Externalities, growth, and regional stagnation

Gunther Maier
Institute for Urban and Regional Studies,
Vienna University of Economics and Business Administration
Vienna, Austria
Email: gunther.maier@wu-wien.ac.at

Abstract

This paper discusses the impact of externalities on economic growth and the long term distribution of economic activities in a system of two regions. We use a standard neoclassical growth model of the Solow-type and augment it with a random process of innovation allocation. The long term behavior of this model is analyzed. As it turns out the dynamic behavior of our model differs fundamentally from that of the standard neoclassical growth model. In the long run always one of the regions attracts all the future innovation and growth while the other region stagnates. We show that this outcome results from an externality in the process of innovation allocation and discuss its significance and sensitivity to changes in the model structure.

This paper is a revised version of a paper that was given at the international workshop "Theories of Regional Development: Lessons for Policies of Regional Economic Renewal and Growth", Uddevalla, Sweden, June 14-16, 1998.

1. Introduction

In recent years, we have seen some fundamental developments in economic theory concerning the understanding of economic growth. The traditional growth theory was replaced by a set of models and arguments that are commonly known as „new growth theory“ (e.g., Romer, 1986, 1990, Rebelo, 1991, Grossamn and Helpman, 1992). 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.

The most crucial assumption is that of a linear homogeneous production function. The creation of innovation cannot be explained in a model of this type. Only when one allows for agglomeration effects (economies of scale or externalities) there are economic incentives to invest in the production of innovation.

In regional economics these advances in economic theory received a mixed reception (Isserman, 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 that agglomeration effects may have for our understanding of regional growth and of regional growth policy. The discussion will show that a 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. We will start from the well known Solow-model of traditional neo-classical growth theory, apply it to an economy consisting of two identical regions, and augment this model with a component that allocates innovations to these regions. Since this additional component introduces agglomeration effects into our model, we can attribute the difference in long term dynamic behavior between the Solow-model (our baseline) and our model to the agglomeration effects.

2. Agglomeration effects, path dependence, and regional structure

We will model the assignment of innovation to our two regions by use of a simple model that was formulated by W. Brian Arthur. 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 region i 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 region i 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 outcome of the models as far as spatial structure and growth dynamics is concerned differs dramatically. Figures[1] 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 at 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 in the early part of the process result from the fact that the addition of one company has a larger impact on the share with a small total number of companies than with a larger one. However, these fluctuation 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.

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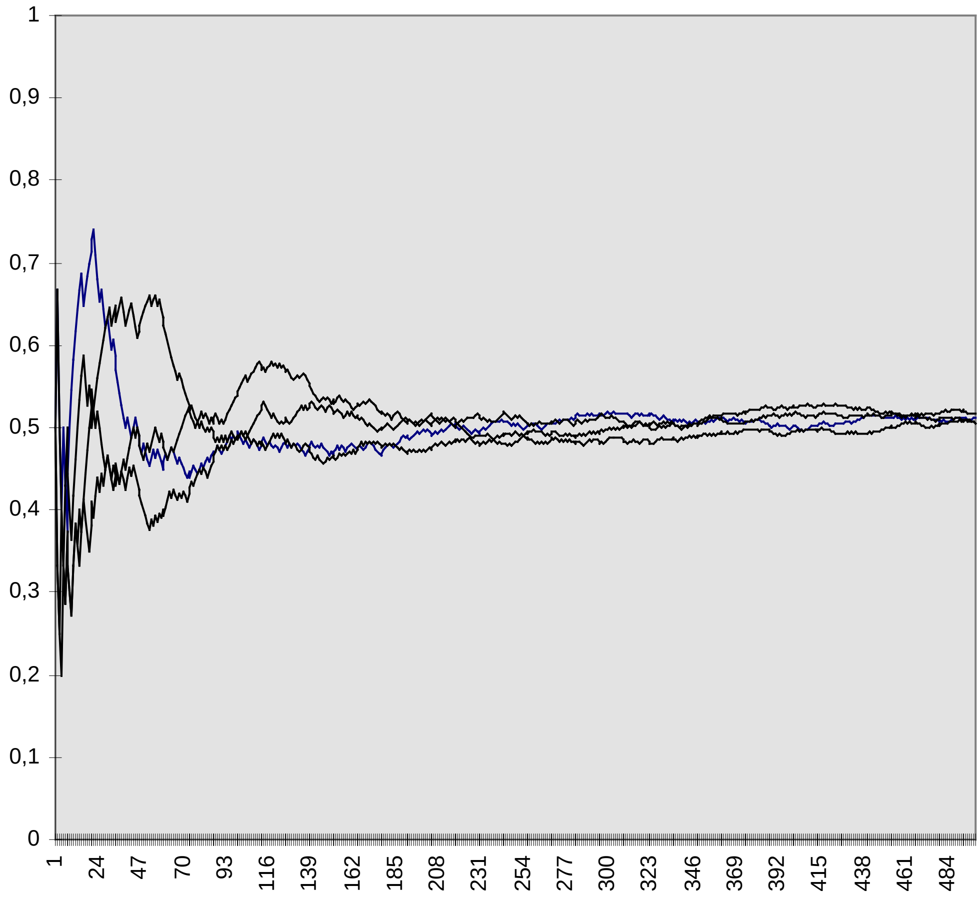
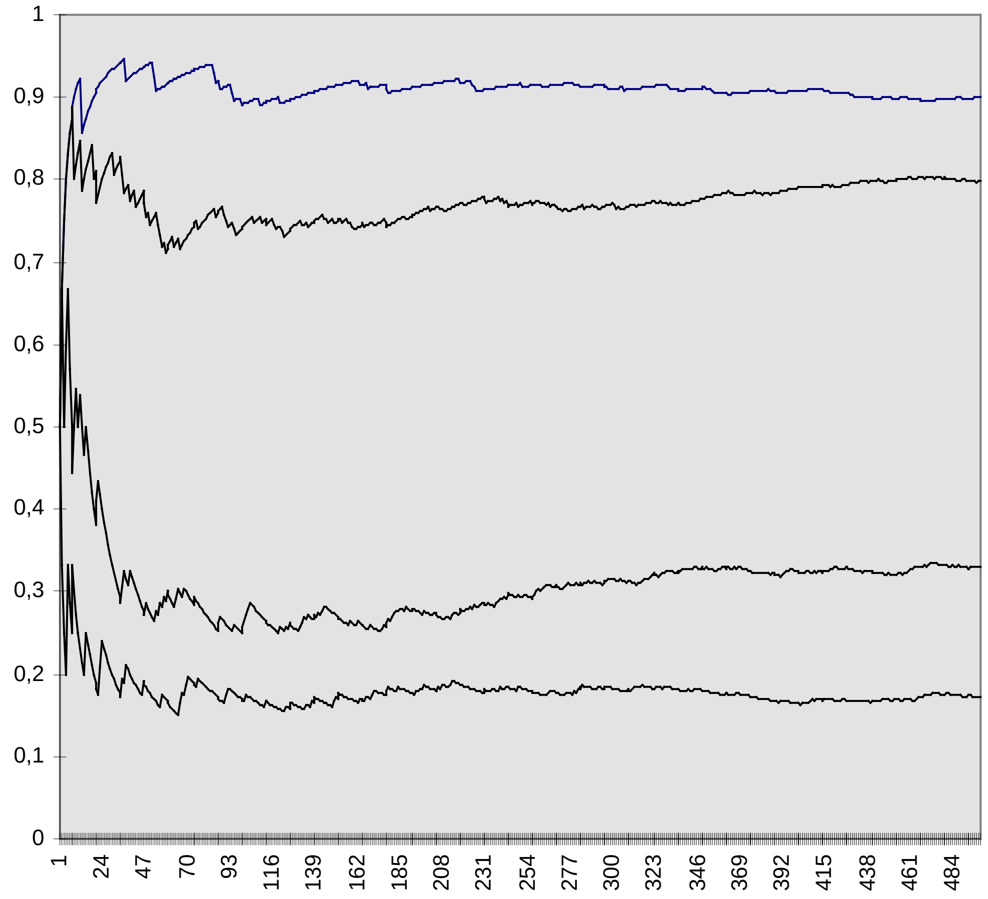
[1] Since the text of this paper was derived from an earlier paper, the figures are out of order. I apologize for this potentially confusing oddity.

Figure 3: Growth paths in a system without agglomeration factors



From fig. 4 we see that the 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, Polya, 1931). From Polya-theory it is known 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-priori what this structure will be. Each possible structure is equally likely.

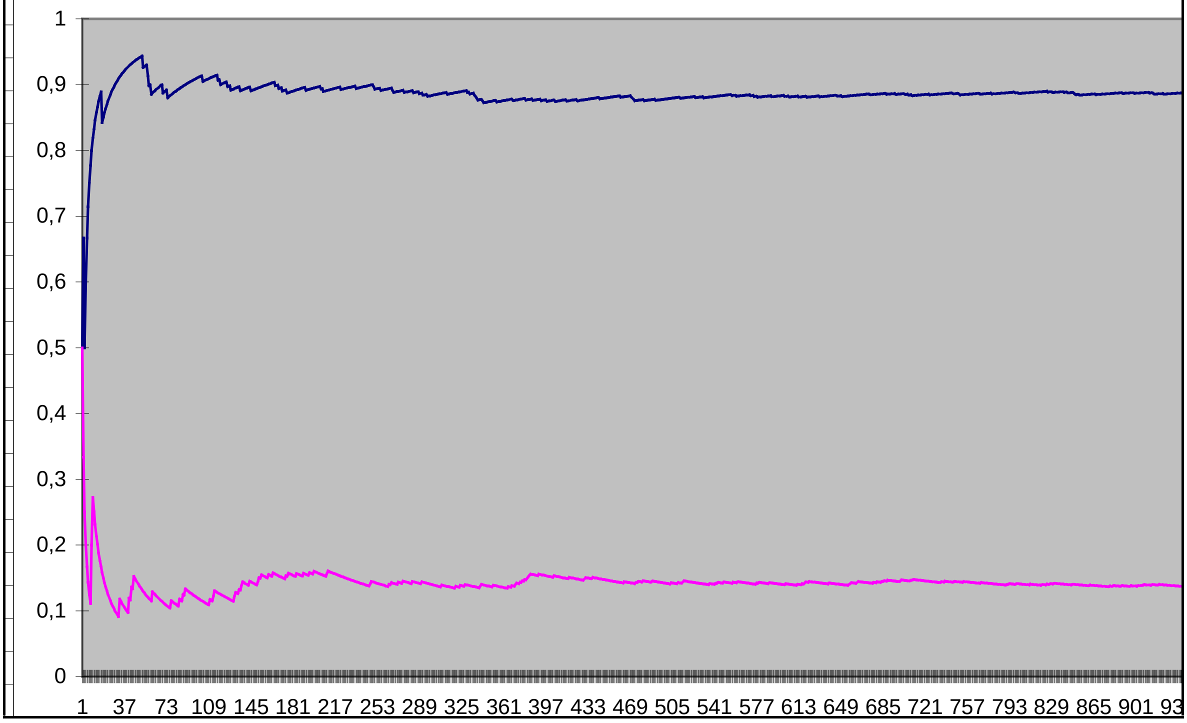
Figure 4: Growth paths in a system with agglomeration factors



As in the case without agglomeration effects, we see strong fluctuations early on. But now these fluctuations do not die out over time, 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 looses early on in the growth process will also loose in the long run in the sense that it will reach only a low share of companies.

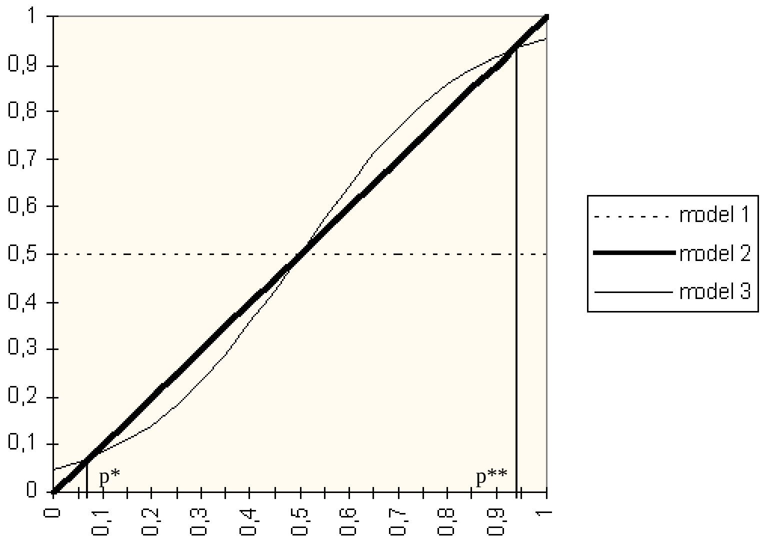
This process with agglomeration effects clearly shows path dependence. The long term fate of the process is determined early on in the process. Because of the relationship between share and assignment probability seemingly small events in the early process accumulate over time to differences in the long 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 forced to be 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.

Figure 5: Impact of early differences in assignment



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.

Figure 6: Dynamics of different model versions



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.

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.

3. Growth and equilibrium in traditional growth theory

In the model that we will discuss in the following section we will combine a traditional neo-classical model of economic growth with Arthur’s random process of allocation that we have discussed above. Therefore, in this section we will take a look at the traditional growth model of the Solow-type (Solow, 1956). 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 from 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 characterized 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.

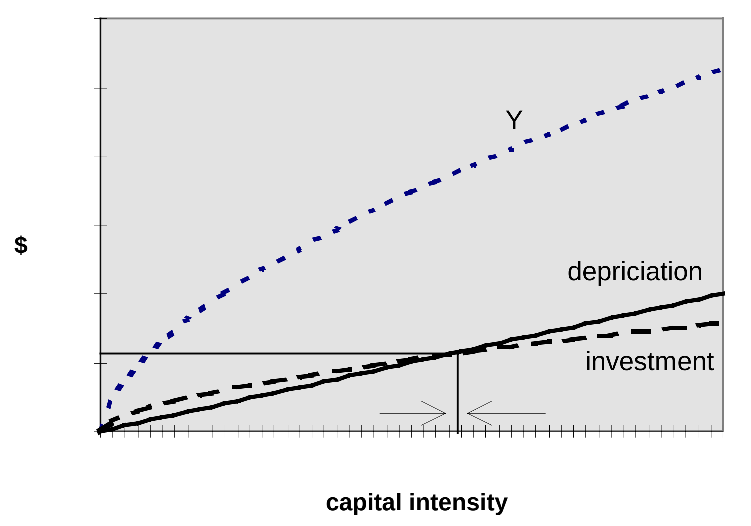
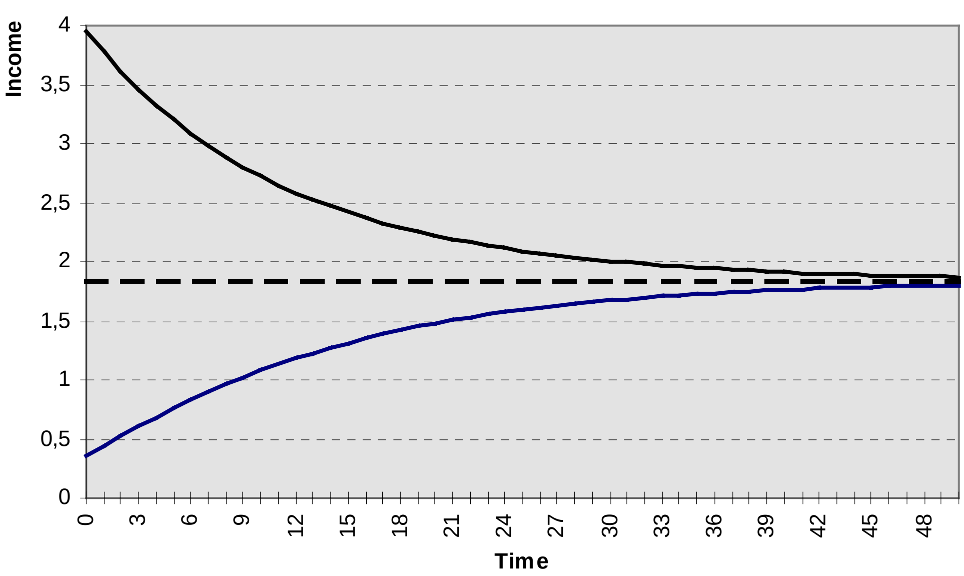


Fig.1: Growth and Net-Investment

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 (Borts and Stein, 1964, Richardson, 1969). 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. We can think of this formulation as a shorthand of a process where innovations are added in constant amounts per time period.

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 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.

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

n 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 modeled according to Arthur's model with agglomeration effects that we have discussed above (see figure 7).

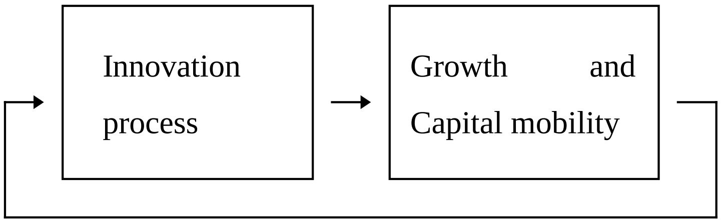
4.2. Model structure

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 region i to receive this additional unit of innovation is assumed to be equal to the region's 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.

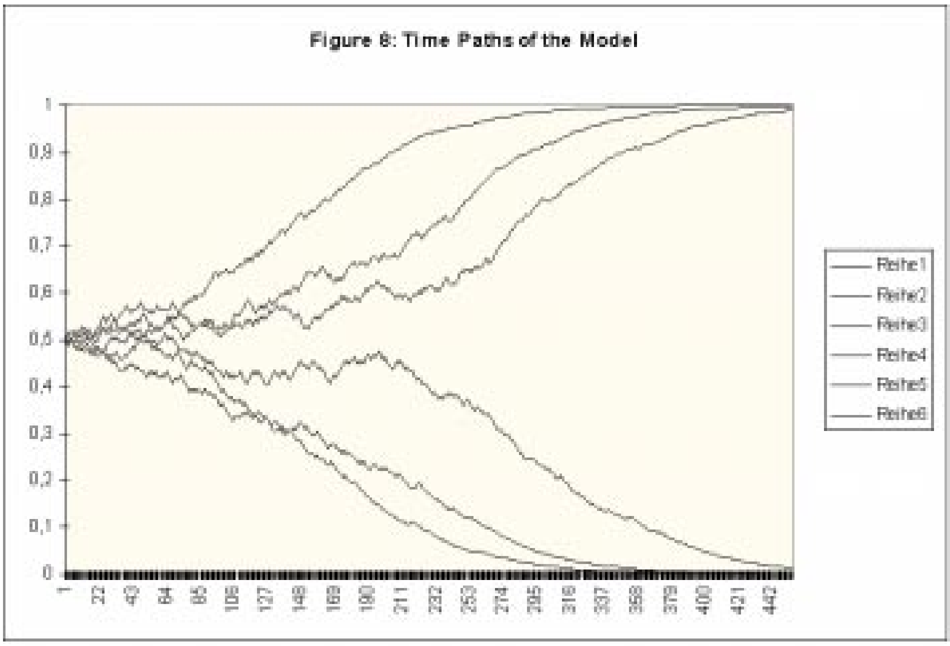


Figure 8: Time Paths of the Model

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 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 Ii 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.

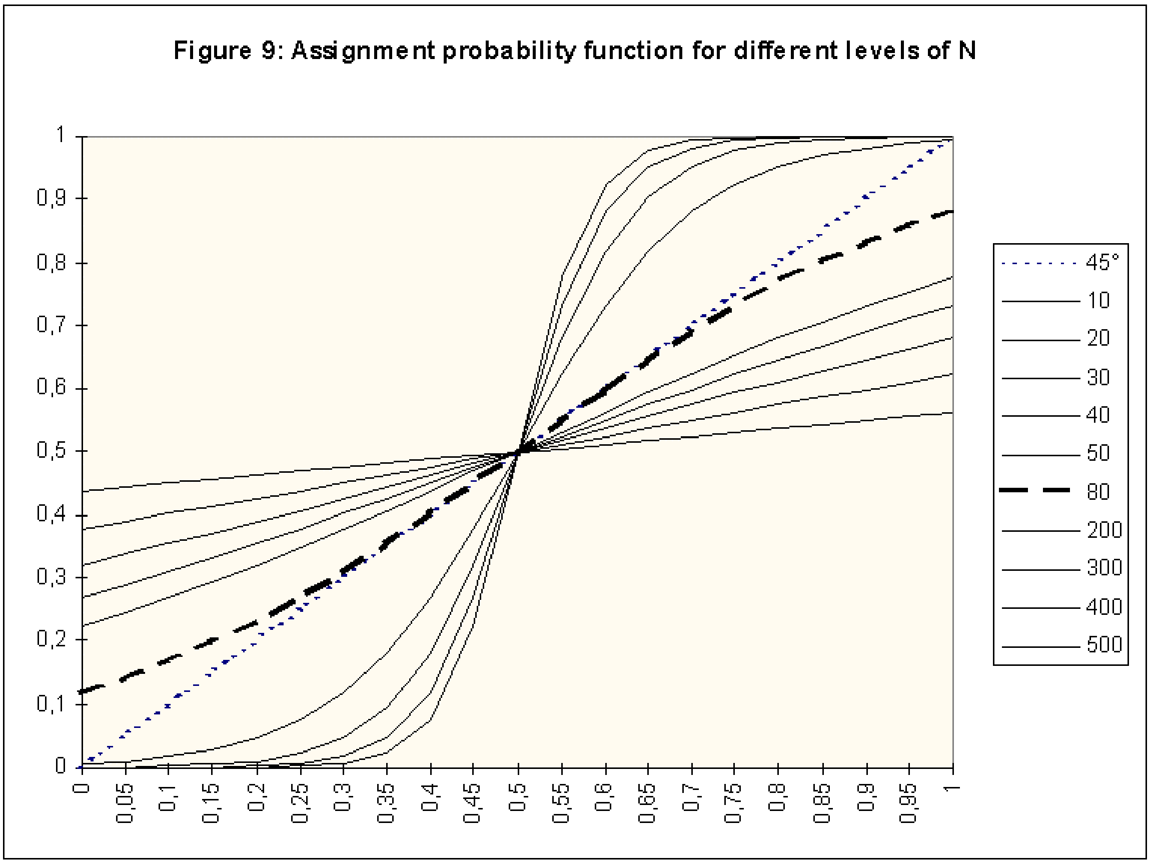
It is easy to see that the function increases monotonically in i_1. Moreover, it has a fixed point at $i_1 = 0.5$ irrespective of the values of τ, N and α. Whether this fixed point is stable or not we find by looking at the slope of the function at this point. When the slope is equal or less than 1 the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



As compared to the standard neo-classical growth theory this result is quite surprising. While in the traditional neo-classical theory the growth process eliminates any growth differentials in the long run, when we augment the model with the Arthur-type assignment process growth always tends to concentrate in one of the regions while the other one falls into stagnation. In the long run the assignment probability always approaches zero for one of the regions and one for the other.

4.3. Some further discussion

The result about the long term behavior of the model that we have derived above is quite surprising. It raises the question of how stable it is with respect to changes in parameter values and model structure. We will look at three factors that may influence the result:

1. capital mobility,
2. the inclusion of land as a production factor, and
3. regional diffusion of innovation.

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.

One may argue that the result of the model is flawed because the model does not take into account the land market and the rising land prices in the prospering region as compared to the stagnating one. When growth begins to concentrate on one of the two regions, one may argue, land will become scarce in this region, land prices will increase, and the region will become less attractive for future development.

After a closer look, however, this argument cannot be supported. The production factor labor that we have taken into account in our model is assumed to be regionally immobile just as land is. Therefore, we can think it as an immobile production factor that captures the effects of land, labor, and probably other immobile production factors. In the process of development the price of labor increases in the prosperous region as compared to the stagnating one in our model. This process, however, is not strong enough to offset the effect of innovation accumulation and inflow of capital.

A third argument that may be brought forward is that we assume innovation to be regionally immobile. When a unit of innovation is assigned to one of the regions it remains there and does not spread out to the other region. This is in contrast with practically all the literature on regional innovation diffusion which shows that innovation is at least partially mobile.

However, we can show that our result holds as long as innovation is not perfectly mobile. To show this, let us assume that a fraction k ($0 \leq k \leq 1$) of the innovations is always equally distributed between the two regions and only the remaining part allocated according to the assignment mechanism that we have applied above. With this assumption the production function becomes

$$Y_i = (\mu_i K)^{\alpha} L^{1-\alpha} \exp[\tau kN/2 + \tau(1-k)I_i].$$

Note that this production function now contains both our model ($k = 0$) and the traditional neo-classical model ($k = 1$). By changing k we can change the composition of the two models.

The condition for the distribution of capital becomes

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

The assignment probability changes to

$$P_1 = 1 / \{1 + \exp[2\tau(1-k)(I_2-I_1)]\}$$

and we see that for larger values of k the assignment probability reacts less strongly to a certain difference in the regional endowment with innovation. However, in order to get some results about the long term dynamics we need to relate P_1 to i_1, the region's share of innovation. Because of the two components of innovation, i_1 now becomes

$$i_1 = [kN/2 + (1-k) I_1] / N.$$

To be able to solve for I_1 we need the restriction $k \neq 1$. Substituting the result into the equation for the assignment probability we find that as long as k is not equal to 1 the model has the same relationship between the region's innovation share and its assignment probability:

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

Therefore, the result holds as long as innovation is not perfectly mobile between the two regions.

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 inter-regionally 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.

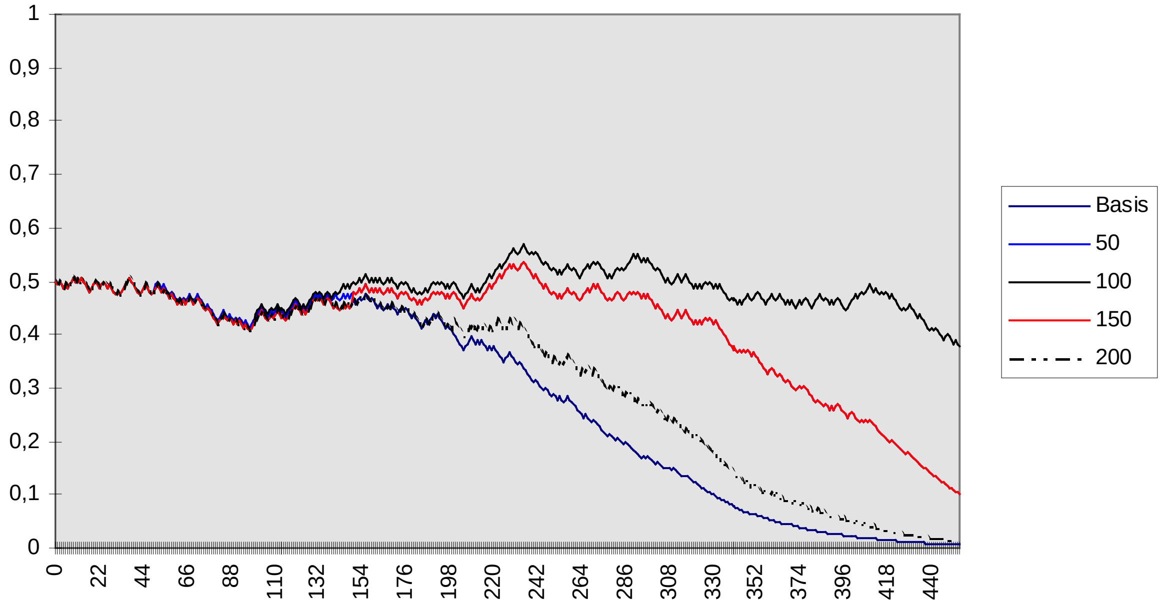
A particular problem for regional policy lies in the initial period of „stability". In this period the shares fluctuate around the desired value of 0.5. When we observe the behavior of the system during this period, we will not see that after a few more time periods it will reach a state of instability. 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

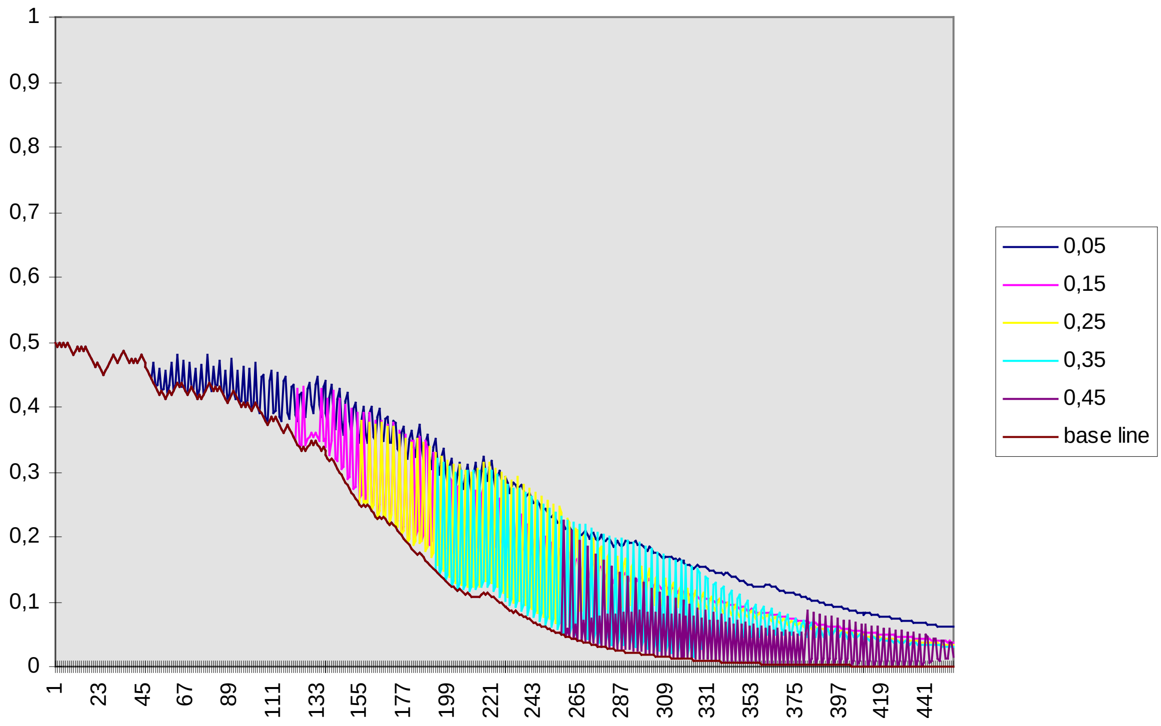


Figure 11 shows a typical simulation run for this type of policy for different threshold values. The second parameter was set to 0.5 which means that the policy maker attempts to balance the distribution of capital. If capital remained constant in the two regions, by transferring 50% of the difference 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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