Influence of Spatial Externalities on Innovation Process

Martina Fronkova

***Abstract*—The main goal of the thesis is to identify agglomeration effects and graphically illustrate their potential impact on the innovation process. Majority of authors consider effects in the transfer of technologies, transfer of know-how and knowledge spillover as the most important agglomeration effects. Variables from the Johansson´s model (2004) are selected as a basis for the formal expression of the agglomeration effects in the innovation process of individual company. The demonstration is supported by graphical model created using fuzzy-logic system in Matlab computing environment. As input parameters were selected: (1) unsuccessful innovative effort, (2) R&D effort and (3) diffusion of innovations. Spatially oriented color-coded graphs are final results.**

***Index Terms*—Agglomeration effect, diffusion of innovation, spatial externalities.**

I. Introduction

Authorship of fundamental knowledge about the factors that support clustering is attributed to British economist Alfred Marshall (1890) who introduced the theories about industries located in close geographic proximity. These theories were presented in his book called Principles of Economics. He argued that such industries gain significant benefits from externalities such a local pool of skilled labor, local pool of specialized supplier and local knowledge spillovers. He also pointed out that concentration of enterprises is caused by presence of some specific infrastructure, natural resources, favorable local conditions or special rights from an authority that allow certain activities in a special place or competencies.

In the following period many other authors dealt with the relationship between geographic agglomeration and scale economies but mainly in the field of regional science e.g. Weber (1909), Christaller (1933), Lösch (1954), Jacobs (1969), Hoover (1970), Ohlin (1979) and others. Their theories were based mainly on the neoclassical tradition and extended for the spatial dimension.

In 1980s and 1990s Marshall´s ideas about industrial districts were rediscovered by contemporary authors and further developed particularly in relation to the transformation of characteristics of the world economy. Very popular became theory of production district (eg Becattini 1978, Brusco, 1982), the theory of flexible specialization (Piore, Sabel, 1984) and theories of learning regions (Lundvall, 1992, Saxenian, 1991, Pinch and Henry, 1999; Malmberg and Maskell, 1999, 2006 etc.). Marshall's work was also followed up by professor Michael Porter, famous for his cluster phenomena.

The main goal of the thesis is to identify agglomeration effects and graphically demonstrate their potential impact on the innovation process.

Examination of the connection between agglomeration effects and innovation effort of individual firms is important. The ability to make successful innovation is the key aspect of competitiveness and being competitive is a priority of each enterprise. The innovation process has become an indispensable part of the technical and economic development. However implementation of innovation requires sufficient business potential, capacities and resources. Otherwise, the process for the company bears the risk and possible losses.

The structure of the thesis is as follows. The second part describes the different types of economic agglomerations. The third part deals with identification of agglomeration effects. The fourth part presents the specific spatial externality - diffusion of innovation. The fifth part deals with formal expression of innovation process of the individual company. Also mathematical model is set up in the fifth part. The sixth part is a graphical presentation of the success of technological innovation using fuzzy-logic system. In the last part (seventh) total results are presented.

II. Overview of the Different types of Economic Agglomerations

The model of Malmberg, Sölvell and Zander is used for better understanding of the different types of agglomeration. This model highlights the conceptual differences between clusters and other types of agglomeration.

TABLE I: Different Types of Economic Agglomeration

DIMENSION	Firms in diverse industries (different activities)	Firms in related industries (similar activities)
Efficiency and flexibility	Metropolis	Industrial Districts
Innovation	Creative Regions	Clusters

Source: Malmberg, Sölvell, Zander (1996)

According to table 1 there are four kinds of economic agglomeration sorted by so called "dimensions". The horizontal dimension is composed of (1) firms in diverse industries and (2) firms in the same or related industries. The vertical dimension consists of (1) forces that either enhance efficiency and flexibility or (2) innovation.

The first type of agglomeration (so called Metropolis)

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relates to general economies concerning to all firms and industries within a particular location. Metropolis attracts a wide range of economic activity and therefore is suitable for headquarters of large international corporations. Second type (so called Industrial Districts) comprises economies that relate to firms engaged in co-related industries. Those two types of agglomerations can be explained mostly by efficiency gains and flexibility. Final two types (so called Creative Regions and Clusters) can be explained as centers of knowledge creation and innovation. Emphasis is put on regional variety of skills and competencies where the unplanned interaction among different actors might lead to new and unexpected ideas and creative designs, products, services and business concepts, as in [1].

III. Identification of Agglomeration Effects

Agglomeration effects are generally defined as spatial externalities resulting from concentration of residents and businesses. In this thesis and based on previous assumption agglomeration effects and spatial externalities are understood as interchangeable. The effects of agglomeration that occur as a result of interactions between agents (firms, public institutions, individuals, etc.) in a particular geographical area are called external agglomeration effects. From the company's perspective these effect might be either positive (so-called external savings) or negative (so-called external losses). External savings lead to cost savings and increase concentration of economic activities. Subsequently external losses cause an increase in costs and reduction in concentration of economic activities, as in [2].

Generally external savings can be classified either as localization savings or urbanization savings.

Localization savings (intra-sectional) are particularly observed in industrial production and are caused by the mutual spatial proximity of firms in the same industry. Reduction of common infrastructure costs, strengthening linkages between businesses, creating excellent relationships, diffusion of innovation, technology sharing, specialization etc. are the positive examples of localization economies, as in [3]. Positive effects attract other entrepreneurs who settle down in the region thus increase price of production factors. Strength of concentration and specialization is regulated by the price increase, as in [4].

Urbanization economies (cross-sectional) are related to the size of the seat and are achieved through localization in urban areas. The urbanization savings reduces the cost of all companies in a particular area regardless their sectional affiliation, as in [5]. Positive effect can be characterized as a proximity and size of the demand, the availability of offices, research and educational institutions, large market of skilled labor, etc. There are also negative effect such as environmental pollution, overload of transport infrastructure and a disproportionate increase in the price of production factors. These negative consequences regulate the urban growth, as in [6].

IV. Spatial Externalities - Diffusion of Innovation

Majority of authors consider effects in the transfer of technologies, transfer of know-how and knowledge spillover as the most important spatial externality (known as diffusion of innovation), as in [7]. Nevertheless no consensus about the origin of diffusion of innovation was reached. The main controversy is guided by the question whether the source is rather specialization or diversity (in other words: whether it is mostly part of localization effects or urbanization effects). Two basic conceptions were adopted to clarify the effects in the innovation field. MAR externalities concept and the concept of externalities by Jacobs, as in [8].

Jacobs (1969) believes that knowledge spillovers are more likely to occur in the industrially diverse environment rather than in uni-sectional. Diffusion of innovation is the stronger the more sectors in the economy are represented, as in [9]. Reference [10] shows that this type of externalities within the region reduces the cost of discovering new ideas and increases the likelihood of accidental discoveries of innovative potential. In other words Jacob ́s externalities bring together companies and economic agents to exchange ideas and knowledge across an industrially diverse environment.

MAR externalities originate from combination of ideas of Marshall (1890), Arrow (1962) and Romer (1986). Its source is mainly regional specialization. In this particular case the effect of diffusion of innovation is as higher as higher is the relative share of the sector in the regional economy, as in [11].

Both of the above mentioned concepts are more of a complementary nature rather than mutually exclusive, as in [12].

V. Spatial Externalities as Part of the Innovation Process of the Individual Company

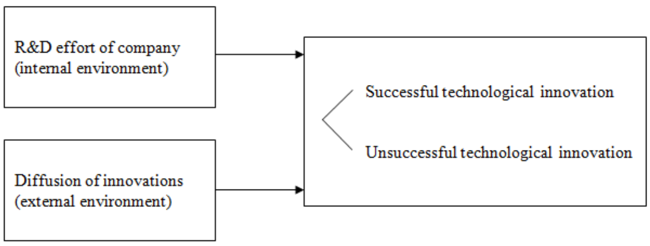

Fig. 1. Influence of external and internal environment on the success/failure of technological innovation.

According to reference [13] the issue might be formally expressed in a stochastic context where the result of innovative effort in the region r is:

(i) successful technological innovation with probability P_r

(ii) unsuccessful technological innovation with probability $1 - P_r$

Let π_r^* denotes the value of profit when innovation efforts is successful. Value of profit when innovation effort is failure to be denoted as π_r^0. Based on above described relationship of both variables can be derived as follows $\pi_r^0 < \pi_r^*$.

Furthermore let us assume that the value of profit is dependent on the research and development (R&D) efforts (R) and on the occurrence of potential diffusion of innovations in the particular region (I_r).

$$\pi_r^{?} = f(R, I_r)$$

The probability of success for a given value of R can be derived as $P_r = P(\frac{\pi_r^*}{I_r})$ where the probability is dependent on the value of I_r.

Final presumption is that the company will carry out technological innovation with the following assumption:

$$P_r \pi_r^* + (1 - P_r)\pi_r^0 \geq \pi^{\min}$$

The conclusion from above described might be interpreted as follows: the company innovates in order to obtain future profit. The value of potential future profit resulting from innovation effort must be greater or equal to stated minimal threshold of profit ($\pi^{\min}$). If this presumption is fulfilled than the innovation is considered as successful.

VI. Graphical Presentation of the Success of Technological Innovation Using Fuzzy-Logic System

Expected profit from successful technological innovation can be represented by fuzzy-logical system. This system is not strictly determined by Boolean logic YES / NO but each fuzzy set value is given by its membership functions expressed by the probability. Fuzzy logic toolbox in Matlab computing environment was used for the construction of fuzzy system. Input variables were selected on the basis of Johansson's theory (2004). His model was reformulated into the Matlab computing environment. Selection of parameters: (1) an unsuccessful innovation effort (in the graphs marked PIr0), (2) R&D efforts (in the graphs marked R), and (3) diffusion of innovation (in the graphs marked Ir). Selected parameters of Fuzzy sets are shown in the following figure.

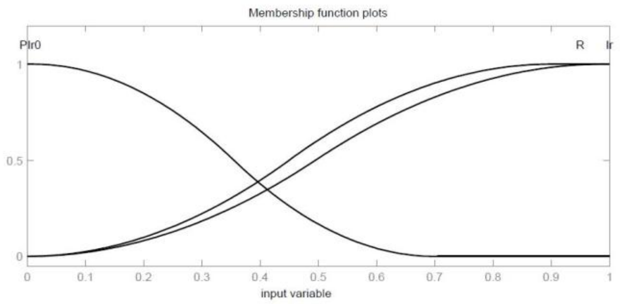

Fig. 2. Fuzzy sets of selected parameters

The horizontal axis characterizes potential profits. Probability of achievement of possible profit is shown on the vertical axis.

From the shape of probabilistic functions of variables can deduced that R&D effort and potential innovation diffusion have a similar pattern. This is caused by the fact that for the research process diffusion of innovation is necessary. This diffusion of innovations makes development process faster. Similarly the diffusion of innovation can ́t be separated from research and development effort.

The output of this model is prediction of gained profit divided into three groups: (1) small, (2) medium and (3) large. Distribution of fuzzy sets is again shown in the following chart.

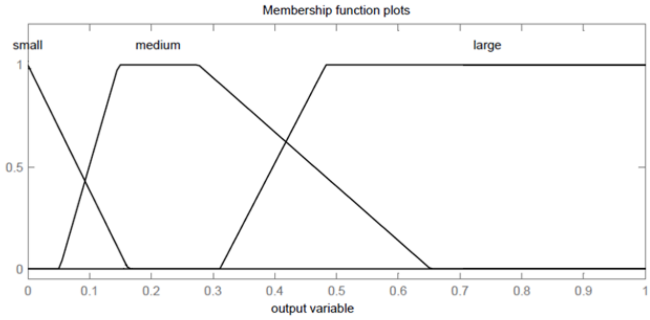

Fig. 3. Pre-defined level of gained value

Mamdani fuzzy model of interference system was picked as the most appropriate. Centroid type was chosen for defuzzification. Interference mechanism was defined according to the following table:

TABLE II: Interference Mechanism

IF	*R*	AND	*Ir*	THEN	*large*
IF	*R*	AND	*NOT PIr0*	THEN	*medium*
IF	*Ir*	AND	*NOT PIr0*	THEN	*medium*
IF	*Ir*	AND	*PIr0*	THEN	*small*
IF	*R*	AND	*PIr0*	THEN	*small*
IF	*R*	AND	*Ir*	THEN	*NOT small*
IF	*R*	AND	*NOT Ir*	THEN	*NOT large*
IF	*Ir*	AND	*NOT R*	THEN	*NOT large*

VII. Results

A. The Resulting 3-D Graph

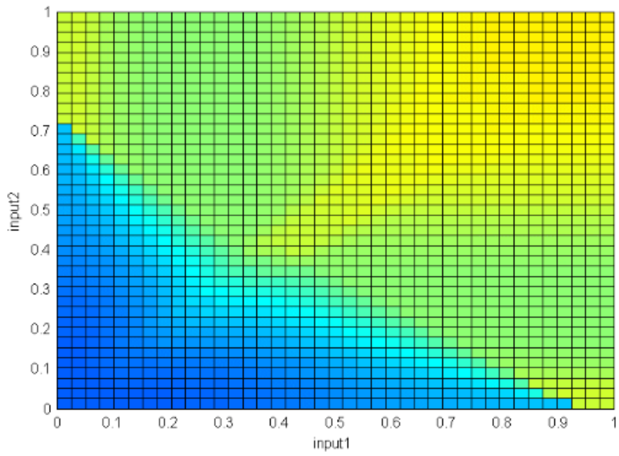

Fig. 4. The resulting 3-D graph

Estimated value of the profit is demonstrated using surface projections of 3-D graph. For better visualization the lowest values are shown in blue, mean values are green and highest values are yellow.

Input 1 and input 2 contain all variables (successful innovation effort, R&D effort and the diffusion of innovation). This adjustment to surface projection was done only for better visualization of results. If the graph wouldn ́t be adjusted the chart would be constructed in 4-D and will be impossible to be read. In case 4-D visualization is preferred three cuts in the planar view of individual variables have to be used. Afterwards these three cuts can be connected in one chart.

B. The Overall Look with Spatial Orientation

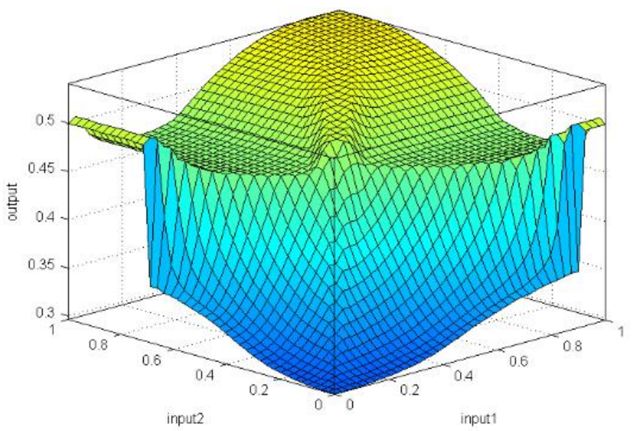

Fig. 5. View from the top

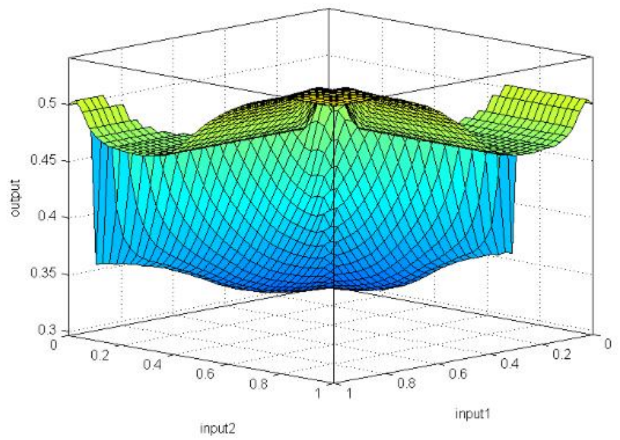

Fig. 6. Bottom up view

Fig. 5 and Fig. 6 show that if R&D effort and innovation diffusion is zero, the value of the expected profit is also zero.

Steep rise can be seen in the turquoise area. This is explained by the existence of notional limits when profit grows very quickly. Example of such notional limit is breakthrough point in the development or sharing of important knowledge.

The yellow area (gradual stagnation of growth) is to be understood as a situation where the expected value of profits does not exceed significantly spending incurred on research and development. Also diffusion of innovation is not being embedded within the territories at the expected speed.

It can be clearly seen that only one aspect (R&D effort or diffusion of innovation) is sufficient to achieve maximal profit. When only one factor is applied on 100% gained profit would be the same as in scenario where both factors are simultaneously applied on approximately 40%.

The chart area shows the limit when the profit is equal to the expected profit. The space above this area represents the situation when the profit is greater than expected profit (see Fig. 5). On the other hand space below this surface is representing the situation when the profit is a smaller than expected (see Fig. 6).

C. Functions of Final Output

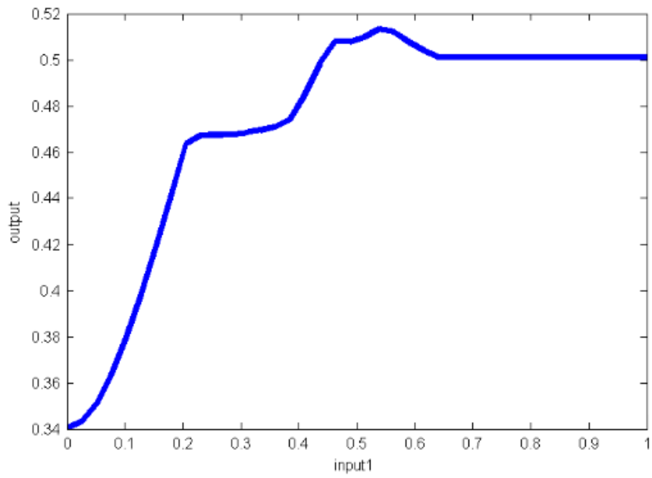

Fig. 7.

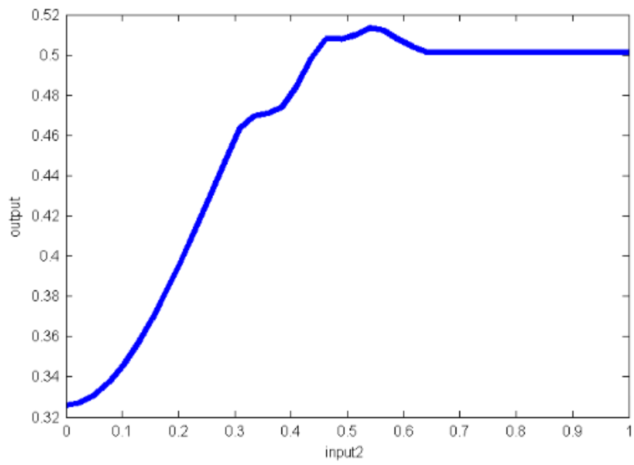

Fig. 8.

From Fig. 7 and Fig. 8 can be derived that the function of possible output is not strictly the same for both inputs despite the fact that they are composed of the same variables. This phenomenon enables us to simulate the real behavior of the system.

VIII. Conclusion

The main goal of this thesis was to identify agglomeration effects and graphically illustrate their potential impact on the innovation process. Variables from the Johansson ́s model (2004) were selected as a basis for a graphical illustration. The illustration was created using fuzzy-logic system in Matlab computing environment. Selection of input parameters was as follows: (1) unsuccessful innovative effort, (2) R&D effort and (3) diffusion of innovations. The next step was to set up all possible scenarios using different combinations of variables. The results were presented in three graphical visualizations – firstly by 3D graph, secondly by general overview with spatial orientation and thirdly by functions of output.

The main finding of whole demonstration was the fact that only one factor (R&D effort or diffusion of innovation) is not sufficient to achieve maximal profit even if it was applied to 100%. In scenario where one of the factors would be applied to 100% the achieved profit would be the same as in scenario where both factors would be applied simultaneously to approximately 40%.

At this point it has to be noted that research on the impact of spatial externalities is such a complicated task that generally valid explanation can´t be provided. This complication lays in fact that examined criteria are immeasurable and their values might be determined only by a subjective estimate of an expert.

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