

Is Academic Science Raising Innovative Productivity? Theory and Evidence from Firm-Level Data

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Recent research points to an evident surge in innovative activity in the United States over the past fifteen years. The recent patent surge could potentially be explained by an increase in the propensity of Americans to patent inventions, rather than an increase in the productivity of American research and development, but the recent research of Kortum and Lerner (1998, 2000, 2003) strongly suggests that recent trends in patenting and related data are more consistent with the latter interpretation. If this conclusion is correct, then it could help explain the widely observed increase in U.S. TFP growth in recent years. But if American R&D productivity has increased, then that raises the question of what factors are driving the increase. This paper attempts to assess the importance of one possible contributing factor increased knowledge spillovers from U.S.-based academic science.

Citations made by patents granted in the United States to articles in the scientific literature increased very rapidly from the mid 1980s through the late 1990s. Over this period, the number of patents granted by the U.S. Patent and Trademark Office to U.S. residents more than doubled, real R&D expenditures in the United States rose by almost 40%, and global output of scientific articles increased by about 13%, but patent citations to science increased more than 13 times. At least in some broad sense that academic science and industrial technology are closer than they used to be. This could mean that publicly funded science is generating more spillovers to industrial innovation than in the past. This, in turn, may have contributed in important ways to the apparent surge of innovative activity in the United States in the 1990s.

This positive interpretation of recent trends in the data is influenced by the theoretical contributions of Evenson and Kislav (1976) and the more recent analysis their work inspired, such as Adams (1990) and Kortum (1997). In this general class of models, applied research is a search process that eventually exhausts the technological opportunities within a particular field. However, basic science can open up new search distributions for applied researchers, raising the productivity and the level of applied research effort at least temporarily. Viewed through this theoretical lens, the concurrence of rapid growth in U.S. private R&D expenditures, even more rapid growth in patenting, mounting evidence of an acceleration in TFP growth, and still more rapid growth in the intensity with which U.S. patents cite academic science would all seem to suggest a response to new technological opportunities created by academic research. Not surprisingly, other advanced industrial nations are deliberately trying to foster closer connections between university-based scientific research and industrial R&D in conscious imitation of the U.S. model. But this is not the only interpretation of recent data trends, and it is not necessarily the correct one. Simply counting patent citations to science across technological and scientific fields, nations, and times, as prior researchers have done, tells us little about the impact the citations (and the knowledge flows that they trace out) are having on the inventive productivity of the citing firms and organizations. This is a serious limitation to our current knowledge, because the implications of increased citations for national technological progress, economic growth, and welfare will be a function of the impact of the underlying knowledge flows on the research productivity of the recipient inventors.

This paper seeks to remedy this gap in our knowledge by combining new theoretical work with new firm-level empirical analysis. The paper introduces a formal model of applied R&D, based on the path-breaking work of Evenson and Kislav (1976). Although the model is quite simple, it generates a number of unambiguous predictions that can then be taken directly to our unique data set. In this model, applied R&D is represented as a search process. Breakthroughs in academic science can enrich the search distributions probed by firms, leading to an increase in the productivity of R&D spending. In our model, firms differ in their ability to benefit from these breakthroughs in academic science. Thus, academic breakthroughs have a differential impact on the cross-section of firms.

We measure the relative strength of the connection between academic science and firm invention by tracking the citations to scientific articles that appear in the U.S. patents of our sample firms. We possess such data for more than 1,200 firms over the period 1983-1999. We use measures of patent quality and total factor productivity, together with firm-level measures of R&D spending, to compute a number of different indices of R&D productivity. For firms in the pharmaceutical industry, broadly defined, we use firm-level data on successful product introductions to create an alternative measure of innovative output. We find support for the predictions of the model, and we find that the measured impact of academic science on research productivity is particularly strong in the biotechnology and pharmaceutical sectors.