Knowledge path dependence, external connection, and radical inventions: Evidence from Chinese Academy of Sciences

Ningning Zhang[1,2], Dingyi You[1], Le Tang[3], Ke Wen[1,2]

[1]Institutes of Science and Development, Chinese Academy of Sciences; [2]School of Public Policy and Management, University of Chinese Academy of Sciences; [3]Department of Economics, Suffolk University

Motivation

PRIs are critical strategic players in a nation's innovation activities.

- PRIs are usually tasked with scientific research and with its application, the so-called research in "Pasteur's quadrant".

Knowledge creation in research institutes has largely been built upon its existing knowledge base, and reliance on past knowledge and experience is common.

- In PRIs, researchers tend to have lifelong employment contracts, so there is little turnover, and research in PRIs tends to be mission-oriented.
- Nevertheless, the impact of path dependency, i.e. the use of and reliance on existing knowledge, on radical inventions is ambiguous.

As technology development has become more sophisticated and complicated, and inter-organizational collaborations are widespread.

- it is curious to see how external linkages affect radical inventions in research institutes.

Research questions

This study fills the gap by providing an empirical analysis of radical inventions at the Chinese Academy of Sciences (CAS), a conglomerate of PRIs in China:

- **How does the utilization and dependence on existing knowledge affect radical inventions?**
- **How do external connections affect radical inventions and mediate the relationship between knowledge path dependence and radical inventions?**

Methods and Materials

Data-set

We compile a novel dataset that combines patent applications and information on CAS institutes.

Variables

- **Radical inventions:** Radical inventions are new inventions, if the first 4-digit IPC code in a patent, applied by institute i in year t, has not appeared in all patents applied by this institute over the last five years.
- **Knowledge path dependence:** Knowledge path dependence characterizes a research institute's behavior in the process of knowledge creation.
- **Connection:** Connection strength demonstrates the frequency of interactions between an organization and its direct collaborators.

Econometric model: Negative Binomial model

$$RadInv_{it} = \exp(\beta_0 + \beta_1 \cdot Path_{it} + \beta_2 \cdot Connect_{it} + \beta_3 \cdot Connect_{it}^2 + \beta_4 \cdot Path_{it} \cdot Connect_{it} + \gamma \cdot Z_{it} + \theta_t + \alpha_i + e_{it})$$

- $RadInv_{it}$ is the number of radical inventions applied by institute i in year
- $Path_{it}$ and $Connect_{it}$ are the explanatory variables .
- Z_{it} is a vector of previously introduced institutional characteristics such as scale, R&D expenditure, age, and patent stock.
- Year fixed effects θ_t control for changes in the macroeconomic environment and systematic changes in patenting activities over time.

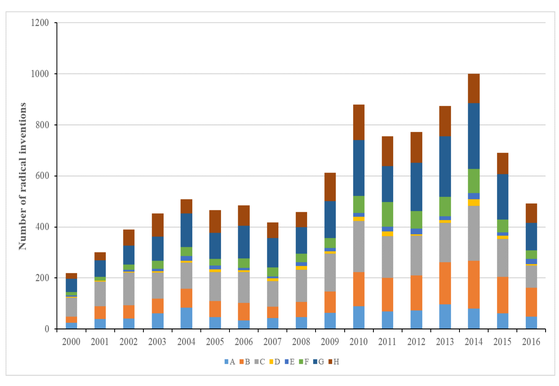

Figure 1. The number of radical inventions according to the eight sections

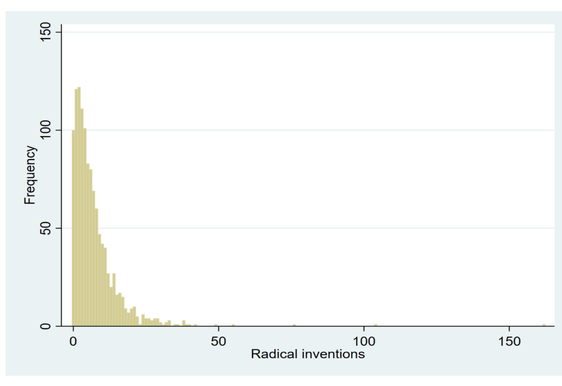

Figure 2. Distribution of radical inventions by institutions

Results

- The coefficient of knowledge path dependence is **negative and significant** at the 0.01 level.
- The negative coefficients of the squared term Connection^2 suggest **an inverse U-shaped** relationship between connection strength and radical inventions.
- The negative and significant coefficient of the interaction term path dependence * connection demonstrates that the negative effect of knowledge path dependence is larger when connection strength is higher.
  - When the connection strength is low, the effect of knowledge path dependence on radical inventions is relatively small (solid line in Figure 3);
  - When the connection strength is strong, the effect of knowledge path dependence on radical inventions becomes large (dashed solid line in Figure 3).

Variables	Main	Subipc	4-digit IPC	Instrument Var
Know_Path_Depen	-0.777***	-0.461***	-0.982***	-1.498**
	(0.132)	(0.131)	(0.118)	(0.73)
Connection	0.189***	0.167***	0.203***	0.217***
	(0.054)	(0.051)	(0.056)	(0.065)
Connection^2	-0.019***	-0.015**	-0.021***	-0.021***
	(0.007)	(0.007)	(0.008)	(0.008)
Know_Path_Depen * Connection	-0.353***	-0.292***	-0.298***	-0.059**
	(0.091)	(0.093)	(0.088)	(0.246)
Control variables	Yes	Yes	Yes	Yes
No. of observations	1122	1122	1122	1088
Log likelihood	-2618	-2725	-2605	-2815
Wald chi2	199	152	228	986

Table 1. Regression results

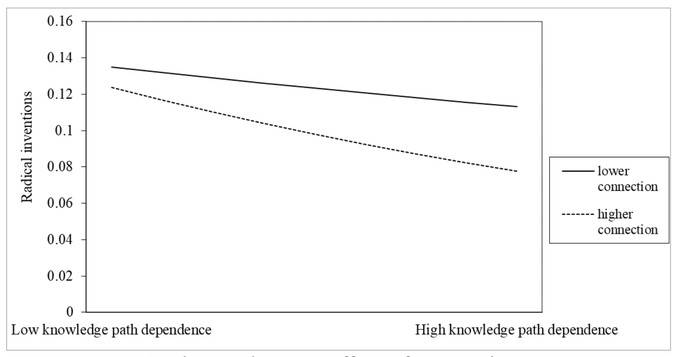

Figure 3. The moderating effect of external connection

Robustness

- Use alternative measures of radical inventions, such as identify radical inventions by newly appeared sub-IPC, and novel combinations of sub-IPC.
- Use alternative measures of knowledge path dependence, such as using information from 4-digit IPC, average dependence in the past.
- Use lagged knowledge path dependent as instrumental variable to address the potential exogeneity between no. of radical inventions and knowledge path dependence.
- Conduct analysis by various disciplines (geo-science, chemistry, life science and medicine, and information science) and by regions (institutes located in Beijing vs institutes out of Beijing).

Conclusions

Knowledge path dependence has a negative effect on radical inventions in PRIs. The more a research institute relies on past knowledge, the more likely it is to be constrained by past experience.

There is an inverted U-shaped relationship between external connections and radical inventions.

- Below a certain threshold, external connections facilitate radical inventions by providing heterogeneous knowledge, and these connections foster trust capital.
- If the connection is too strong, crossing the threshold, it may prevent radical inventions. Because of frequent interactions, homogeneous, less diversified knowledge may be generated, resulting in fewer breakthroughs in research.

The relatively weak connection negates the effect of knowledge path dependency that leads to radical inventions. This mitigates the effect of knowledge path dependence and encourages the exploration of new knowledge, which leads to radical inventions.

Implications

- Discourage the same principal investigators (PIs) from leading multiple research projects to reduce knowledge path dependence.
- Funding agencies should pay attention to the research process and delineate achievable goals, such as how to sustain collaborations at the beginning.
- Research institute administration should encourage extensive and diversified collaborations with external partners, while discouraging ties or collaborations with repeat partners.

Contact

Name: Le Tang
Organization: Department of Economics, Suffolk University
Email: ltang7@suffolk.edu

Name: Ningning Zhang
Organization: Institutes of Science and Development, Chinese Academy of Sciences
Email: zhangningning19@mails.ucas.ac.cn