphs show the reference growth path and then growth paths for exogenous assignment of $1/50$ of the units of innovation to the region at periods 50, 100, 150, and 200. Identical random numbers were used for these simulations. None of the policies can keep the system at a balanced path and none can turn the displayed region from the losing to the winning one in the long term distribution of economic activities.

Figure 10: Policy Implication - exogenously assigning one fifth of innovations



The figure shows quite clearly the importance of timing of the policy measure. When the policy is applied at period 200 it has the least effect. It can raise the growth path over the baseline, but toward the end of the observation period the effect has almost vanished. Obviously, at period 200 the growth path had already moved too far down from a balanced distribution for the policy to have a major impact. Although we assign only half the number of units of innovation at that time, when the policy is applied at period 100 it has the biggest impact. The growth path remains balanced for a much longer period of time and even exceeds the 50% mark for quite a number of periods. However, at the end of the observation period the growth path starts to turn down.

When we apply the equivalent policy fifty periods earlier, its impact is less pronounced. Interestingly, we get the same long term outcome from this timing as when we apply the policy at period 150. The respective curves coincide for periods beyond 150. The reason for this seems to lie in the fact that the policy is applied already in the stable period of the system and that its effect is partly washed away before instability sets in. This indicates that in such a dynamic system a policy may not only be applied too late but also too early for its full impact.

Finally, let us briefly turn toward interregional transfer of capital as a possible policy for keeping the distribution of economic activity balanced. We assume that policy has the authority to transfer capital from one of the regions to the other. Whenever the share of production in

the regions deviates by more than a certain threshold from the ideal value of 0.5, the policy maker looks at the distribution of capital between the two regions and implements a policy that in the next period shifts a certain percentage of the capital difference from the less capital intensive region to the more capital intensive one. So, the policy measure has a time lag of one period and takes into account the situation in only one time period. Parameters of this policy are

1. the threshold when the policy will become effective, and
2. the percentage of the difference in capital that is transferred.

Figure 11: Effects of interregional transfer of capital

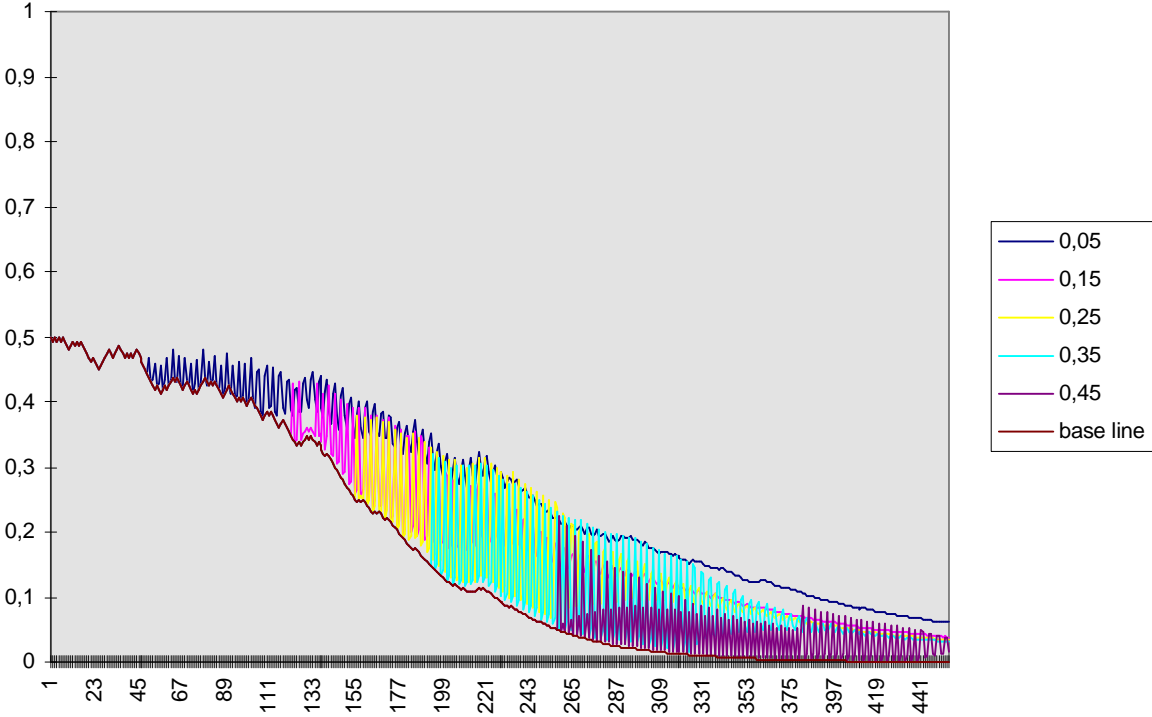


Figure 11 shows a typical simulation run for this type of policy for different threshold values. The second parameter was set to 0.5 which means that the policy maker attempts to balance the distribution of capital. If capital remained constant in the two regions, by transferring 50% of the difference the policy maker would balance the capital stock in the regions. As we see from the figure, the policy produces a lot of turbulence but no fundamental change in the long term result. When the system exceeds the threshold for the first time, the policy is implemented, capital transfer moves the production share back down under the threshold so that in the next period the policy is discontinued. This creates the fluctuations that are displayed

in figure 11. After some periods, however, capital transfer cannot push the production share below the threshold any longer, the policy remains in place, the fluctuations stop, but the system continues to drift away from an unbalanced distribution – despite of the policy being in effect.

As we can see from figure 11, the level of the threshold does not make much difference. When policy makers are more sensitive the tendency toward the extreme outcome of the system is generally delayed, but even very sensitive policy interventions cannot save the system from its final fate. This is the case despite the fact that the policy is assumed to transfer a substantial amount of capital. Even more powerful policies (higher values of the second parameter) yield qualitatively the same result. They only generate more severe fluctuations.

5. Concluding remarks

In this paper we have discussed different concepts of regional economic growth. We have reviewed the traditional neo-classical growth theory and the critique that has been brought forward by polarization theory and new growth theory. As it has turned out, agglomeration effects (economies of scale and externalities) play an important role in the newer concepts of economic growth. Therefore, in section 3 of the paper we discuss agglomeration effects, their relation to spatial structure, and the implications they have for the long term dynamics of a process. We could see that spatial structure and agglomeration effects are closely related. They imply and require each other. In section 4 of the paper we discuss a simple model that implements some of these concepts. The model combines a traditional neo-classical growth model with a stochastic model of innovation that implies agglomeration effects. The results of the model are quite striking. Instead of a tendency toward equilibrium and balanced growth the model produces economic disaster in the long run. It converges toward a distribution where one region has almost all production and all future growth and the other region stagnates. We could not find any meaningful policy that was able to avoid this extreme outcome.

The discussion in this paper illustrates a fundamental shift of paradigm that is taking place in economic theory. The work of new growth theory has shown that agglomeration effects are an essential element of a modern economy and that we cannot understand the functioning of an economy without allowing for agglomeration effects.

However, when we accept this argument also other factors that have been outside the consideration of the traditional economic theory move into its center. With agglomeration effects we necessarily get spatial structure, we get path dependence of growth processes, „lock-in“-phenomena, and long term implications of historical events. The new paradigm opens up the gates to a luxurious garden full of inefficiencies, disequilibria, divergent processes, non-linear dynamics, bifurcation points, etc. We have only made the first cautious steps into this garden. Its diverse landscape is far from explored yet.

But, with this change in paradigm many of the policy guidelines that we have used in the past become obsolete or at least questionable. The price mechanism does not guarantee an efficient allocation, economic growth processes do not necessarily converge, certain policies may work only in specific situations, good or bad luck may determine the long term fate of an economy, etc., etc. Most importantly for us regional economists is the fact that the spatial dimension cannot be ignored any longer. Spatial structure and spatial differentiation influence the amount of agglomeration effects that are at work and may therefore have major implications for the long term fate of an economy. But this brings into the play areas like spatial price theory, theories of spatial economic structure, etc. Economics is becoming much more complicated than in the past and has fewer decisive answers to give. But, it is becoming much more exciting.

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