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Introduction

This volume is the fourth publication of the National Bureau of Economic Research (NBER) Innovation Policy and the Economy (IPE) group. The appreciation of the importance of innovation to the economy has increased over the past decade. At the same time, an active debate continues regarding the implications of rapid technological change for economic policy and the appropriate policies and programs regarding research, innovation, and the commercialization of new technology. This debate has intensified with the economic and security challenges that our nation has recently faced.

The IPE group seeks to provide an accessible forum to bring the work of leading academic researchers to an audience of policy makers and others interested in the interaction between public policy and innovation. Our goals are:

- To provide an ongoing forum for the presentation of research on the impact of public policy on the innovative process.
- To stimulate such research by exposing potentially interested researchers to the issues that policy makers consider important.
- To increase the awareness of policy makers (and the public policy community more generally) concerning contemporary research in economics and the other social sciences that informs the evaluation of current or prospective proposals relating to innovation policy.

This volume contains the papers presented to the group's meeting in Washington, DC, in April 2003.

In "Crafting Defense R&D Policy in the Anti-Terrorist Era," Manuel Trajtenberg analyzes how the aftermath of the terrorist attacks of September 11, 2001, has changed the context for constructing and evaluating defense R&D policy. He first highlights two insights. First, the

United States has an overwhelming advantage over all other countries in its base of scientific and technological knowledge for new weapons and other defensive systems. No other country is even attempting to compete, and if any did, they would need a major change in their expenditure level, and a long time, for them to catch up. Second, Trajtenberg shows that defense R&D is still overwhelmingly concentrated in "big systems," such as nuclear weapons, missiles, aircraft, and submarines, which can deter other nations but which are not likely to be useful in fighting terrorism.

The paper then turns to an analysis of the economics of fighting terrorism, considering the relative value of combating terrorism at its source compared to defending vulnerable U.S. targets. It shows that combating terrorism at its source is a classic public good and that investment in this good is likely to be much more cost-effective than defending targets. This analysis suggests a major reorientation of defense R&D priorities away from large systems, where we already have an overwhelming advantage, toward intelligence gathering and technology for the analysis of intelligence. Trajtenberg concludes by observing that such a reorientation would have positive consequences for the economy because the companies likely to play a key role in the new technologies are much more dispersed than the small number of traditional contractors who design and build large weapons systems.

In "Technology Policy for Energy and the Environment," Adam B. Jaffe, Richard G. Newell, and Richard N. Stavins address the important policy issues that arise at the nexus between technology policy and policy for the environment and energy. They analyze the implications of the interaction of market failures associated with pollution and the environment with market failures associated with the development and diffusion of new technology. These combined market failures imply a strong *prima facie* case for public policy intervention to foster environmentally beneficial technology. Both theory and empirical evidence suggest that the rate and direction of technological advance is influenced by incentives from the market and from regulation.

The literature summarized by Jaffe et al. suggests that environmental policy based on incentive-based approaches is more likely to foster cost-effective technology innovation and diffusion than policy based on command-and-control approaches. In addition, society's investments in the development and diffusion of new environmentally beneficial technologies is likely to be less than socially desirable in the presence of weak or nonexistent environmental policies that would

otherwise foster such technology. Positive knowledge, adoption spillovers, and information problems further weaken innovation incentives. While environmental technology policy is fraught with difficulties, the authors advocate a long-term view based on a strategy of experimenting with different policy approaches and systematically evaluating their success.

In the next paper, "The Human Resources Revolution: Is It a Productivity Driver?" Kathryn Shaw assesses the empirical evidence and policy issues associated with the human resources revolution. While managers and practitioners have long emphasized the role of human resources practices, economists and policy makers have only recently begun to evaluate the impact of human resources policies on overall productivity growth. Shaw suggests that advanced human resources practices (ranging from team-based problem solving to incentive pay, to training) have facilitated the strong productivity record since the mid-1990s, both directly and as a complement to the intensive adoption of information technology. Synthesizing a wide body of empirical research, Shaw offers substantial evidence that the human resources revolution has been an important source of productivity growth over the past decade.

Turning to the policy issues, Shaw emphasizes two implications. First, the advantages to innovative human resources practices can be realized only when the U.S. workforce possesses a strong human capital foundation. In other words, maintaining a high record of productivity growth depends on an inclusive education policy to ensure that an ever-increasing share of the workforce is in possession of the basic skills required to take advantage of workplace reorganization. Second, though the private sector has invested intensively in advanced human resources practices, many of these investments have not been measured consistently or expensed correctly as an accounting matter. The lack of standards by which to measure workplace organization implies that society finds it difficult to identify and diffuse productive practices as quickly as possible. In addition, the lack of an accounting framework may result in ineffective adoption by firms, particularly those participating in public equity markets. Optimal adoption of these practices may be facilitated by government investment in facilitating better accounting systems that acknowledge, and thus encourage, investment in people.

More generally, Shaw's analysis highlights the broad range of measures that must be considered for effective innovation policy. From

accounting rules to investments in primary and secondary education, an effective innovation environment depends on a range of policy levers that are usually considered beyond the scope of traditional science and technology policy concerns.

The final two papers consider the recent debate over the patent system. In the first of these two papers, "Prospects for Improving U.S. Patent Quality via Postgrant Opposition," Bronwyn H. Hall, Stuart J. H. Graham, Dietmar Harhoff, and David C. Mowery consider alternative designs for the patent system. The authors are motivated by the recent surge in U.S. patenting and expansion of patentable subject matter, which has increased the backlogs that patent examiners face and raised concerns that patents of insufficient quality or with inadequate checking of prior inventions are being issued in some cases. They also worry about the rise in patent litigation and its costs, which they fear may be having a harmful effect on the incentives to innovate.

Hall et al. review the prospects for improving the operation of the U.S. patent system and lowering its cost by changing the administrative process at the U.S. Patent and Trademark Office. At present, the primary administrative procedure for a challenge to the validity of a U.S. patent is the re-examination proceeding, which may be initiated by any party during the life of the patent. A more elaborate and adversarial procedure for challenging the validity of patents in the immediate aftermath of their issue is the opposition proceeding used by the European Patent Office. The authors consider the likely effects of introducing such an opposition process in the U.S. patent system, focusing in particular on the ability of such a process to improve the quality of patents and reduce the length of time that the current reliance on litigation requires to ascertain the validity of the relatively valuable patents contested in court. The authors argue that the welfare gains to such a system may be substantial.

The final contribution to this year's volume, "The Gaming of Pharmaceutical Patents" by Jeremy Bulow, undertakes a policy analysis of recent attempts by brand-name pharmaceutical firms to game the generic entry process. As part of the Hatch-Waxman Act, the Food and Drug Administration (FDA) permits generic pharmaceutical firms to apply for the right to enter markets, where the patents on which a pharmaceutical firms' market exclusivity is based can be shown to be invalid. The FDA balances this provision with a thirty-month stay of generic entry once the brand-name firm contests the generics' invalidity claim. In addition, the FDA grants the first generic entrant into a

pharmaceutical market a 180-day exclusivity period, beginning at the time that the generic is first introduced into the market. These interacting procedures provide an incentive to brand-name pharmaceutical firms to settle patent invalidity suits so that generic entry is delayed as long as possible. Not simply a theoretical possibility, so-called Hatch-Waxman agreements have become increasingly popular over the past five years and have resulted in several antitrust enforcement actions.

Jeremy Bulow offers a novel policy analysis of these agreements. In addition to describing the different types of observed agreements between brand-name and generic pharmaceutical companies, Bulow undertakes a nuanced economic analysis, yielding clear policy guidelines. For example, agreements involving a cash payment by the brand-name firm in exchange for a delay of the generic firm's entry are clearly anti-competitive and violate the antitrust laws. Also, premising the 180-day rule on the date of entry by the first generic (rather than, for example, on the first day of feasible entry) is simultaneously inefficient and anti-competitive. On the other hand, agreements involving no direct payments from the brand-name to the generic firm may enhance welfare as long as no other anticompetitive effects are introduced. Overall, subtle economic analysis is required to craft effective policy analysis in an area that involves interactions among FDA regulatory procedures, intellectual property standards, and antitrust law. Despite these complexities, policy makers must be vigilant against patent holders paying competitors to stay out of the market.

As with previous years' volumes, we end on an optimistic note. While the issues involved are undoubtedly difficult, the essays highlight the role that economic theory and empirical analysis can play in evaluating key policies affecting innovation. They suggest that contemporary research in economics can inform the evaluation of current and prospective innovation policy alternatives.

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