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## Introduction

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**Biographical notes:** Andreas Pyka is a Professor of Economic Theory at the University of Bremen, Germany, and since August 2007 he is a Visiting Professor at the TU Delft. His research topics are Neo-Schumpeterian economics and innovation research with a particular focus on collective innovation processes and the industrial organisation of innovation. Methodologically, he is engaged in the field of agent-based computational approaches as well as in approaches coming from complexity theory.

Petra Ahrweiler is a Professor of Innovation and Technology Management (focus STI Policy) at the University College Dublin, Ireland. Her research interests cover economic sociology and science, technology and innovation policy. She uses agent-based simulation for scenario modelling in policy research.

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Talking of globalisation we often assume that economic development and all social functions follow some global and universal trends affecting and unifying all parts of society while heterogeneity and variety is sacrificed for a single over-powering pattern of development. Empirical research in economics, however, shows us a complex reality of economic phenomena which seem to be deeply intertwined with cognitive, institutional, organisational and political contexts – contexts which provide a world of institutional variety, historicity, path-dependence and complexity (see Dopfer, 2006).

Without doubt, innovation-driven economic development shows features of complex systems:

- 1 the intensity of interactions – in particular in knowledge generation and diffusion activities – is very high (Pyka et al., 2007)
- 2 positive feedback effects such as success-breeds-success-effects (Cantner, 2007) are playing an important role

- 3 economic development is driven by the interplay of firm actors, public research institutions and financial actors (Hanusch and Pyka, 2007) and cannot be understood nor explained by looking only at isolated actor populations; this is due to co-evolutionary dynamics between the different actor groups
- 4 predicting the future development is impossible because of the fundamental uncertainty of innovation processes (Knight, 1965).

Thus, innovation and learning on the micro-level of economic actors are responsible for the emergence of structures on the system level of industries with high dynamics and high industry performance as, e.g., observed for knowledge-intensive industries such as biotechnology-based pharmaceuticals (see Ahrweiler et al., 2006).

Taking into account these complexity issues, policy research needs to enable policy actors to accompany, support and direct successfully innovation-driven development. Policy-making in complex social systems is no clear-cut cause-effect process. The terms complexity and uncertainty were already much discussed within the critique of the principal-agent theory of policy-making (see Conceicao et al., 2000). It turned out to be difficult to design policy-making as a game just between a principal and its agents (as e.g. in Guston, 2000): empirically we see something different, namely (1) every agent is subject to certain strategic behaviours of many other agents; (2) every agent is located in a technological, regulatory, political and economic context; (3) every agent has a certain experience and history with suffering strategic behaviour; (4) every agent is changing over time, etc. Furthermore, strategy formation is no longer a privilege of governmental actors as principals. In most policy domains, the term 'governance' hints at the fact that there are non-governmental actors involved in policy-making and control issues. Coordination mechanisms appear from the interaction of participating agents in a sector; these strategies and coordination mechanisms might even interfere with desired goals and impacts of governmental policy strategies. The task therefore remains to develop a complexity-adapted way to support policy design and analysis in innovation systems.

These complexity issues form a topic, which is basically neglected in Mainstream Economics where concepts such as the representative household and the representative firm are applied in order to abstract from heterogeneity, which allows the application of rigorous calculus. Without doubt, by this, economics has gained deep insights embedded in a formal elegant framework.

However, neglecting complexity issues is also a major source for oversimplification, in particular, when it comes to the analysis of economic development processes. There is a wide agreement that the most important driving force of economic development is technological progress and with it innovation processes.

Innovation itself introduces a first heterogeneity, as one can differentiate between innovating and non-innovating actors. Furthermore, learning and innovation processes are fed by different knowledge sources: Universities and public research institutes, R&D laboratories of private firms and entrepreneurs. These different actors do not only bring in their different knowledge stocks but combine their individual competencies in varying ways, having in mind varying strategies and finally introduce varying innovative solutions.

All these different characteristics may lead to complex interaction patterns and synergetic benefits in the form of spill-over effects, network and other positive externalities. Modern innovation research therefore puts heavy emphasis on complexity issues and its adequate representation in the analysis of economic development processes.

Basically, the analysis of patterns and its formation processes in innovation networks is at the heart of these new approaches which aim for a better understanding of the origins and regularities of economic development.

This special issue addresses complex processes in innovation networks and investigates their effects and implications. The contributions cover major sources of complexity such as cognitive/behavioural, geographical, institutional, organisational and political/regulatory dimensions.

The first three papers focus on cognition and location and embed network emergence into particular institutional settings. Beckenbach and Daskalakis discuss in their contribution the difficulties in collecting and compiling information on innovation and on the underlying processes. To address the intangible nature of knowledge and the complexity of innovation processes, new approaches are necessary to generate a fine-grained empirical picture integrating the cognitive dimensions of the involved agents. In their paper on innovation collaboration in Austria and Finland, Dachs, Ebersberger and Pyka show that the geographical dimension also matters. Confronted with identical questionnaires (the so-called Community Innovation Survey), firms in both countries seem to follow different behavioural patterns in their cooperation initiatives. Applying Social Network Analysis (SNA), Gloor, Grippa, Kidane, Marmier and von Arb come to a rather similar conclusion when they show the varying participation of industrial and academic participants in networks connecting entrepreneurial and scientific communities in different locations. Both results indicate the importance of path dependencies and institutional determinants in networking behaviour.

Then a management-oriented perspective is applied discussing the strategic options of network participation. The SNA again provides the methodological background of the contribution by Mote, Whitestone, Jordan and Hage. The authors analyse the reverse effect of social networks on the perception of actors concerning their working environment. Their approach allows the evaluation of different network structures concerning their suitability for promoting research. Lichtenthaler also takes a management perspective on knowledge generation and exploitation in innovation networks. He develops an integrated strategic approach for knowledge exploitation in networks allowing the explanation of differences between firms with respect to profitability. In particular, the author stresses the important mutual dependencies between internal and external knowledge exploitation.

The next contribution models network emergence from the theoretical point of view of modern innovation economics. In their paper, Wu and Brabazon are developing an agent-based simulation model within a Neo-Schumpeterian framework. Their simulation approach allows observing the ongoing system change as well as the investigation of systemic and organisational features by highlighting the development of emerging network structures.

Finally, policy conclusions are drawn from a co-evolutionary perspective stressing the importance of complementarities between innovation and finance and from applying concepts from SNA. Messica and Agmon stress the mutual dependencies between venture capitalists and firm actors with respect to economic performance of innovation networks, which are politically designed for the support emerging new industries. Roediger-Schluga and Barber finally analyse research networks created in various EU Framework Programmes. Searching for small-world and scale-free properties in these politically initiated networks they emphasise the advantageous effects of these network features for knowledge creation and diffusion.

The contributions of this special issue should help the reader to understand the complex mechanisms and dynamics of innovation in networks. Of course, more questions are raised than answers are given. However, any research results dealing with complexity will turn out to be crucial for shaping and governing innovation processes which are so important for present day firms and more general: for all economies at the edge of the transition to a knowledge society.

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