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The role of pest resistance in biotechnology R&D investment strategy

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Abstract

The biotechnology industry has become highly concentrated due to two factors: large research and development (R&D) investments in biotechnology, and an intense period of mergers and acquisitions during the late 1990s and beyond. In this paper we explore the link between R&D and market concentration in the biotechnology sector. In this sector the potential development of resistance by insects to pest control biotechnology has to be accounted for. The central question is whether the pest resistance effect reinforces or weakens the link between R&D investments and concentration. To address this, we develop a standard game-theoretic model of strategic innovation between an incumbent and a potential entrant but introduce a risk of pests developing resistance. Firms are thus faced with two types of threat to their innovation—from rivals within the market 'competitive threat' and from pests 'pest threat'. To combat these threats they make two types of R&D investment 'competitive R&D' and 'pest R&D'. We show that the incumbent is likely to invest less (more) in competitive R&D than the entrant when innovation is *drastic* (*non-drastic*). We find that introducing the pest effect has different impacts on relative incentives depending on whether we allow firms to react to the threat of pest resistance or not. In addition, we show that accounting for the ability of pests to develop resistance to technologies increases industry concentration.

JEL classification: Q16; L1; C72

Keywords: Resistance; R&D; Strategic interaction; Innovation

1. Introduction

This paper seeks to test whether there is a possible theoretical link between two features of the biotechnology industry: the increasing concentration of the biotechnology industry; and the problem of pest resistance and strategies of firms to deal with such resistance.

Evidence of increasing concentration in the plant biotechnology sector is provided in the literature [4,10,15,21]. Firms have sought to horizontally and vertically integrate as a response to the changing market environment in which they operate. For instance, horizontal integration has occurred as firms seek to pool

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research and development (R&D) resources to exploit economies of scale and scope, increase the rate of innovation and reduce the unit cost of acquiring regulatory approval [10]. Vertical integration has occurred in response to the increasing relative importance of distribution and marketing channels to deliver the technology as it becomes commercialised.[1] In addition to the market environment influencing the R&D strategies of these firms, a smaller number of firms are determining the direction and rate of innovation [4,9]. An increasingly important part of these firms' investment portfolios is expenditure on extending the life of their technology, specifically through strategies aimed at delaying the development of pest resistance to the technology [2]. The substantial R&D and regulatory costs involved in bringing an innovation to the market limit the possibility of having a range of 'back-up' technologies should the current one fail. Many firms have collaborations with entomologists researching the dynamics of pest resistance. For example, Monsanto has extensive projects with scientists studying resistance in cotton pests [2]. In general, spending on the management of resistance by firms is substantial and rising [25].

Previous work on resistance within an industrial organisation framework has focused on how market structure affects the development of resistance, noting that, because monopolists suboptimally supply the market and resistance is positively related to the use of technology, the development of resistance will be slower than if the market is supplied competitively [2,5,12,19].[2]

Our paper takes a different stance: we address the implications of pest resistance for investment in R&D and how this in turn affects market structure.[3] To think about this, consider the simplest case where there is a single (monopolistic) firm deciding how much to invest in a new technology, given that both it and its existing technology are subject to a given, exogenous, risk of pest resistance. It is straightforward to see that in such a situation, the effects of pest resistance on investment in R&D are ambiguous. By reducing the returns to future technology, pest resistance reduces the incentive to innovate. By reducing the returns to existing technology, it increases the incentive to innovate. Which effect dominates depends on how profitable the current technology is. In this paper, we go beyond this simple analysis in two respects. First we allow for firms to affect the risk of pest resistance by their choice of R&D. Second, we conduct our analysis in a context where there are strategic interactions between firms in both the product market and R&D. These strategic interactions affect market structure. Using a conventional model of strategic R&D between an incumbent and an entrant, introducing pest resistance and the possibility of using R&D to reduce pest resistance, we study both absolute and relative incentives to invest in R&D. As in the simple monopoly story, pest resistance reduces the returns to current and new technologies. However, it is not immediately clear whether it scales down all profits equally and hence, relative incentives remain unchanged, or whether there is a differential impact on incentives and hence, on market structure.

In the following we distinguish between two categories of R&D investment. A firm faces two threats to the survival of its technology—from its rival and from pests. In response, it invests in R&D to stay ahead of its rival, which we will refer to as 'competitive R&D', and it also invests in R&D to combat pest resistance, which we will refer to as 'pest R&D'. There are two possible outcomes of competitive R&D. The first is *drastic innovation*, where the new technology is so efficient it wipes out the incumbent's existing technology. The second is *non-drastic*, where the new and old technologies can co-exist in the market.

We show that the incumbent is likely to invest less (more) in competitive R&D than the entrant when innovation is *drastic* (*non-drastic*). We find that introducing the pest effect has an opposing (reinforcing) impact on the gap between the competitive R&D of the incumbent and entrant, depending on whether or not

[1]Perhaps the firm that best exemplifies the vertical integration strategy is Monsanto, which has aggressively invested in its technology base, as well as acquiring many seed companies. In 1998 alone, Monsanto acquired DEKALB Genetics Corp., Cargill's international seed business and Plant Breeding International Cambridge Ltd. [6]. As a result, Monsanto is generally regarded to be at the forefront of developments in the new technology [6,14,24]. Novartis, Zeneca, DuPont, Dow AgroSciences and AgrEvo have all been involved in similar efforts, albeit on a reduced scale relative to Monsanto [13].

[2]Although Goeschl and Swanson's [12] paper does include an R&D sector, the factor driving resistance in pests is the deployment of the technology.

[3]Two referees suggested that it would be useful to provide actual examples of technologies we have in mind. A short note on the nature of resistance and the technologies designed to combat it is available through JEEM's online archive of supplementary material, which can be accessed at http://www.aere.org/journal/index.html.