Knowledge: gift or burden of innovation?

Siyuan Lyu

Department of Economics, SUNY Stony Brook University

(siyuan.lyu@stonybrook.edu)

My personal website

My Curriculum Vitae

Abstract

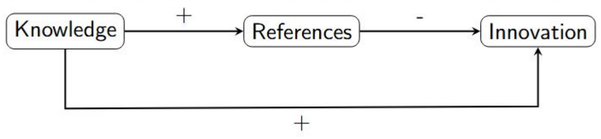
- This paper examines the role of knowledge accumulation in the innovation process by distinguishing between the accumulation of general field knowledge and the specific knowledge directly referenced in individual innovations.
- First, the paper provides a theoretical model following Arora et al.(2021), discusses how knowledge accumulation can reduce innovation costs, while directly referencing existing knowledge increases the difficulty of innovation.
- Second, the paper also provides some empirical evidences utilizing data compiled by Park et al.(2023) and NBER Patent Project database to show that field-level knowledge reserves promote both innovation and citations, whereas direct citations constrain innovation.

Introduction

- The role of existing knowledge in the development of innovation has been subject to two main discussions: “Burden of Knowledge” by Jones (2009) and “Recombinant growth” by Weitzman (1998). This leads to the main research question of the paper:

What is the role of knowledge in R & D?

- In this paper, we separate references, the existing ideas that are directly learned and imitated in the process of innovation; and knowledge, public and general science that supports innovation.
- The relationship between knowledge, references and innovation at firm level is described in the followin



Model

- Two agents (firms’ R&D teams) are choosing their research project independently. Agent i chooses a research project (α_i, I_i), where α_i is the use of knowledge (references) and $\alpha_i \in [0, k]$, where k is the stock of public knowledge. $I_i \geq 0$ measures the unique innovation developed by i . The game has two stages. In the first stage, both agents choose (α_i, α_j) as how many references they are going to learn; in the second stage, agents choose (I_i, I_j) as how much innovation they will input into the project, and then the payoffs realize.
- Agent i is maximizing the following payoff:

$$V_i = I_i - c_1 {I_i^2}/{2} + c_2 I_i I_j + b\alpha_i - \phi(\alpha_i, k) I_i - \gamma\alpha_i$$

where $I_i - c_1 {I_i^2}/{2} + c_2 I_i I_j + b\alpha_i$ is the benefit of the project,$\phi(\alpha_i, k)$ is unit innovation cost, with $\phi_1 < 0, \phi_2 > 0, \phi_{12} < 0$. γ is education cost. We further assume $|c_1| > |c_2|$.

- In the equilibrium, there is ${\partial I_i^*}/{\partial \alpha_i} < 0$, ${\partial I_j^*}/{\partial \alpha_i} < 0$, ${\partial I_i^*}/{\partial k} > 0$, ${\partial I_j^*}/{\partial k} > 0$ under the assumptions on innovation cost functions and strategic complementarity, i.e., innovation decreases in both own and rival's references and increases in public knowledge.
- And there is ${\partial \alpha_i^*}/{\partial k} > 0$ under the assumptions on innovation cost functions, i.e., references increase in public knowledge.
- Knowledge amplifies the negative impact of references on innovation, and if ${\partial^2 I_i^*}/{\partial \alpha_i \partial k}$ is large enough, then there must be

$$\frac{dI_i^*}{dk} = \frac{\partial I_i^*}{\partial k} + \frac{\partial I_i^*}{\partial \alpha_i}\frac{\partial \alpha_i}{\partial k} < 0$$

That the overall effect of knowledge on innovation is negative.

Data and Variables

- Data: Park et al. (2023) and NBER Patent Data Project
- Collect 3,154,114 patents published between 1976 and 2006. Each patent is assigned to a field based on NBER patent classifications.
- Define Innovation of a patent as the fraction of patents citing it without citing its references among all patents citing it.
- Define References of a patent as the total number of patents cited by it.
- Define Knowledge of each year in each field as the total number of patents published in the field before the year.
- Other variables: Originality; Age; Team Production; Diversity; Competition; etc.

Empirical Strategy

- To investigate the effects of general field s knowledge and references on innovation of patent i at time t, the paper adopts a linear model as follows:

$$Innovation_{ist} = \beta_0 + \beta_1 Knowledge_{st} + \beta_2 References_{ist} + \boldsymbol{X\delta} + \varepsilon_{ist}$$

- To investigate the possible mechanism that explains the positive effect of knowledge and the negative effect of references:

$$Citation_{ist} = \beta_0 + \beta_1 Innovation_{ist} + \beta_2 References_{ist} + \boldsymbol{X\delta} + \varepsilon_{ist}$$

- To test the relationship between knowledge and references:

$$References_{ist} = \beta_0 + \beta_1 Knowledge_{st} + \boldsymbol{X\delta} + \varepsilon_{ist}$$

Empirical results

A. Basic patterns in knowledge, references and innovation

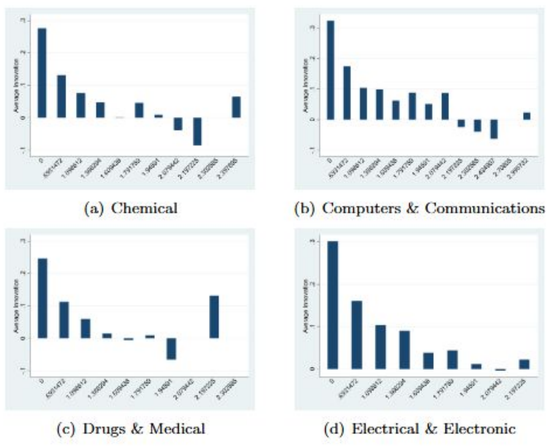


Fig. 1. (Left) In 1978, innovativeness within each NBER field (same knowledge) declines in references

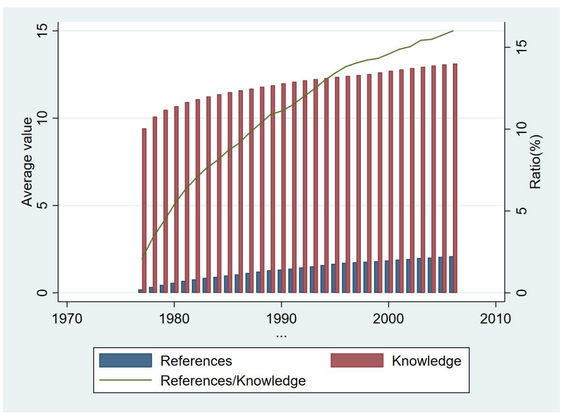


Fig. 2. (Right) References increase in knowledge accumulation both in abstract and relative amounts

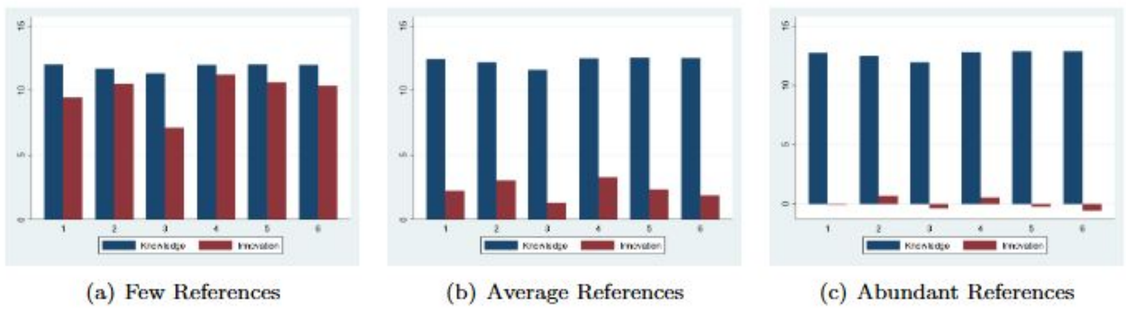


Fig. 3. Among all NBER fields, controlling the amount of references, patents’ innovativeness shows a positive correlation with knowledge.

B. Main empirical results

	Clustering NBER subfield		Clustering NBER field	
	Innovation	Alter Innovation	Innovation	Alter Innovation
Knowledge	0.0120***	0.0120***	0.0330***	0.0309***
	(0.000)	(0.000)	(0.000)	(0.000)
References	-0.0451***	-0.0529***	-0.0448***	-0.0528***
	(0.000)	(0.000)	(0.000)	(0.000)
Obs	2454595	2465161	2454595	2465161

	Citation
Innovation	0.600***
	(0.000)
References	0.300***
	(0.000)
Obs	1884944

	References
Innovation	-0.955***
	(0.000)
Knowledge	0.186***
	(0.000)
Obs	2454595

Conclusion

- The researcher makes use of two types of existing ideas: references and public, general knowledge.
- Knowledge could encourage innovation by cutting costs of innovation directly.
- References could hinder innovation by making it harder to innovate.
- Knowledge will also encourage references and mitigate the negative impact of references on innovation.
- While knowledge makes both innovating and referring easier, the overall effect of knowledge accumulation on innovation is negative. This is because references have a larger negative effect.

References:

Ashish Arora, Sharon Belenzon, and Lia Sheer. Knowledge spillovers and corporate investment in scientific research. American Economic Review, 111(3):871–898, 2021.

ichael Park, Erin Leahey, and Russell J Funk. Papers and patents are becoming less disruptive over time. Nature, 613(7942):138–144, 2023.