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Opportunities and benefits as determinants of the direction of scientific research☆

Jay Bhattacharya[a], Mikko Packalen[b,*]

[a] Stanford University School of Medicine, CHP/PCOR, 117 Encina Commons, Stanford, CA 94305-6019, United States
[b] University of Waterloo, Department of Economics, 200 University Avenue West, Waterloo, ON N2L 3G1, Canada

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ABSTRACT

Scientific research and private-sector technological innovation differ in objectives, constraints, and organizational forms. Scientific research may thus not be driven by the direct practical benefit to others in the way that private-sector innovation is. Alternatively, some – yet largely unexplored – mechanisms drive the direction of scientific research to respond to the expected public benefit. We test these two competing hypotheses of scientific research. This is important because any coherent specification of what constitutes the socially optimal allocation of research requires that scientists take the public practical benefit of their work into account in setting their agenda. We examine whether the composition of medical research responds to changes in disease prevalence, while accounting for the quality of available research opportunities. We match biomedical publications data with disease prevalence data and develop new methods for estimating the quality of research opportunities from textual information and structural productivity parameters.

1. Introduction

Scientific research and private-sector technological innovation differ in objectives, constraints, and organizational forms. For example, the for-profit objective that drives private-sector innovation is muted in much scientific research.[1] This particular difference is important in part because other differences are likely linked to it. For example, Aghion et al. (2008) view the fact that individual researchers have more control over their agenda in scientific research than in private-sector innovation as the defining characteristic of academia. They conjecture that this difference is due to the non-profit nature of scientific research.

A key virtue of for-profit allocation is that decisions made by for-profit firms must necessarily respond to changes in the market, or else risk failure. There is abundant evidence that for-profit producers innovate according to market demand. Non-profit allocation, on the other hand, imposes looser budget constraints (Lakdawalla and Philipson, 2006). In principle, looser constraints could divorce production decisions from demand. For example, the choice of topics could be driven by the prospect of influencing other scientists (e.g. Dasgupta and David, 1994; Saha and Weinberg, 2008) rather than the expected social benefit.

These considerations raise the possibility that the direction of scientific research does not respond to market demand in the way that private-sector technological innovation does. Alternatively, some – yet largely unexplored – mechanisms drive the direction of scientific research to respond to the expected public benefit, as has been argued by Rosenberg (1982). In this paper we test these two competing hypotheses. This question is important because any coherent specification of what constitutes the socially optimal allo-

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* Corresponding author. Tel.: +1 519 888 4567.
E-mail addresses: jay@stanford.edu (J. Bhattacharya), packalen@uwaterloo.ca (M. Packalen).

[1] In the Background Appendix we examine the connections between industrial R&D and academic research in the biomedical sector and how pharmaceutical innovation reflects largely the functioning of for-profit incentives and academic medicine and biomedical publications reflect largely non-profit incentives.

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cation of research would require that scientists take the public benefit of their work into account in setting their agenda.

To test these two competing hypotheses of scientific research, we examine whether the composition of medical research responds to changes in disease prevalence. For drug-related medical research we also condition on the quality of available research opportunities. We focus on disease-driven medical research examined here because it represents the majority of research in medicine at least in terms of publication output.[2]

Our focus on medicine is appropriate because, while there may be good reasons to insulate some research activities from the vagaries of the market, academic medicine is not such a market. There is little extant evidence that academic medicine actually does so respond to the market (that is, to the epidemiology of patient health) and the view of academic medicine as an "ivory tower" persists. The role of technological progress in producing gains against diseases implies that the study of factors that determine the direction and magnitude of that progress – including the study of what determines the direction of academic medical research – are especially important from health and health economic perspectives.

Our analysis is agnostic about why medical research would respond to changes in disease prevalence and research opportunities. The available data do not enable us to differentiate between theories of scientific research such as altruism, prestige maximization (see e.g. Merton, 1973 [1942]; Glaeser, 2003; Stern, 2004), and the availability of government funding.[3] The specific mechanisms are important but so is understanding the relationship between the direction of scientific research and characteristics that determine the socially optimal allocation.

Only a handful of studies have examined the determinants of scientific research and non-profit innovation in general. Rosenberg (1982) emphasizes that private-sector technological innovation yields important inputs to scientific research. He conjectures that the direction of scientific research is in part driven by the quality of research opportunities and the expected rewards from research. Lichtenberg (1999) and Lichtenberg (2006) find a positive correlation between public biomedical funding and both disease prevalence and disease severity and between cancer prevalence and the number of biomedical publications. In contrast with these two analyses, we use exogenous variation in disease prevalence to identify the induced innovation effect. Finkelstein (2004) finds that the impact of vaccine policies on the number of new patent applications is small and statistically insignificant for both non-profit and for-profit entities. Unlike all three analyses, we condition on available research opportunities.[4]

The literature on the determinants of the direction of private-sector technological innovation is more extensive. The induced innovation hypothesis originated in Hicks (1932) and Schmookler (1966). Recent empirical studies of the induced innovation hypothesis in the pharmaceutical industry include Acemoglu and Linn (2004); Finkelstein (2004); Lichtenberg and Waldfogel (2003) and Yin (2008).[5] Our research opportunity concept corresponds to the technological opportunity concept examined by Scherer (1965) and Schmookler (1966) as well as by Popp (2002).[6]

Our methodology to estimate the quality of research opportunities builds on the methodology of Caballero and Jaffe (1993); Jaffe and Trajtenberg (1996) and Popp (2002). Our method extends this by permitting the probability that a given knowledge cohort is used in research to depend not only on the quality of a given knowledge cohort but also on the quality of other existing knowledge cohorts. Also, we construct the scientific opportunity variable from textual information, rather than citation information. This considerably expands the information base from which research opportunities can be measured. For example, citations in scientific publications seldom capture research opportunities generated by private-sector technological innovation, whose role Rosenberg (1982) emphasized.[7]

2. Theory

We present a model in which the socially optimal allocation of research across diseases is influenced by disease prevalence and quality of research opportunities, implying that any good allocation mechanism would induce research to respond to these characteristics. The analysis has also implications for how to measure quality of research opportunities.

2.1. A model of the social benefit from medical research

We assume that each unit of research is identified by three characteristics: the disease i which the research examines, the year t in which the research is conducted, and the cohort f of the research opportunities that are pursued in the research.[8] The benefit from research depends on three factors: (1) the extent of research effort (N_{itf}), (2) the number of people who benefit from the research (M_{it}), and (3) the quality of the research opportunities.[9]

[2] Throughout our sample period over 60% of publications in medicine are linked to a disease (this can be seen from Fig. 2a in Section 7.1). Our match of publication data and disease prevalence data captures roughly 50% of all disease-linked research (see Section 7.1). The three measures of drug-related research that we employ (see Section 4.1) represent between 20% and 45% of all disease-matched research (see Section 7.1).

[3] Throughout our sample period – based on medical researchers' self-reports – only 11% (13%) of disease-linked research (all research) is supported by National Institutes of Health (NIH) or other U.S. government sources (authors' calculations from the publications data). These low numbers suggest that our estimates are not necessarily driven by responses to changes in government funding priorities.

[4] Examination of the research opportunity effect and development of associated methods is important for three reasons. First, while it is implausible that researchers *within* a research field would not redirect research effort in response to changes in research opportunities, it is not nearly as evident that scientists would very often switch fields to take advantage of greater research opportunities. Second, it is obviously important to condition on research opportunities in estimating the induced innovation effect if the two variables are correlated. Third, from an allocative efficiency perspective it is important to understand how the research opportunity effect varies across organizational forms and across types of individuals.

[5] Newell et al. (1999) and Popp (2002) examine induced innovation in the energy sector. In addition to Acemoglu and Linn (2004), also DellaVigna and Pollet (2007) exploit changes in the age demographics of the population for identification.

[6] The previous version of this paper (Bhattacharya and Packalen, 2008a) included estimates of the induced innovation effect in pharmaceutical innovation, which we omit here for presentational clarity. The analyses of aging and obesity induced innovation are related to the empirical studies on preference externalities by Waldfogel (2003) and George and Waldfogel (2003). In a companion paper (Bhattacharya and Packalen, 2008b) we calculate the welfare effect of the induced innovation externality of obesity. The reader is also referred to this companion paper for references to the medical and economic literatures on obesity.

[7] Related work includes Azoulay et al. (2007, 2009) who determine patentability research from the textual content of publications, and the graphical analysis of topic bursts by Mane and Börner (2004).

[8] These assumptions are, of course, simplifications as a research project in medicine does not necessarily examine only one disease and may rely on opportunities that do not all belong to the same opportunity cohort f. We address these issues in our empirical analysis (see Sections 4.1 and 4.2).

[9] We thus assume that the benefit from research does not depend on the severity of the disease. This is in part due to lack of exogenous variation in severity over time, but is also consistent with the findings of Acemoglu and Linn (2004). From a theoretical perspective, for an increase in the severity of a disease to increase the expected benefit from research on the disease the increase in severity should be accompanied with an increase in the expected progress that could be made against the disease. The validity of latter condition is not evident to us given the incremental nature of technological progress.