TECHNOLOGY-PUSH, DEMAND-PULL, AND STRATEGIC R&D INVESTMENT

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Overview

In this study, a bilevel modeling framework is constructed to determine the combination of technology-push and demand-pull policies that induces the socially optimal level of innovation for a given technology policy application. The framework is bilevel in that it features inner agents (profit-maximizing firms) and an outer agent (welfare-maximizing policymaker). The inner problem is an oligopoly game in which each firm solves a two-stage stochastic decision problem. The firm chooses process and product R&D investments in the first stage and then chooses output levels in the second stage. The outcome of product R&D is uncertain. In the outer problem, the policymaker seeks to identify the combination of technology-push and demand-pull policy interventions that induces the firms to reach a Nash equilibrium with the highest expected social welfare. This framework goes beyond previous studies of strategic innovation in oligopoly settings in that it explicitly incorporates uncertainty and includes a leader-follower interaction between the policymaker and the private sector. It is relatively compact but captures three critical market failures: incomplete appropriability of R&D, a negative production externality, and imperfect competition. To assess the implications of the model for technology policy, two sets of numerical simulations are conducted. The first set is used to investigate how the optimal policy intervention depends on the primary motivation for innovating, with examples drawn from the energy supply and demand sectors. The second set is used to explore how key outcomes and policy recommendations vary with the relative strengths of the three aforementioned market failures.

Methods

The model employs concepts from optimization, game theory, microeconomics, industrial organization, and stochastic programming.

Results

Findings reveal that the optimal combination of technology-push and demand-pull policies, as well as the ease of enhancing welfare through technology policy, vary depending on whether the primary motivation for innovating is to address a negative externality, reduce cost, or create demand. Stronger spillovers reduce product R&D expenditures but lead to higher welfare because they make each dollar of R&D more effective. Greater competition causes each firm to invest less in product R&D, but total industry R&D actually rises because this effect is more than offset by the presence of more firms in the market. While welfare decreases with competition in the absence of technology policy, welfare increases with competition if optimal technology policies can be imposed.

Conclusions

According to traditional reasoning, spillovers and competition are viewed as market failures that lead to suboptimal innovation effort. The results of this study point to a more nuanced conception. Even though stronger spillovers and greater competition reduce per-firm product R&D expenditure, they often enhance welfare by making each dollar of R&D more effective and increasing the number of firms attempting to innovate, respectively. In addition to elucidating the potential benefits of spillovers and competition, the findings suggest how the proper balance of technology-push and demand-pull policies depends on the motivation for innovating. Although the numerical simulations are parameterized in a stylized fashion, they demonstrate a highly general methodology for evaluating technology policy interventions in the energy industry as well as others.