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Title and Abstract

Title	Knowledge mechanisms, innovation system synergy and regional economic dynamics in Hungary: a firm level analysis
Abstract	One of the most promising features of the diverse literature on regional innovation systems (RIS) is its capacity to integrate theories and ideas. For example, RIS draws equally on local institutions (Lundvall *et al.*, 2002) and knowledge bases (Asheim and Isaksen, 2002) while asking the question why innovation output and technological change differs across regions (Cooke *et al.*, 2004). This framework provides a common base for evolutionary and institutional-geographical analyses (Boschma and Frenken, 2006), while the introduction of complex system approach into economic geography opens the floor for quantitative approaches—measurement and simulation—in the analyses of RIS (Martin and Sunley, 2007). A triple helix argument might enter the discussion at this point. The context of the paper is given by the diverse nature of Hungarian regional economic growth during the early 2000's. Hungary, being a small and open economy, enormously leans on foreign investments. In addition to that, the Hungarian economy was challenged by post-socialist transition and an upswing of globalization simultaneously. This has left a footprint on regional economies as well (Authors, 2011). Those regions and sectors grew dynamically in which foreign-owned companies invested. But foreign firms also re-structured regional innovation systems, because Hungarian subcontractors were not able to catch up with their standards and these regions became dependent on the companies without real spill-over effects (Authors, 2012; Authors, in preparation). The gap between dynamic and lagging regions widened: foreign companies integrated few regions into international levels, while the majority of regions lagged with a prevailing effect of stagnating domestic companies. The study follows methodological developments in the measurement of synergy at the regional level by using indicators derived from complex system theory and entropy statistics (Leydesdorff *et al*., 2006, Leydesdorff and Fritsch, 2006) and elaborates on triple helix measurement over time. Our argument focuses on knowledge mechanisms in RIS (knowledge exploration, knowledge exploitation, and organizational control). We claim that knowledge mechanisms influence spatial firm dynamics like growth, entry, and exit. The argument also stresses that synergy among these mechanisms can be measured as reduction of uncertainty at the system's level (Authors,

2011; Strand and Leydesdorff, in press), which makes the driving forces in regional innovation systems identifiable (e.g. FDI) and therefore it provides new insights for regional growth models.

Synergy of an innovation system is usually understood as dynamic interaction of subsystems in the literature. For example, two subsystems are generally distinguished in RIS: knowledge exploration subsystem (universities, PROs etc.) and knowledge exploitation subsystem (companies, clusters etc.); their interaction is enhanced by economic and science policy (Tödtling and Trippl, 2005). A well functioning RIS equally draws on the two subsystems, and regional advantage is constructed when government is involved as well (Etzkowitz and Leydesdorff, 2000). Synergy can be considered as a mark of the quality of a RIS, because established local institutions and/or behaviour patterns then reduce uncertainty the local actors have to face within a configuration. Synergy reduces costs of decision making, strengthens collaboration, and can be expected to lead to more efficient innovation activities.

Because complexity measurement can handle only one type of entity (be it firm, publication or patent), RIS synergies and complexity approach are synchronized in model that follows Storper's (1997, at pp. 26 ff.) "holy trinity" conjecture. This argument emphasises that interrelationships among three independent dimensions –technology, organization, and territory– shape regional economies. Three independent dimensions are depicted in Figure 1 as well, but the organizational dimension of the "holy trinity" is substituted by economic exchange relations, as the latter can be expected to determine the size and scope of firms through transaction costs in the market (Coase, 1937). Knowledge mechanisms –knowledge exploration, knowledge exploitation, and organizational control– are defined as interactions among two dimensions. The system self-organizes itself when knowledge functions operate on each other; this is called innovation system synergy.

Knowledge exploitation is associated with the reuse of existing competences and means (March, 1991); at the system level it represents the interface between economic welfare and technological knowledge creation (Gibbons *et al.*, 1994) and does not necessarily depend on geographical locations, because economic welfare is created at the level of global markets, even if certain technologies originate in single regions. *Knowledge exploration* is associated with creating new alternatives (Baum *et al.*, 2000); this function is place-dependent rather than market-dependent mechanism, because tacit knowledge is essential in creating new knowledge and it relates significantly to places (Jaffe *et al.*, 1993; Acs *et al.*, 2002). *Organizational control* is defined as collective institutions and mediating organizations that increase the probability of the emergence of new knowledge (Loasby, 2001); these mechanisms operate mainly in territorial units.

Regional innovation systems do not stand alone, but permanently interact with other RIS, as well as organizations at the level of national and international innovation systems (Tödtling and Trippl, 2005). However, the extent of the interregional interaction between systems varies across regions (Asheim and Isaksen, 2002). For example, decisions taken in distant headquarters of foreign-owned firms may riff knowledge mechanisms off the region. Therefore, the relation with other systems has to be taken into consideration when measuring innovation system synergy, and a fourth

dimension is added to the previously developed three dimensional model (Leydesdorff *et al*., 2006; Leydesdorff and Sun, 2009; Leydesdorff and Ivanova, in preparation).

One-, two-, three-, and four-dimensional entropy values are measured along four analytically independent distributions of Hungarian high-tech, medium-tech and knowledge intensive service firms (technological class, size, location, internationalization) by a newly developed routine (Leydesdorff *et al.*, in preparation) for years 2002 and 2005. RIS synergy is measured as mutual redundancy that is defined at the level of the aggregate of the entropies mentioned. Synergy arises when these distributions depend on or overlap each other (such as in the case of spurious correlations): the value of three-dimensional mutual redundancy is negative in this case, whereas a positive four-dimensional mutual redundancy signs RIS synergy (Leydesdorff and Ivanova, in preparation). The values of two dimensional mutual redundancies illustrate the interface of two distributions, which is interpreted as three knowledge mechanisms: knowledge exploration (technology and geography), knowledge exploitation (technology and organization) and organizational control (organization and geography). The effect of foreign-owned firms on synergy was calculated by decomposing entropy into foreign and domestic subsets (Figure 2a).

Preliminary results suggest that T_{TGO} and T_{TGOI} values are very stable over the 2002-2005 period. Interestingly, knowledge exploration (T_{TG}) has not changed positively in regions where expected: neither in regions where foreign firms have significant positive effect on synergy (e.g. Budapest's agglomeration, and North-West counties) nor in university centres of Eastern regions (Csongrád and Hajdú-Bihar counties) (Figure 2b). Therefore, the paper will analyse correspondences of firm level dynamics (firm entry and firm exit) and knowledge mechanisms and innovation system synergy.

A firm level logit regression was built in which the independent variable was the increase of T_{TGO} in the region (1 if increased, 0 if not). First results suggest that both firm exit and firm entry affect the change in innovation system synergy negatively, but incumbent firms have positive significant effect. The influence of foreign-firms entry on synergy dynamics is positive and significant only in regions where synergy is based on the foreign subset. These promising findings confirm previous results and might provide new research questions that aim to address regional dynamics from a perspective mixing elements of triple helix, regional innovation system, and complex systems argument.