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Regional innovation networks from two perspectives – innovation as an essence of local development (The Case of Slovak region)

Diversity of human knowledge which can be considered as a precondition of technological change leads to more or less economic development. The role of space could not be ignored and it is necessary to understand why networks of innovative actors can have a local dimension which is stronger or weaker in the sense of economic geography and economics of knowledge. The paper uses social network analysis to create networks of innovative actors – one for innovators and one for inventors. The main aim of applying mentioned concepts is to recognize actors that can be considered as carriers of knowledge and to identify differences among them. Calculated characteristics of networks suggest that in the case of Košice region, the bulk of knowledge can be found on the inventor´s side.

Keywords: innovation, regional, Slovak, local development
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Introduction

Innovations are the core of technological change which is not only considered as driving force of economic development in particular area but which is also seen as the comprehensive network of interactions among different innovation actors (individuals, firms, public institutions and other organizations) (*Fischer* 2000). Innovation begins with the idea generation and it finishes with knowledge commercialization. In other words, idea leads to research, research to development, development to production and production to marketing (as innovations) (*Kline and Rosenberg* 1986). The human capital is considered as an essential precondition for the development of knowledge (*Greenhalgh* and *Rogers* 2010), but on the other hand, there are a lot of others factors that influence on knowledge generation or theirs diffusion and these factors are usually concentrated in a space. Diversity of human knowledge depends on existing environment and this diversity leads to more or less "cognitive distance" which can be opportunity but also a challenge. The cognitive distance develops a personal knowledge but the greater cognitive distance means harder to understand of innovation partners. The spatial concentration of mentioned factors has impact on the regional inequality in economic and technological development (*Fornahl* and *Brenner* 2003). Geographical proximity, cultural and institutional conditions bring not only spatial advantage but also advantage in productivity which is linked with each economy. Centers of geographical agglomeration become innovation centers because of their collectivity, networks of contacts, knowledge, structure and institutions (*Amin* and *Thrift* 1994). It is helpful to study this geographical agglomeration in the sense of regional innovation networks based on knowledge flow. In the sense of distance and proximity, "proximity school" (*Boschma* 2005) provides types of differences between areas and their impact on potentials for knowledge interactions among innovation actors – physical, functional and relational proximity (*Torre* and *Gilly* 2000). Physical proximity is based on the geographical dimension of agglomeration economies, which brings saving of transaction and transportation cost and which is especially important in exchange of tacit knowledge (*Lundquist* and *Trippl* 2013). In other words, factors as quality of the transport infrastructure and political-administrative set-ups that are related with the mobility of goods and people (*Torre* and *Gilly* 2000) have impact on interaction between different actors in a local economy.

On the other hand, functional distance indicates differences between regions in innovation performance as a result of inefficient knowledge flow between areas if these territories are reaching high differences in their innovation capacity (*Lundquist* and *Trippl* 2013).
Relational proximity is associated with non-tangible dimensions like cognitive, organizational, social, institutional, cultural, technological proximity and others (*Boschma* 2005). In terms of innovation processes which are preconditions of local development, a certain degree of relational proximity between innovation actors is a core assumption for knowledge exchange and collaboration in area and among areas (*Lundquist* and *Trippl* 2013).

Due to proximity mentioned above, it is natural to assume, that in most areas, the innovative effort requires networks of innovators which are localized within the communication space (*DeBresson* 1999). The concept of innovation processes on the local level is based on the assumption that regional innovation systems can be found anywhere. Probably all regions have own regional innovation system (*Doloreux* and *Parto*, 2005). The concept of regional innovation systems comes from national innovation systems as a subsystem of knowledge generation and diffusion including research and development organizations, education bodies and other organizations (technology transfer agencies, companies and cluster located in the region) (*Lundquist* and *Trippl* 2013). It tries to explain factors that influence on innovation production and to describe characteristics of main institutional actors. The geographic level of knowledge economy indicates the importance of specific and regional sources that stimulate the innovative capacity and firm competiveness (*Dolorex* and *Parto* 2005). Networking of innovation processes can be linked with system approach to innovations under assumption that innovation system could have a better performance in conditions of the internal interaction and existing external relations (*Fritsch* and *Graf* 2012). The interactive learning process which combines knowledge from different actors generates the collective asset in the production system (*Doloreux* 2002) which can contributes to the local development. Systemic innovations require intensive flows of knowledge, resources and human capital within and between innovation systems (*Lundquist* and *Trippl* 2013). The role of space could not be ignored in generation and diffusion of new knowledge on international, national, regional or local level. Networks of innovators can be constructed with using of patent applications (*Fritsch* and *Graf* 2012), because one way how to bring knowledge to the market is by patenting and patents as innovation outputs allow the exchange of industry knowledge (*Baycan* and *Stouhg* 2011). Due to this approaches, the paper focuses on the regional innovation network from two perspectives – regional innovation networks through innovators according to *Fritsch* and *Graf* (2012) and regional innovation networks through inventors. Reason for applying of these two perspectives is recognizing actors that can be considered as carriers of knowledge and identifying differences among them. In the case, that innovative regions are situated near the national boundaries, networks of innovators do not exceed these boundaries, mainly due to cultural traditions in these areas (*DeBresson* 1999). Mentioned openness of border regions is a one reason for paper focusing on Košice region, in the terms of Slovak regional innovation networks. It is necessary to understand why networks can have a local dimension which is stronger or weaker in the sense of economic geography and economics of knowledge. The paper uses social network analysis which provides concepts and tools that highlight the structural properties of localized collaboration networks.

From knowledge creation to economic development

As was mentioned above, spatial factors play a crucial role in generating and diffusing of knowledge while development of knowledge can be characterized as follows:

- Cognitive process with respect to whole community,
- Interactive process within firm,
- Collective process which is ongoing in each area,
- Internally nonlinear process which is involved in synergy,

- Process which is based on the local relations and which creates social networks, external integration and traditions of public or private links (Camagni and Capello 2009).

In general, knowledge can be divided in to two main groups: non-codified (implicit) and codified (explicit) knowledge. The flow of explicit knowledge can be obtained through written form and this knowledge can be absorbed by its reader and understood in a specific language. On the other hand, the human ability to absorb codified knowledge is rarely automatic. The idea of "transfer knowledge without effort" is something no real because the absorption of explicit knowledge also requires prior knowledge (*Jensen, Johnson, Lorenz* and *Lundvall* 2007). In this sense, non-codified knowledge seems to be more important as widely and readily available codified one. The basic mechanism of combining current knowledge is represented through interactive processes among firms and different economic and social actors (*Cappelin* 2004).

From the traditional view, knowledge has a private character and is developed through expenditures on research and development and it is incorporated in technologies and products. Diffusion of this knowledge is not random and it depends on the geographical proximity. Adoption of technologies brings for firms a high cost of adjustment. On the other hand, modern approach explains knowledge as a result of learning processes, knowledge is partially public and its diffusion is related to spatial barriers (*Camagni* and *Capello* 2009). Deeper understanding of mechanisms of learning and accumulation of knowledge is useful tool for studying of restructuring processes and diversification in regions, where new codified and non-codified knowledge are generated (*Cappelin* 2004).

Knowledge as one of the economic growth determinants

It should be noted, that economic growth is a necessary but not sufficient condition of economic development because the economic development on different levels means an increase in living standards of inhabitants in particular area (*Todaro* and *Smith* 2011). Technological progress was first time implemented in to growth models by *Solow* (1956) as an exogenous variable. Solow model indicates that the growth per inhabitant must be stopped if there is any further improvement in technologies. *Neoclassical theories* of economic growth assume that technological progress arises through influencing of exogenous conditions. Nevertheless, the obvious lack of these theories is the very concept of technological progress as the exogenous variable which is situated outside the model and the explanation of a long term growth through neoclassical theories can be marked as unsatisfactory. The technology advantage means the generating of new ideas that are partially noncompetitive and therefore, they have the characteristics of public goods. In terms of technology change, if noncompetitive knowledge is added to production, returns to scale tend to growth however this condition is in a conflict with assumption of perfect competition that operated under constant returns to scale (*Barro* and *Sala-i-Martin* 2004). Extended Solow model of the neutral technology change takes into account a technology progress which shifts the production function in economy because according to the noncompetitive knowledge, two or more producers can use similar knowledge in comparison to traditional production factors as labor and capital. Despite the extension of model, technological change is only result of gradual accumulation of capital which is not related to labor force, although human capital can be considered as a basic assumption of knowledge development. This is one reason for *models of endogenous growth* development, where human knowledge is immediately spread to the whole economy and it means that diffusion process can begin directly because knowledge is noncommercial (*Barro* and *Sala-i-Martin* 2004). Models of endogenous growth suppose that the economic growth is pushed by accumulation of knowledge if knowledge is basic form of capital generated in technological process. This fact leads to the preconditions that countries which reach the higher level of knowledge capital, can achieve more dynamic economic growth (*Romer* 1986). In the studies of *Schumpeter* (1939), not only technological knowledge but mainly innovations are determinant of economic growth – once the innovation is separated from the producer it becomes visible internal factor of change. Innovations with all their effects bring changes in to the economic process and this impact of innovation can be, according to Schumpeter, marked as "*economy evolution*". In other words, the technology change opens new markets however the production is still only combination of production factors. On the other hand, when innovations are added to the transformation process then production factors can be combined in new improved ways. Whenever a current amount of outputs requires less production costs as the same or lower production and if there are not declining price factors, then it is more likely that firm uses product or process innovations. Under these assumptions, innovations tend to aggregate and concentrate in selected sectors because companies are following each other in generating of successful inventions. It can be supposed that next wave of innovations will be realized in the same or neighbored areas as anywhere else. The approach of economic growth which is explained through the production function is insufficient due to uncertainty and diversity related to innovations. It is one reason for development of *evolutionary economy* by *Nelson* and *Winter* (1997) – the economic growth is a result of evolutionary system based on the corporate practices.

Generally, evolutionary economy, institutional economy, new geographical economy, learning economy and network approach can be considered as core theories influencing the creation of regional innovation networks (*Doloreux* 2002). According to the evolutionary economy, technological change is the endogenous variable (like models of endogenous growth) which has impact on the economy on different levels. It should be noted, that technological development and institutional aspects play a key role in the transformation of the economic system towards sustainable development (*Mulder* and van den *Bergh* 2001). From the view of knowledge systems, carriers of knowledge are constantly able to discover new technologies and ways of organizing as well as new patterns of behavior (*Dosi* and *Winter* 2000). Technology learning process can be seen as the "heart" of evolutionary approach in relation to the economic development due to the fact, that under assumptions of evolutionary theory, the long-term growth is result of knowledge co-evolution and knowledge are used and supported through institutions (*Nelson* 2007).

The role of space – knowledge economy

In 70-ties and 80-ties of the last century, attention was focused on "*scientific based*" or high-tech sectors, while regions with these sectors were labeled as "progressive" with ability to bring the transformation of an economy (process innovations and restructuring of traditional sectors). In the next phase, the attention was pointed on "*scientific*" regions as results of innovation effort which efficiency can be measured with using R&D indicators: R&D inputs (public and private investment to research and development activities and human resources) and R&D outputs (number of patents, papers) (*Camagni* and *Capello* 2009). The main aim of evolutionary theory is to identify "cognitive capacity" which is the ability to transform inventions to innovations and to the productivity through cooperation or market interaction. Attention is shifted on the cooperative learning process which is driven by factors as is geographical proximity, network relations, interaction and creativity. In this view, abstract space becomes much more real with functional, hierarchical, economic and social interactions (*Camagni* and *Capello* 2009). Due to the fact that knowledge generation is probably subject to special norms, values or culture which is common for some area, it is helpful to study innovation processes within this area. In other words, the role of space is crucial in generation, diffusion and absorption of new knowledge on the international, national, regional or local level.

Knowledge processes are processes in which fragmented knowledge inputs are combined for the knowledge outputs (*Antonelli* 2006) and then they are spread via networks and via intended effort by agents with aim to build bulk of knowledge in particular area. Networks can vary according to their structural form, but it is necessary to understand why networks can have a local dimension. Papers deals with networks of innovation actors on the regional level following findings of *Trippl* (2011) which indicate that star scientists has a tendency to embed themselves in their current location of work by creating new knowledge asset in relation to regional firms, research institutions and policy actors. The movement of star scientists to specific places has a fundamentally impact on both scientific progress and regional economic development. It should be noted, that location tendencies of star scientists leads to "*islands of innovation*" which represent a well-known phenomenon – strong clustering of science, research and innovation in particular geographical areas which can be marked as world poles of science (*Hilpert* 1992). The other reason for studying networks of innovation actors on the regional level is, that especially tacit knowledge have a components that can be transferred only by personal relations and these relations are supported through geographical proximity, which means that narrow regional networks and integration of local actors to global flow of knowledge can create an excellent environment for effective regional innovation system (*Fritsch* and *Graf* 2012). However, geographical proximity also creates a barrier for the flow of new information into existing networks from the external environment (*Boschma* 2005).

The paper uses region as a geographical area of extending across space and time to identify network characteristics of innovation actors, although there is lot of controversy in using regions as suitable geographical units. Typically one is that in most cases, regions are only formal units which were established as a need for aggregating smaller geographical units (census districts, municipalities, provinces, etc.). It means that these regions don´t meet functional ties which include the network linkages as is transport migration, trade and capital flows and central-place links as is settlement hierarchy (*Agnew* 2013). Despite to the fact that regions are often politically defined by governments, in some cases (North West England region), spatial development strategy focused on a network conception, could not escape the politico-administrative aggregation of geographical units inherited from the past (*Harrison* 2013).

Usage of regions as suitable units differs over field of study. *Agnew* (2013) emphasizes four general conceptions of region. The first approach of distinctive regional communities sharing socio-political characteristics focuses on the persistence of socio-political traits from the past. Other view on the regions is over tensions and conflicts associated with state formation and disintegrations – regions as political territories. Third concept is related to industrialization, urbanization and trade with networks like main points of interest which tie together regions through hierarchies of cities and their hinterlands. The last one considers regions as societies which share a wide range of social and cultural characteristics and try to examine behavior of community across social indicators.

Methodology

Regional networks of innovative actors (innovators, inventors) can be created by using social network analysis (SNA) which requires relational data about a group of actors in the system. Social network analysis tries to identify the structural properties of localized collaborations in network. According to *Fritsch* and *Graf* (2012) paper uses patent applications to generating networks of innovative actors. On the other hand, *Fritsch* and *Graf* (2012) define nodes of networks like innovators; paper follows this approach but compares them with networks created through inventors (inventors like nodes). In other words, patent application offer information about name and address both inventors and innovators. The question is which one is the carrier of knowledge and can be considered as a bulk of knowledge in particular area. Patent applications include any innovative effort therefore article deals with every application available on web site of Slovak Office of Industrial Property. It should be noted, that applicants have an opportunity to sign application under national patent office but also under European patent office what is main disadvantage of this approach (patents approved by European patent office have wider coverage as patents approved by national patent offices). Results of mentioned suggestions are two networks of innovative actors that can be distinguishable in the sense of number of nodes, density, centralization, number of internal and external links and other network characteristics. It is helpful using data from patent applications for longer time period, for example 5 years, in this case form year 2008 to 2012. The principle of cooperation can be observed in other studies focused on the flow of knowledge: between projects (CENTROPE R&D Network, 2010), co-authors networks (*Velden, Heque* and *Lagoze* 2012).

Due to the fact that major cities probably have the higher economic and innovative activity, it can be supposed that “stronger” regional innovation systems (“stronger regional innovation networks) are more effective (*Baycan* and *Stough* 2011), nevertheless very close relations can lead to the “lock in effect” in the region. Patents are used as outputs of innovation effort however, they can be seen as a source of conflicts between “openness” and discretion” of researcher (researchers focus on applied research with the prospect of financial success) – patents probably lead to conflicts of interests and values and to institutional barriers (*Baycan* and *Stough* 2011). It is common that a lot of innovations cannot be patented, but the growth number of patents mirrors the industrial innovation capacity. Due to the facts mentioned above, *Greenhalgh* and *Rogers* (2010) emphasize following advantages and disadvantages of patent statistics:

Advantages of patent statistics:

- Patents indicate inventions that can be the innovation,
- Data availability,
- Costs for application and maintaining a patent would not be lower as the value of invention in the future,
- Invention that should be patented has to pass by test of novelty and creativity,
- Patents can be classified in to technical fields.

Disadvantages of patent statistics:

- Some inventions could not be patented,
- There are other forms of intellectual property (designs),
- Sectors are different according to the intensity of using patent system,
- Some patents are used as a tool of competitive strategy,
- Some inventions could not be considered as innovation.

Slovak patent data can be characterized by weak cooperation and by occurrence of many individual actors, therefore networks of innovators are created only on the individual level (applicants are individuals). It should be noted, that in the case of inventors, they usually stand out as individuals. The adjacency matrix in both cases is weighted twice: by size of “team” (the number of inventors on the common patent application) and by number of common patent applications. The article evaluates one of the border Slovak regional innovation networks situated in Košice region – from the side of innovators and inventors. Networks characteristics and network visualization is calculated and generated in statistical program R (packages igraph and sna).

Analysing of networks – comparison of two perspectives

The coverage of patent application over time period 2008 – 2012 in Košice region according to innovators and inventors is shown in *Table 1*. Due to the number of isolates and overall number of patent applications, networks of inventors seem to be more interconnected as like network of innovators. It could be supposed that knowledge flow is more intensive among inventors which know each other from the joint projects. On the other hand, innovator is also the owner of the patent and he has all rights and obligations associated with this property. Although it is natural to suppose that all inventors on the application form will be also owners of patents, payments related to patents can be result of the fact, that in the case of Slovakia, patent applications have lower number of innovators than inventors.

Table 1: Patent applications in the Košice region (network of inventors and innovators)

Košice region	**number of patent applications**		**number of isolates**	
	network of in-ventors	**network of in-novators**	**network of inventors**	**network of innovators**
2008	24	18	3	13
2009	13	15	7	8
2010	51	25	18	12
2011	18	18	4	14
2012	20	11	8	4
Overal	**126**	**87**	**40**	**51**

Source: Slovak Office of Industrial Property

Table 2 describes regional networks characteristics of innovators and inventors that are calculated in statistical program R (packages igraph and sna). The size of a main component is the biggest part of a network that is connected within, but disconnected from other parts of networks. In the sense of innovative actors, the networks main component indicates the share of actors that have access to a bulk of local knowledge (*Wasserman* and *Faust* 1994). In the case of Košice region, the main component achieves higher value on the inventor's side. The next network characteristic is density which defines the total number of observed lines in a graph divided by the total number of possible lines in the same graph and according to *Wasserman* and *Faust* (1994) it can be expressed as follows:

$$\Delta = \frac{L}{g(g-1)} \qquad (1)$$

While *L* is the number of lines and *g* is the number of points. From this point, it means that with network density number of connections grow. Due to the number of existing innovation actors (number of nodes), the observed density is higher on innovators side however as was mentioned above and as is indicated in *Table 2*, the share of isolates is lower in the network of inventors. This situation can be explained by number of edges, among inventors there is almost approximately thrice more edges than in the case of innovators. It should not be forgotten that the density is calculated with respect to a number of existing nodes (actors). Findings are consistent with assumption that inventors could bring to economy more bulk of knowledge in comparison with innovators in the sense of local development (innovations as indicators of the economy development). Košice region seems to be strongly regionalized according to the number of external connections in both cases - existing barriers in flow of knowledge. Centralization of network is a synonym for heterogeneity of its actors and can be calculated as follows:

$$C_D = \frac{\sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]}{max \sum_{i=1}^{g}[C_D(n^*) - C_D(n_i)]} \qquad (2)$$

Where $C_D(n_i)$ in the numerator are the g actor degree indices and $C_D(n^*)$ is the largest observed value (Wassermann, Faust, 1994).

Networks of innovators as well as networks of inventors in Košice region can be defined by low homogeneity. It means that networks of innovative actors are highly fragmented and fragments form clusters of different types.

Table 2: Characteristics of networks

Košice region	network of inventors	network of innovators
centralization	0,0316	0,0408
size of main component	11	6
density	0,0155	0,0204
number of nodes	172	84
number of edges	228	71
number of internal edges	165	54
number of external edges	63	17
share of isolates	0,3175	0,5862

Source: author´s own work

The cooperation of innovative actors is shown in *Figure 1* (networks of inventors) and in *Figure 2* (networks of innovators). Size of node (inventor, innovator) depends on the number of connections that pass through this node. Simultaneously the node size indicates the power of existing collaboration among innovators. This collaboration is presented by thickness of edge that is weighted by number of actors and number of common patent applications. These figures point out the amount of patent applications field by women and men (women as node of grey colour and men as node of black colour). It is clear that more innovative effort can be found on the men´s side as a result of working position of men or other sociological and cultural factors. Networks of inventors are less fragmented with more significant parts and wider edges. On the other hand, created clusters in both networks have the form of resemble stars (all actors are connected) and triangles or there are connections only among two actors.

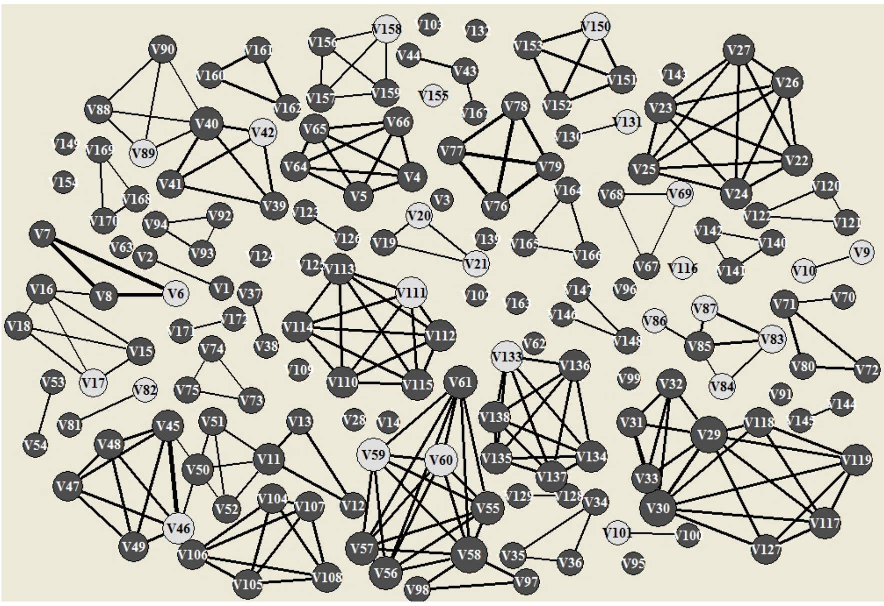

Figure 1: Network of inventors
Source: author´s own work

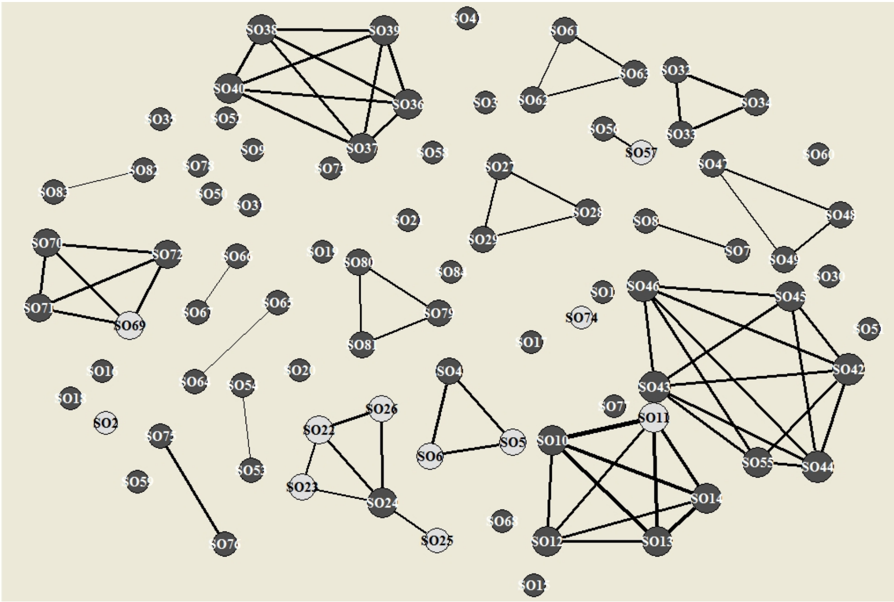

Figure 2: Network of innovators
Source: author´s own work

Conclusion

The starting point of this paper was to consider knowledge flow between innovative actors as one of the crucial factors of a local development. The certain degree of relational proximity between innovative actors is a core assumption for knowledge exchange and collaboration in area and among areas and it is helpful to study and evaluate this collaboration in the sense of social network analysis. Social network analysis leads to an understanding of the complex geographical and technological structure of particular actors. The paper focuses on the innovation network from two perspectives – innovation network through innovators and networks through inventors. Reason for applying of these two perspectives is recognizing actors that can be considered as carriers of knowledge and identifying differences among them. Mentioned networks are constructed with using of patent applications which offer requires relational data about a group of actors in the system. To identify characteristics of innovation actors, the paper deals with regions as a geographical areas of extending across space and time, although there is a lot of controversy in using regions as suitable units.

By way of conclusion, it seems clear that due to the number of isolates and overall number of patent applications, network of inventors are more interconnected like network of innovators, in respect to Košice region. These findings suggest that knowledge flow is more intensive among inventors which know each other from the joint projects. It should be noted that the innovator is also the owner of the patent and although it is natural to suppose that all inventors on the application form will be also owners of patents, payments related to patents can be result of the fact that patent applications have lower number of innovators than inventors. With respect to the size of main component in networks, the share of actors that have access to a bulk of local knowledge is higher on the inventor´s side. Although observed density is higher on innovators side, the share of isolates is lower in the network of inventors and in this network is almost thrice more edges than in the case of innovators. These findings are consistent with assumption that inventors could bring to economy more intangible assets in form of knowledge in comparison with innovators in the sense of local development (innovations as indicators of the economy development). Networks of innovators as well as networks of inventors in Košice region can be defined by low homogeneity – networks of innovative actors are highly fragmented and fragments form clusters of different types. On the other hand, networks have more significant parts and wider edges.

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