THE USAGE OF SYSTEM DYNAMICS IN REGIONAL SCIENCES

Lucie Sobotková
University of Pardubice, Faculty of Economics and Administration, Institute of Economics

Abstract: *The paper deals with presentation of system dynamics as the tool for modeling of economic processes. The model of regional competitiveness is used for closer characteristics of this discipline. The system dynamics enables to search and mutually to combine "hard" and "soft" processes in regional economy. The searching retroactive reactions of elements of system to interference with regional economy is the next important character.*

Keywords: *Regions, Competitiveness of Regions, System Dynamics, Model of Competitiveness, Simulation of Model.*

JEL Classification: *O15, O18, R11, R15.*

1. Introduction

The creation of economic models is very sophisticated matter. The creation of models is especially complicated on that account that on the one hand tries to realize economic reality in simplified form and on the other hand tries to reach maximum credibility. Te next problem of modelling relates with influencing by human sense of reality. Hence this sense is only able to analyze the limited quantum of causal linkages among elements of a model. The backward reaction among original elements to evolution of a whole system is not reflected by human sense.

The discipline of system dynamics is the basis of mentioned problems. This discipline tries to intercept all feedbacks of particular elements with each other. The models (outputs) can be used especially for prediction of e.g. economical politics, economical behaviour of various subjects etc. The principle of system dynamics is for its presentation applied to field of regional studies. Hence regional economic models try to describe and analyze "soft" factors as well which influence by principal way the processes in a region.

The instruments of system dynamics it is possible to use only that time if it is possible to describe a region as a system of subjects and relations among them. The conception of the region as the system can be founded e. g. in publication written by Skokan (2004). The wider elaboration of this question is caught by Hudec et al. (2009), who underlined the importance of opened region for increasing its ability to adapt to continually changing conditions.

In case of regional competitiveness and its effort to achieve of required level of competitiveness it is necessary to mention the group of Berman Group (2006). The emphasis is especially put on interference of relevant factors of competitiveness. In terms of foreign authors can be mentioned Kitson et al. (2004), who notices relations among basic factors of competitiveness structured in hexagonal form, eventually

Gardiner et al. (2004), who deals with hierarchical structure of factors of regional competitiveness.

2. The General Dynamic Model in Graphical Form

The dynamic model can be expressed in graphic form where are evident relations among particular components of the system. The used method of graphical presentation of the above-mentioned system is causal loop diagrams or stocks and flow diagrams. The model can be displayed by the help of icons which enable an orientation in the model. In following Fig. 1 are illustrated the most important types of symbols which will be further used for representation of surveyed regional models.

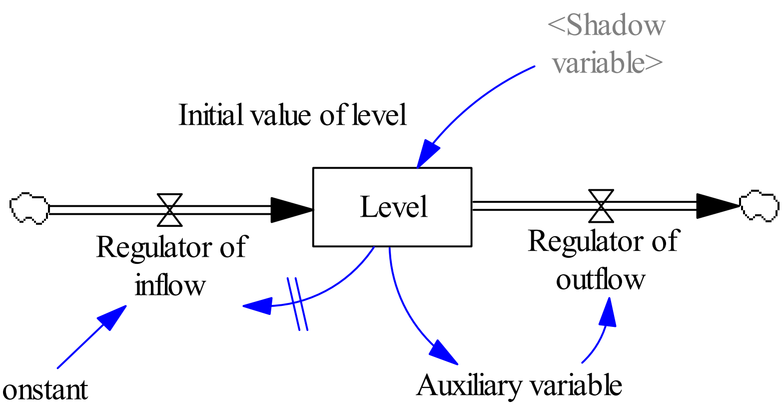


Fig. 1: The symbols used in dynamic models

Source: modified according to (Forrester, 1961) and (Burianová, 2007)

The level presents the accumulation in the system. It is the present value of those variables, which are the result between inflows and outflows. Each level has the own initial value and can be further influenced by constants and other variables. The causal feedback among variables is expressed by single indicator. The double indicator presents flow (inflow or outflow) which is influenced by regulators.

The simple arrow illustrates the causal linkages among variables (eventually among constants and variables). Double crossed arrow (illustrated between "level" and "regulator of inflow" in figure 1) represents the delay. Two-line arrow represents above mentioned flow (inflow or outflow) which is influenced by regulators. The flow can start or can finish in some accumulation or can go out the system (expressed by symbol of cloud – means border of a system). Every accumulation represents the state variable, the outflow represents the negative part of dynamic equation and inflow is the positive part of this dynamic equation.

The auxiliary variables are the next elements of the system. These variables represent exogenous variables and exact functions. Each auxiliary variable has the formula which expresses the value of this variable in dependence on other elements of system which have the linkage with it. The regulators are in principle the auxiliary variables. The shadow variables represent the other part of system. However these variables are the cross-over bridge among particular models.

3. The Description of Chosen Models of Competitiveness of Region

The competitiveness model of regions consists of the following sub-sections:

- demographic model,
- labour market model,
- capital and production model,
- infrastructure model,
- quality of life model.

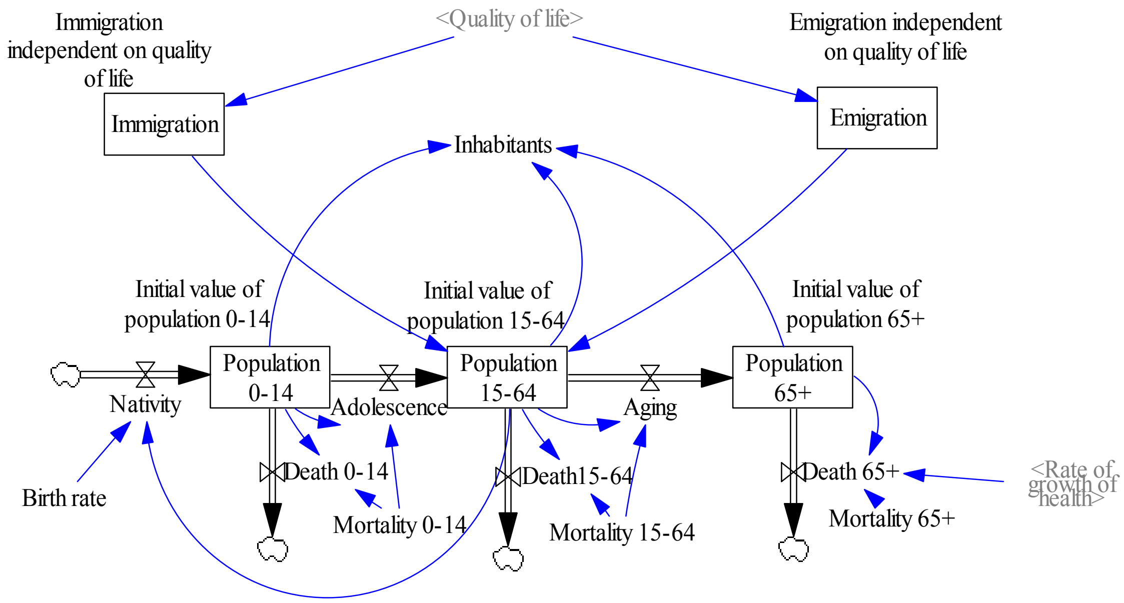


Fig. 2: The demographic model

Source: (own construction)

The demographic model shows the changes in the composition of the population due to natural movement of population and migration. The basis of the model is to create a descriptor of aging, which is based on the above mentioned population distribution and relationship between them. Status of the population is affected by the birth and death rate. The rate is essentially a constant, which reflect the population's reproduction rate, or the proportion of dead people in the population. Another important factor that affects the status of the population in a region is migration. The level of immigration (or emigration) is divided in the model into immigration (emigration) dependent on the degree of improvement in quality of life, and into immigration (emigration) not dependent on this measure. The model assumes that an increase in quality of life encourages inward migration from other regions. On the contrary, reducing the quality of life will result in a gradual decline in population caused by the departure of the population outside the surveyed region.

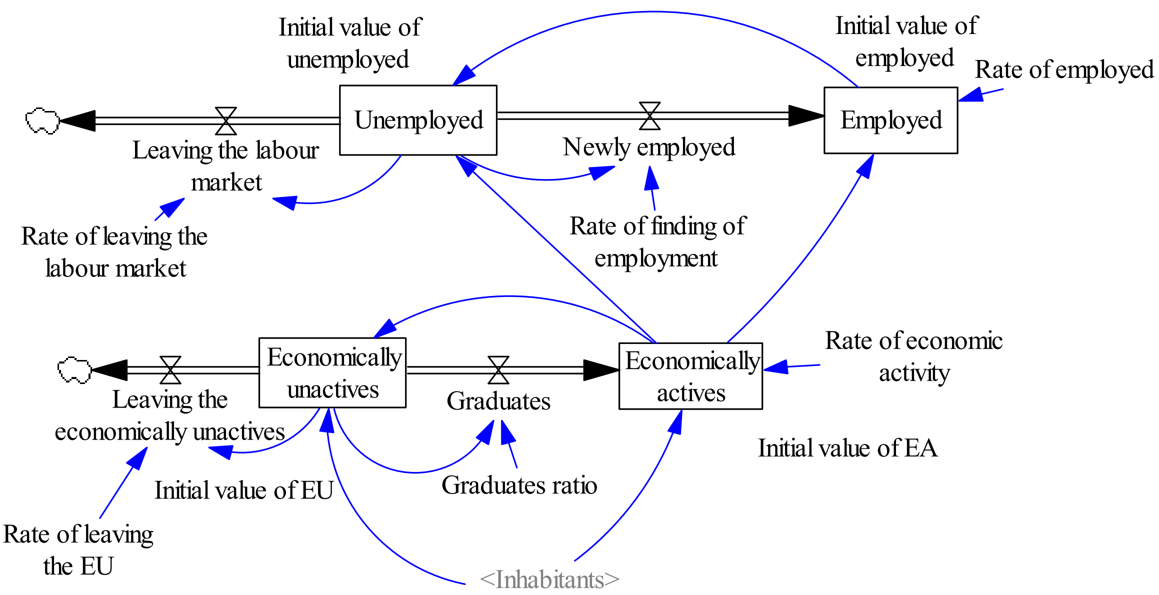


Fig. 3: Labour market model

Source: (own construction)

The model of labour market is connected with the mentioned above demographic model through the variable “population”. The model divides population according to the level of economic activity into:

- economically active (EA),
- economically inactive (EU).

The economically active population can be further divided into:

- workers,
- unemployed.

Among these four levels is the movement of people, which is expressed by auxiliary variables:

- graduates - the number of students who completed their studies and enter the labour market (for simplicity the entry of graduates into the labour market is only considered, women re-entering the labour market after maternity leave are not considered, etc.),
- leaving the labour market - the number of unemployed who are not searching for a new job, or those leaving the labour market,
- EU exit - number of economically inactive inhabitants who leave a system.

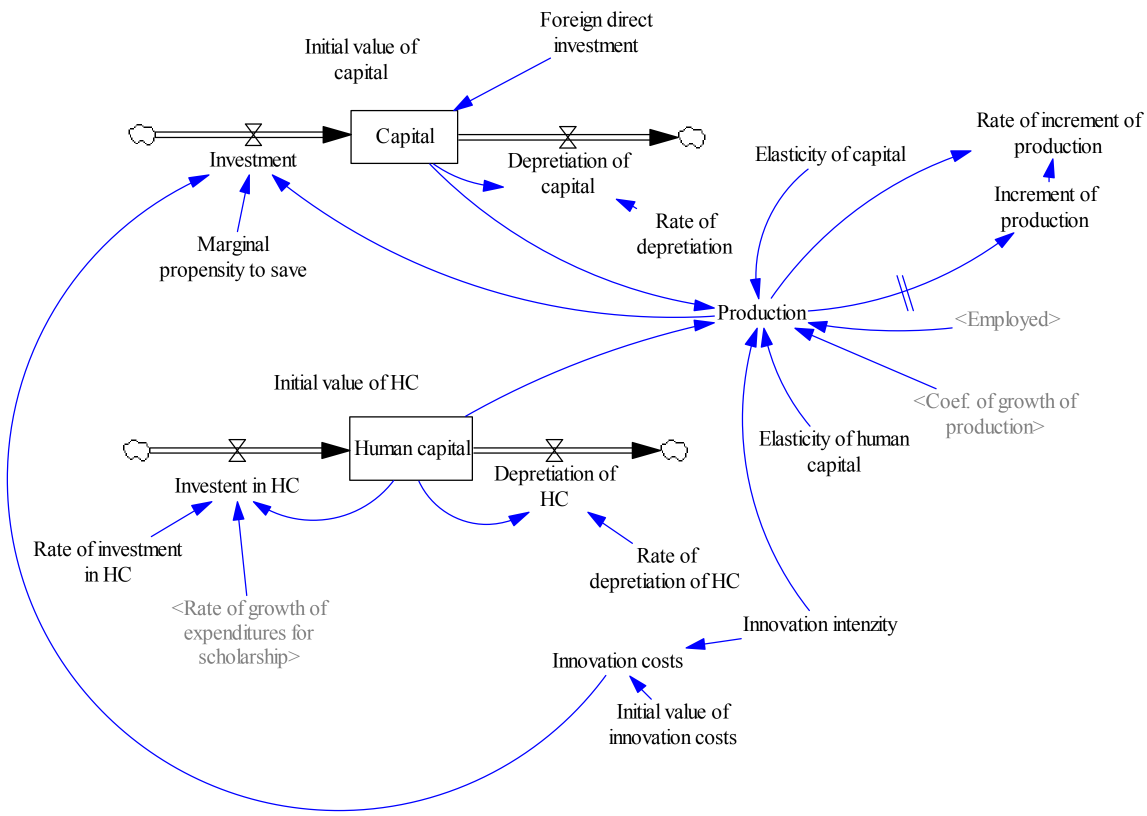


Fig. 4: The capital and production model

Source: (own construction)

The capital model results from the Solow model of stable growth. A prerequisite of this model is to identify the region with the Cobb-Douglas production function, which considers a constant returns to scale, and includes technical improvements (given exogenously). This technical improvement in the model is represents by the growth rate of production that is influenced by changes in infrastructure.

Other components of this model are foreign direct investment (FDI) and the intensity of innovation. The amount of foreign direct investment is determined by the influences outside the regional economic system. In the model, their amount is not dependant on the production size of the economy.

The intensity of innovation is a share of the cost of innovation and a firm’s income. Such innovation costs affect both production growth and they also have an affect on the level of investment in the economy. The relationship between innovation and product is expressed by multifactor productivity which is represented by product growth by constant amount of capital and labour.

Another component of the model is human capital. An increase in the size of human capital is education and level of investment. The measure of investment is furthermore increased by measure of annual growth in expenditures on education.

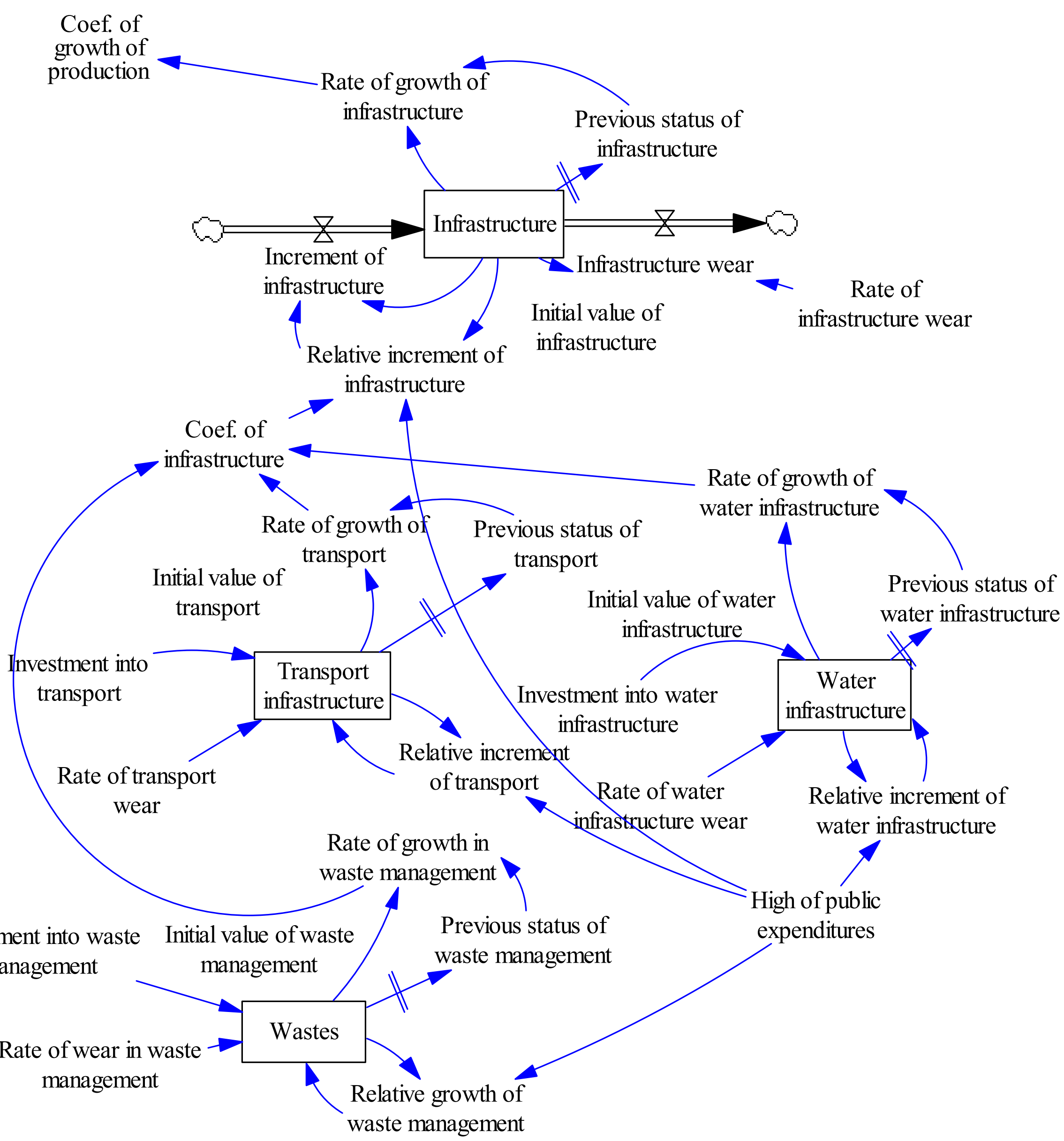


Fig. 5: The infrastructure model

Source: (own construction)

The model of infrastructure displays impacts of chosen types of infrastructure on regional production. The infrastructure is in this model is divided into:

- transport infrastructure,
- water infrastructure,
- waste management.

The limiting factor for all three studied examples is public infrastructure spending. With the growing demands on infrastructure the cost for its maintenance and expansion also increases. Agglomerative losses are proved here. For each type of infrastructure, it is necessary to determine the relative growth of the kind of infrastructure; the size of growth will limit the amount of the investment.

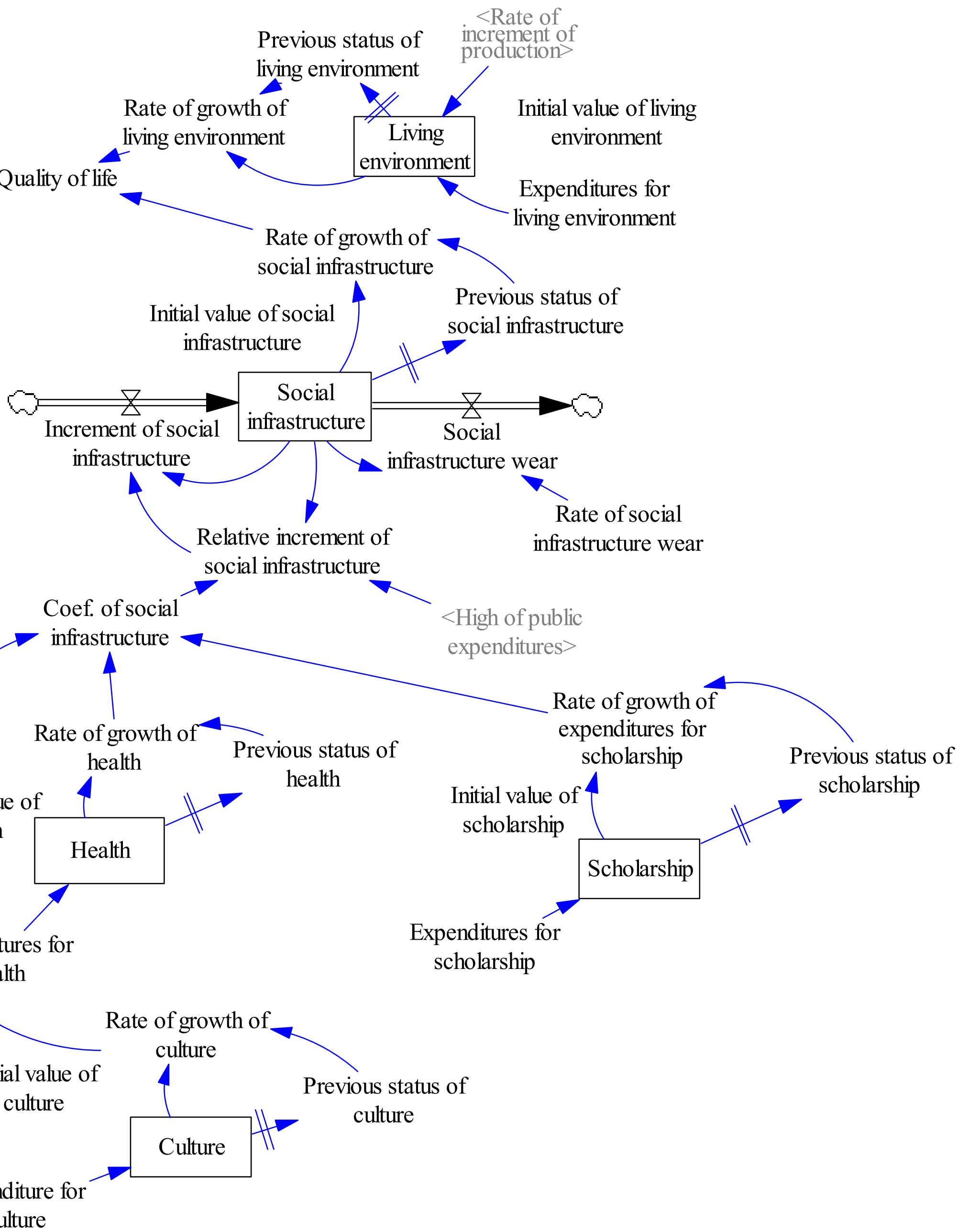


Fig. 6: The quality of life model

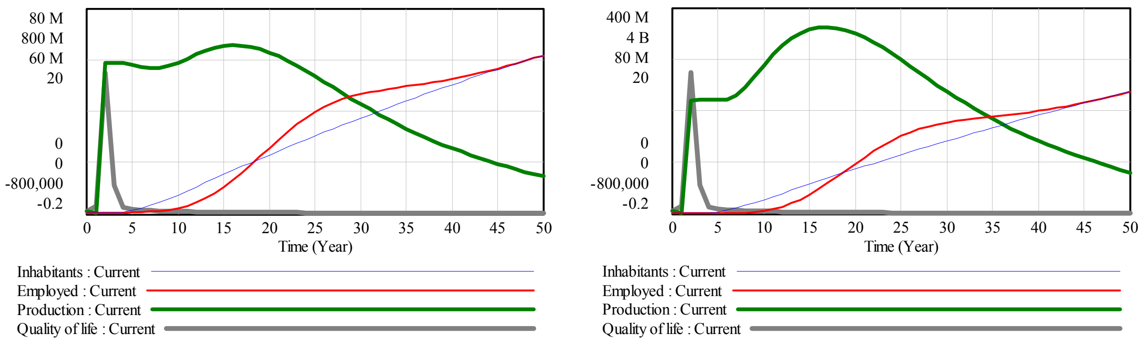
Source: (own construction)

In terms of the quality of life model, the chosen elements in social infrastructure contribute to its growth. This is a part of the infrastructure, which provides spatial, temporal, and proportional access to social services and activities affecting all sectors of human development. Therefore health service, education, and culture are collected in this model. Quality of life is further influenced by the living environment, where a positive working relationship between the amount of expenditures and improvement of living environment, is assumed. The state of the environment is also affected by increment in production. The existence of negative externalities, whose external symptom environmental pollution, is assumed.

As was stated above, quality of life becomes in the searching model a factor which influences migration flows in a region. Enhancing quality of life will cause a positive migration balance and on the contrary, its reduction will result in an out-flow migration of inhabitants from the region.

4. Simulation of Model of Competitiveness

The current competitive model was simulated in the program Vensim PLE. For this reason, it was necessary to add graphical models of functional dependencies between the different levels, auxiliary variables, and constants. Before running the simulation, the time horizon of 50 years was set and further, time step equal to 1 was set. This means that the simulation program made 50 repeated cycles of model. The graphical output displayed shows that the time horizon of 50 years is sufficient to detect trends in the examined variables.



situation before change situation after change

Fig. 7: The influence of migration of regional competitiveness

Source: (own construction)

The most important factor in the demographic model is migration. Simulations showed that an increase in the influx of people into the economy increases the value of the controlled variables. Trend component are virtually unchanged in graphs.

In case of production we can speak about sharper growth. After reaching its peak, the product of regional economy began to drop once more. During a period of 50 years (eventually 50 repetition of the given cycle) the peak in product shows the slightly higher values as in the case of primary model. The relationship between migration and employment growth occurred only in growth of absolute values. The trend in the curve remained unchanged. It is possible to deduce, from the above mentioned, that an increase in the number of incoming residents only caused the dislocation of all searching variables in absolute values. The trend of the curves remains unchanged. It can thus be concluded that migration has a short-term effect on the competitiveness of a region.

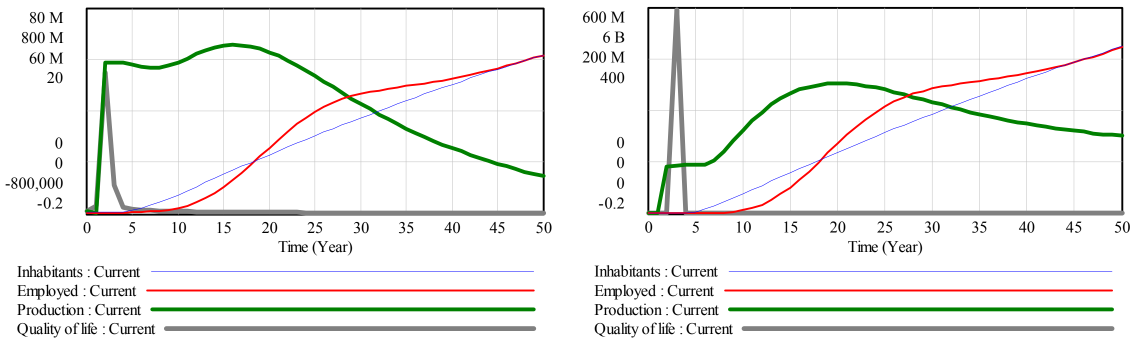


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Fig. 8: The influence of increasing of intensity of innovation on regional competitiveness

Source: (own construction)

The intensity of innovation is another factor which is simulated in the model. By comparing the observed values can be stated that there was an overall increase in all indicators. Increased rates of innovation, on the one hand, caused higher growth of production in absolute values, on the other hand, the decrease of production is decelerated in longer time period. The trend of other curves does not change in this case. Therefore it is possible to deduce the long-term influence on the competitiveness of region.

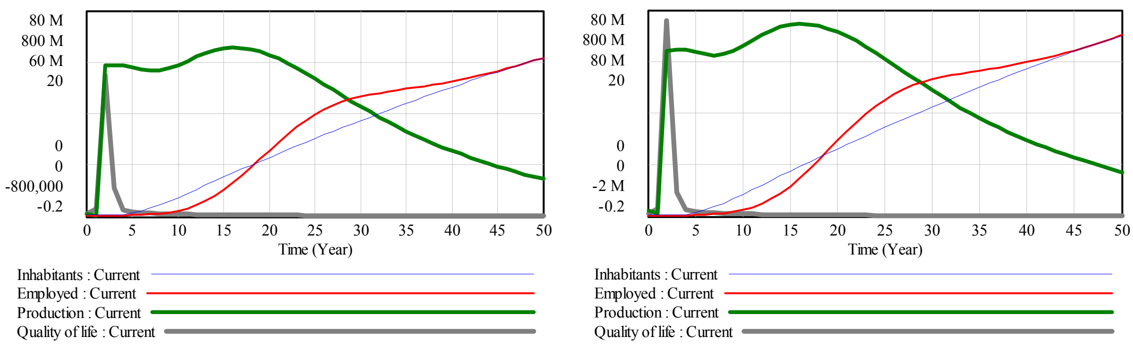

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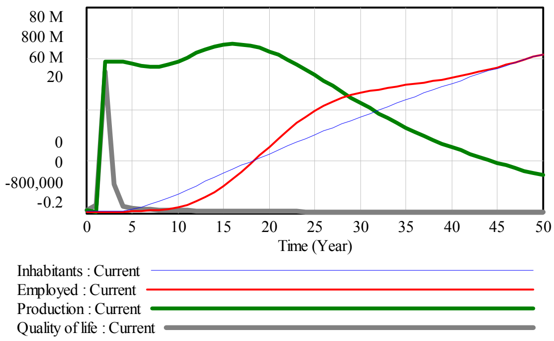
Fig. 9: The influence of increasing of foreign direct investment on regional competitiveness

Source: (own construction)

The influence of exogenous factor was tested in the third case. This factor is represented by foreign direct investment. We can speak about the shift in absolute values of searched indicators (see the previous exogenous factor of migration). The trend of all curves does not in principal change. Also the direct foreign investments support the regional competitiveness. However it is not possible to conclude from performed simulation at essential change of processes which ensure the sustained growth of competitiveness of regions.



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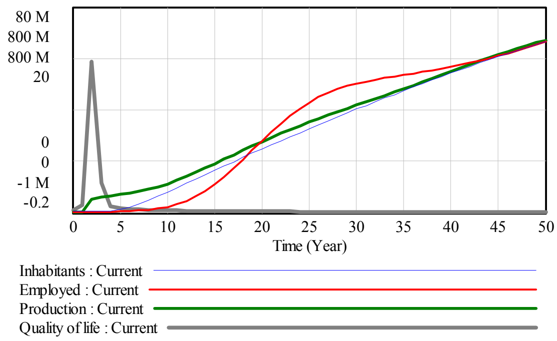

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Fig. 10: The influence of increasing of rate of investment in human capital on regional competitiveness

Source: (own construction)

The increasing rate of investments in human capital brings different results in comparison with previous searched factor of regional competitiveness. The figure 10 shows the change in trend of production function. Investments in human capital bring the growth of production of the region. For the present it is not possible to speak about sustained growth of competitiveness in case of this simulation because the count of cycling was limited at 50 stages. It is possible that the trend of curves will change by the choice of longer time horizon.

5. Conclusion

The system dynamics represents one of many methods which enables to search various processes not only of economic character. This article is focused on presentation of discipline of system dynamics and for its application was chosen the question of regional competitiveness. The system dynamics namely enables to search the processes in all their causal relations. The human mind is not able to analyze the more sophisticated causal chains. Furthermore many mutual feedbacks of elements of a system occur in reality.

The model of regional competitiveness - comprehensive of five submodels influencing economic performance of a region - was used as an example. The models of system dynamics serve on one hand for analysis of relations in terms of region and on the other hand for prediction of evolution of this matter. These dynamic models namely enable to involve influences of “soft” processes in a regions as well. These processes can be connected with the notion of quality of life. It is necessary to take into account the “soft” factors in case of searching purely economic interventions in regional economy.

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Contact Address

Ing. Lucie Sobotková, Ph.D.

University of Pardubice, Faculty of Economics and Administration, Institute of Economics

Studentská 84, 532 10 Pardubice, Czech Republic

E-mail: lucie.sobotkova@upce.cz

Phone number: +420 466 036 161