Research Policy 47 (2018) 390–398

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Welfare improvement windows for innovation policy

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ARTICLE INFO

Keywords:
Innovation policy
R&D rivalry
Industrial organization
Competition
Subsidies
Spillovers

ABSTRACT

The question this article addresses is, how far from its optimal level can an innovation policy be implemented at, yet still improve social welfare relative to the laissez-faire outcome? The concern for policymakers is that even an intervention which enhances welfare if set at its optimal magnitude might actually make matters worse if implemented to the wrong degree. Understanding the performance of suboptimal policy levels is practically important, since the complexity and uncertainty of innovation make optimal policy magnitudes elusive in the real world. The model developed herein to investigate this issue is an R&D rivalry game where firms invest in R&D, then engage in Cournot competition. A policymaker seeks to improve welfare by choosing the levels of an R&D subsidy and consumer price subsidy. Results show that the *welfare improvement window*, defined as the set of all policy levels that improve social welfare, can be worryingly narrow. However, certain features of an innovation process and market lead to wider welfare improvement windows, such as stronger spillovers and moderately costly R&D. Policymakers stand a better chance of improving social welfare by intervening where these features are present.

1. Introduction

Based on widely recognized innovation market failures, previous studies have derived optimal innovation policy interventions within a diverse array of modeling frameworks. While this research has contributed significantly to our theoretical understanding of innovation policy, optimal interventions are elusive in the real world. Innovation processes are remarkably complex and subject to high degrees of parametric and structural uncertainty. In consequence, any model of innovation is inherently stylized and yields policy recommendations whose likelihood of being optimal in the real world is essentially zero.

The fundamental question this article addresses is, how far from its optimal level can an innovation policy be implemented at, yet still improve social welfare relative to the laissez-faire outcome? The concern for policymakers is that even an intervention which enhances welfare if set at its optimal magnitude might actually make matters worse if implemented to the wrong degree. The model developed herein to investigate this issue is an R&D rivalry game where firms invest in R&D, then engage in Cournot competition. A policymaker seeks to improve welfare by choosing the levels of an R&D subsidy and consumer price subsidy. The set of all policy levels that enhance social welfare constitutes the *welfare improvement window*. Interventions that fall within this window yield net social benefits, while policy levels outside the window make society worse off than doing nothing at all. How wide is the welfare improvement window, and what features of an innovation process and market does its size most critically depend on?

To summarize findings, the welfare improvement window can be worryingly narrow, confirming the difficulty of enhancing welfare through innovation policy. However, certain features of an innovation process and market lead to wider welfare improvement windows, such as stronger spillovers and moderately costly R&D. Policymakers stand a better chance of raising social welfare by intervening in contexts where these features are present.

The remainder of this article is organized as follows. Section 2 contains a literature review that outlines the economic rationale for innovation policy and discusses modeling frameworks developed to investigate R&D in the past. Section 3 describes the model constructed for this study. Section 4 presents numerical simulation results, with a focus on the welfare improvement window and the key determinants of its size. Section 5 concludes the article with a summary of its most salient findings and policy implications.

2. Literature review

2.1. Economic rationale for innovation policy

Innovation is affected by numerous market failures, some of which lead to underinvestment in R&D, and some of which lead to overinvestment. The consensus view, however, is that markets engage in too little innovative activity, and that intellectual property protection or

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https://doi.org/10.1016/j.respol.2017.12.009
Received 19 July 2016; Received in revised form 16 October 2017; Accepted 20 December 2017

R&D subsidies are warranted to further incentivize innovation (Jones and Williams, 1998).

The market failure most commonly invoked as an economic rationale for innovation policy is that innovators cannot fully appropriate the benefits of their innovative efforts. Some benefits spill over to other firms, and other benefits are captured by consumers. As a result, the market left to its own devices undertakes too little innovation relative to the social optimum. Empirical research has confirmed the existence of R&D spillovers (Bernstein and Nadiri, 1988; Jaffe, 1986) and estimated the gap that they induce between private and social rates of return to R&D (Bernstein and Nadiri, 1988; Mansfield et al., 1977).

If the products of innovation are rival but non-excludable, then governments can intervene by assigning intellectual property rights (Lundvall and Borras, 2005). But, as Arrow (1962) argues, it is virtually impossible to make innovation completely appropriable, since legally imposed property rights create only a partial barrier to the diffusion of information. Furthermore, while intellectual property rights can stimulate innovation, they restrict the dissemination of its benefits below the optimal level and introduce market power into the post-innovation product market. If the products of innovation are non-rival and non-excludable (e.g., knowledge), then governments can subsidize innovation or conduct innovation themselves (Lundvall and Borras, 2005). The present analysis focuses on subsidies as a form of policy intervention.

In addition to knowledge being a public good, innovation involves several other market failures that can merit policy intervention. R&D investment is a risky endeavor with highly uncertain outcomes (Arrow, 1962). It is unlikely that an insurance market could develop to protect against this risk due to moral hazard, as it would be difficult or impossible for an external observer to assess whether an R&D project fails because of the nature of the problem or because of poor performance by the researchers. Innovation often requires large fixed costs to establish a research program, a problem that Arrow (1962) refers to as indivisibility. When fixed costs are large, marginal cost pricing for the product would imply that the overall project is unprofitable for the innovator. In technological domains like energy, where negative externalities (e.g., air pollution, climate change) are commonly unpriced, R&D is sometimes promoted as a means of ameliorating the externality problem (Bosetti et al., 2009; Nemet and Kammen, 2007).[1]

While the market failures reviewed above lead firms to undertake too little R&D, innovation investment can also be too high. For example, when multiple firms race to obtain a patent, they do not account for the reduction in their rivals' marginal benefits due to their own innovation. The result is excessive duplication of R&D effort (Reinganum, 1989). In the context of R&D-based growth models with vertical innovation, each new innovation destroys the monopoly rents of the previous innovator, and there can be excessive creative destruction (Verspagen, 2005). In the presence of such negative externalities, taxes that reduce R&D spending can be justified.

2.2. Non-tournament R&D rivalry games

The model developed for this study belongs to the class of non-tournament R&D rivalry games that has been analyzed in the industrial organization literature. The non-tournament distinction indicates that multiple firms can earn rewards for successfully innovating, in contrast to the winner-take-all assumption of tournament games including patent races. Non-tournament R&D rivalry games typically represent an oligopoly where firms compete in two stages. They choose R&D investment levels in the first stage, then compete in the product market by selecting production levels in the second stage. These models have often been applied to investigate the relationship between competition and innovation, and to study the effects of spillovers. The brief review here focuses on how these models have represented features which the present analysis also incorporates, such as process and product R&D,[2] competition, spillovers, uncertainty, and policy intervention.

In their pioneering study, Dasgupta and Stiglitz (1980a) analyzed an oligopoly where firms invest in process R&D. Their findings provided theoretical support for the inverted-U hypothesis. While a monopolist generally has insufficient incentives to innovate, R&D expenditure declines with competition at high levels of rivalry.[3] Levin and Reiss (1988) extended the Dasgupta and Stiglitz (1980a) framework by incorporating product R&D in addition to process R&D, and by including R&D spillovers. They demonstrated analytically that process and product R&D may be complements or substitutes depending on the parameter values, particularly the relative magnitudes of spillovers. D'Aspremont and Jacquemin (1988) restricted their analysis to a duopoly with process R&D and spillovers, but advanced the literature by comparing social welfare in three cases: a fully cooperative case, a fully non-cooperative case, and a hybrid case in which firms cooperate in the R&D stage but not in the product market stage. The authors showed that social welfare can be enhanced by allowing firms to engage in cooperative research where they share the costs and results of a research project. Suzumura (1992) conducted a similar welfare analysis to that of D'Aspremont and Jacquemin (1988), but generalized the model to an oligopoly and considered a wider variety of welfare specifications. His findings demonstrated that strong spillovers lead to insufficient innovation in both the cooperative and non-cooperative equilibria. Several other studies explored the differences between Bertrand and Cournot oligopolies with R&D (Lin and Saggi, 2002; Qiu, 1997; Symeonidis, 2003).

Policy intervention and uncertainty have been incorporated into past studies of non-tournament R&D rivalry, but to a limited extent. Leahy and Neary (1997) explicitly analyzed optimal policy interventions in an oligopoly with process R&D. They considered the first-best intervention featuring both R&D and product subsidies, as well as the second-best intervention featuring only an R&D subsidy. They determined that strategic firm behavior justifies higher subsidies unless R&D spillovers are weak and firms' actions are strategic substitutes. Tishler and Milstein (2009) added uncertainty to a Cournot oligopoly model with both process and product R&D by treating R&D outcomes as random variables. They found a U-shaped relationship between competition and innovation based on two competing forces: a strategic effect that increases R&D effort with competition and a demand reduction effect (due to competition among substitute products) that decreases R&D effort with competition. The implication is that firms may spend excessively on R&D to escape competition when rivalry is intense. After much research on the topic, the relationship between competition and innovation remains subject to intense debate.

While the model developed herein belongs to the class of non-tournament R&D rivalry games, it is worth briefly discussing tournament R&D rivalry games and R&D-based growth models to the extent that these other classes have incorporated uncertainty and policy interventions.

2.3. Tournament R&D rivalry games

In tournament R&D rivalry games, competing firms allocate resources to R&D in pursuit of some reward conferred on the first firm to succeed. The reward is often interpreted as the monopoly rents earned

[1] Pigouvian taxes would be the most logical policy response, and the R&D approach can introduce a host of other distortions.

[2] The literature draws a distinction between process and product R&D. Process R&D makes existing production processes more efficient and reduces production costs. Product R&D intends to develop new products that are fundamentally different from anything which existed previously, and which offer new benefits (Chandy and Tellis, 2000; Scherer, 1982).

[3] Kamien and Schwartz (1976) suggested the theoretical possibility of an inverted-U-shaped relationship between competition and innovation. Aghion et al. (2005) provided some empirical evidence.