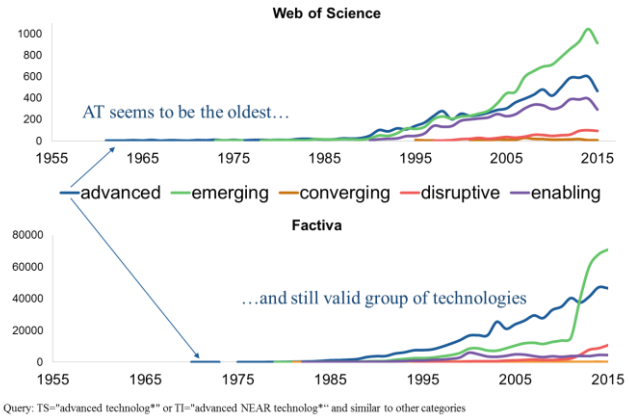
Introduction

Since 1960-s, there is growing interest in the development and use of new technologies accompanied by a strong trend on behalf of decision makers to regulate related processes at institutional and national levels. One of the key categories, which emerged together with a set of definitions and distinction criteria for R&D, was a notion of advanced technology. Comparing to other sounding categories such as emerging technology or others that are of recent interest (e.g. see Rotolo et al., 2015) the category of advanced technology seems to remain one of the key ideas used in professional literature until present (see Fig. 1). As long as there is continuous interest in rise, development and dissemination of new technologies, especially from the policy-making perspective, it is important to understand how perception of certain categories change in professional discourse over time, and who are the key drivers of these changes.

Figure 1. Number of documents in Web of Science and Factiva databases: 1955 – 2015



Query: TS="advanced technolog*" or TI="advanced NEAR technolog*" and similar to other categories

Literature review

Our task is to look at changes that happen from time to time in the structure of professional communication about advanced technology in order to identify those elements that fill in lacunas and feed further academic discussions. Therefore, we suggest referring to the approaches that focus on the analysis of citation distributions, specifically, the co-citation analysis and its applications to mapping invisible colleges (Gmür, 1973) or clusters of science (Small, 1999) as well as searching for emerging topics (Small, et al., 2014). The second source of inspiration is classical graph theory that shows how spatial configuration of elements may characterize their role in a network. Here we pay attention to the studies that highlighted the relationship between centrality and communication processes in small networks (Bavelas 1948, 1950), showing that centrally positioned actors could accumulate information flows from dislocated parts of a network and therefore influence behavior of other linked members (Smith, 1950; Leavitt, 1951). Following ideas of R.K. Merton, we assume that those actors in academic networks that gain more attention from their peers receive more citations and therefore will hold more central positions (Small, 2004). We suggest using betweeness centrality to look at the group of authors connected by shortest paths passing through a vertex. Papers with higher betweenness are essential in a network as long as they mark 'structural holes' that provide opportunities for mediating knowledge flows in a wider community of actors (Burt, 2002).

Method

In order to identify central elements in co-citation networks that structure discussions on advanced technology within the selected period of 1961-2015 the following four steps were taken. First, a set of documents for further analysis was identified. The data were extracted from the Web of Science Core Collection database for the period from 1961 until the end of 2015. The dataset included 8190 documents of all types, extracted from all citation indexes (accessed: 15.04.2016). Then, based on the overall publication dynamics we diveded the time interval into several smaller intervals according the the publication activity in the field. At the third stage, we used VOSviewer for constructing co-citation networks that were later analyzed in UCINET (for betweenness calculation). For parameters of co-citation networks see Table 1.

Table 1. Metrics of co-citation networks on advanced technology studies

Interval	Number of references	Threshold	References meeting threshold	Connected nodes	
				number	share
1961-1990	1268	1	1268	128	10%
1991-2000	18827	1	18827	2606	14%
2001-2010	66533	2	3050	1658	54%
2010-2015	79484	2	3197	2376	74%

Finally, we identified elements of the networks that appear in at least two sequential intervals and using R programming language investigated whether they demonstrate statistically grounded difference in betweeness centrality values.

Discussion and conclusions

Our analysis shows, that while between the first and second period there were no similar authors, for the next periods null hypothesis about absence of difference in values was rejected at the 5% significance level.

Table 2. Hypothesis testing results

Period	Mean betweenness of authors who move	Mean betweenness of authors who don't move	Wilcoxon statistics	p value
1991 – 2000	31822.6	3124.6	18827	< 0.01
2001 – 2010	17883.2	5986.6	3050	< 0.01

High betweenness centrality of the papers cited in several periods implicate their central (or 'bridge') positions in the co-citation network. These nodes fill the structural gaps in the existing studies linking various thematic clusters of the research field. Thus, between 1990s and 2000s this gap comprised socio-economic studies (54 papers in economics and management vs 6 in technology). On the contrary, in 2000-2010 papers in technology and engineering play a central role (45 papers in technology vs 38 in economics and management). There is an observable penetration of the concept from social sciences to natural and engineering disciplines. Papers that get over the next period demonstrate significantly higher values of betweenness centrality that may allow considering them as knowledge providers.

References

1. Barley, S. (1986). Technology as an occasion for structuring: Evidence from observations of CT scanners and the social order of radiology departments. Administrative science quarterly, 3 (1), 78–108.
2. Bavelas, A. (1948). A mathematical model for group structures. Human Organization (7), 16–30.
3. Bavelas, A. (1950). Communication patterns in task oriented groups. Journal of the Acoustical Society of America (22), 271–82.
4. Burt, R.S. (2002). The social capital of structural holes. In M. F. Guillén, R. Collins, P. England, & M. Russell (Ed.), New Directions in Economic Sociology. Thousand Oaks, CA: Sage Foundation, 203–47.
5. Gmür, M. (1973). Co-citation analysis and the search for invisible colleges: A methodological evaluation. Scientometrics, 51 (1), 27–57.
6. Leavitt, H. (1951). Some effects of communication patterns on group performance. Journal of Abnormal and Social Psychology (46), 38–50.
7. Rotolo, D., Hicks, D., & Martin, B. (2015). What is an emerging technology? Research Policy, 1827–43.
8. Small, H. (1999). Visualizing science by citation mapping. Journal of the American Society for Information Science, 50 (9), 799–813.
9. Small, H. (2004). On the shoulders of Robert Merton: Towards a normative theory of citation. Scientometrics, 60 (1), 71–79.
10. Small, H., Boyack, K. W., & Klavans, R. (2014). Identifying emerging topics in science and technology. Research Policy, 43 (8), 1450–67.
11. Smith, S. (1950). Communication Pattern and the Adaptability of Task-oriented Groups: an Experimental Study. Cambridge, MA: Group Networks Laboratory, Research Laboratory of Electronics, Massachusetts Institute of Technology.