Bias in Market R&D Portfolios

by

Luís cabral*

Faculty of Economics

New University of Lisbon("Nova")

July 1992

Working Paper nº 188

Abstract

Based on a simple "contest" model of product innovation, we provide a necessary and sufficient condition for the market to be biased against risky R&D projects. We find that, in accordance with conventional wisdom and contrary to much of the previous theoretical literature, market competition implies an equilibrium level of risk which is too low from society's standpoint. The intuition for the result in terms of the "business stealing" effect is provide. Key words: R&D competition; oligopoly. J.E.L. Classification Numbers: L13, O31.

* Financial support was provided by a grant from Pfizer Pharmaceuticals to the Center for Economic Policy Research, Stanford University. I am grateful to Lanny Arvan, Ching-to Albert Ma, Michael Riordan, Pankaj Tandon, and seminar participants at the University of Illinois, Urbana-Champaign, and Boston University for useful comments and suggestions. The usual disclaimers apply.

1 Introduction

Most of the economics literature on Research and Development (R&D) has focused on the total amount spent on R&D, regardless of its composition.¹ However, under the heading of "R&D expenditures" a variety of quite heterogeneous components is comprised: basic research, applied research, and development; process innovations and product innovations; improvements to existing products and discovery of new products; short-term and long-term projects. To quote from Mansfield (1981): "Economists must recognize that, for many purposes, the composition of R&D expenditures may be as important as their total size." (p. 614)

As an exception to the main trend in the literature, a series of recent papers have looked at the issue of allocating R&D resources across projects with different degrees of risk. This includes Klette and deMeza (1986), Bhattacharya and Mookherjee (1986), and Dasgupta and Maskin (1987).² In the models presented in these papers, firms are engaged in a "winner-takes-all" patent race. A project consist of a probability distribution over discovery dates. A riskier project is one with higher probability of very early and very late discovery dates. The main conclusion is that the market is generally biased in favor of relatively more risky R&D projects. The idea is that the private marginal benefit of an increase in risk exceeds the social marginal benefit. From the firm's point of view, expected payoff improves with an increase in risk because the expected date of the first discovery decreases and the probability of being the first to discover increases. However, from society's point of view only the first component matters.

In many industries, however, competition is quite different from the "winner-takes-all" game assumed in the papers cited above. A prominent example is that of the pharmaceutical industry. The process of getting a new drug into the market consists essentially of two stages: first, to discover and to patent the new drug; and second, to get it approved for marketing by the regulatory agency (in the U.S., the Food and Drug Administration, FDA). Given the relatively narrow scope of protection offered by drug patents and the approval system, it often happens that several companies holding different patents have to compete in the product market.³ The issue of timing is thus

¹ See, for example, the survey papers by Reinganum (1989) and Cohen and Levin (1989).

² There is also an empirical literature focusing on the composition of R&D expenditures. Mansfield (1981) finds that larger firms seem to carry out a disproportionately larger share of the basic research, but that the same is not true for risky R&D or R&D aimed at entirely new products and processes. Link (1985) estimates that an aggressive strategy and the existence of a centralized R&D lab have a positive effect on the share of basic and long-term research. Furthermore, he finds that producer goods industries tend to allocate relatively more funds to process innovations rather than product innovations. See also Link (1982), Scott and Pascoe (1987).

³ For example, *Genentech*, *Beecham*, *Wellcome* and *Hoechst* all hold patents for anti-

relatively secondary. In fact, it is not uncommon that a drug with a later patent is the first to be approved for marketing.

As an attempt to address this issue, Bagwell and Staiger (1990) consider a (timeless) duopoly model in which firms choose risky investments which determine their cost or quality level and then compete in prices. They show that a given firm's profit is a convex function of its cost or quality level as well as its rival's cost or quality level. In addition, they show that consumer surplus is also a convex function of the firms' cost or quality level. As a result, there are two positive externalities to risk-increasing R&D investment, which implies that the equilibrium level of risk is lower than the socially optimum level of risk.

The focus of this paper is similar to that of Bagwell and Staiger (1990). We also consider a timeless model of innovation (what Reinganum, 1989, calls a "contest" model) and ask the question of whether there is a bias in favor or against risk in the choice of R&D projects. There are however two important departures from the analysis of Bagwell and Staiger (1990). First, our results are presented in terms of a necessary and sufficient condition which characterizes the nature of competition in the product market. Second, the model is constructed in such a way that a monopolist would choose the socially optimal degree of risk. Therefore, any bias found in the equilibrium oligopoly solution can be wholly attributed to the effect of competition.

We find that, for a variety of assumptions regarding product market competition, the market is biased against risky R&D projects. As we shall see, the intuition for this result can be given in terms of the so-called "business stealing" effect.

2 Basic model

Since the main focus of the paper is on the composition of R&D portfolios, we will assume throughout that each firm has a fixed R&D budget, which we normalize to be equal to one. We will consider each firm's decision of allocating its R&D budget between two different product-innovation projects (in two different markets), and denote by x the amount allocated to the first project ($1 - x$ is thus allocated to the second project). By investing x in the first project, a firm has a probability $f(x)$ of discovering a new product in the first market. Its payoff, conditional on successful innovation, depends on the number of innovations in the same market and is given by p_k , where k is the number of firms with successful innovations in that market ($k = 1, 2$). The second project is a mean-preserving spread of the first one. The probability

heart-attack medicines. According to *The Economist* (October 15, 1988, p. 89), "nobody really knows yet which drug does the job best." The most likely outcome is that all firms will share the market.

of successful innovation is given by $f(1-x)/\gamma$ and payoffs (conditional on successful innovation) are given by γp_k , $\gamma > 1$. Therefore, given probability of success by the rival, the expected value of the two projects is equal, while the variance is greater for the second one. The model of R&D competition consists of two firms simultaneously choosing values x_i to allocate to the first project ($i = 1, 2$).

We are especially concerned with the impact of competition on the equilibrium composition of R&D portfolios. Therefore, it is useful to make the assumption that there is a constant proportion between profits and social surplus across projects. Accordingly, we assume that social surplus is given by s_k in the first market and γs_k in the second one. In fact, as we shall see, this implies that the monopoly and the social optimum values of x are equal, i.e., $x^M = x^*$.⁴ It would be easy to find reasons why the private optimum does not coincide with the social optimum value of x . For example, the first project might be research leading to an "orphan drug," i.e., a drug for which the proportion between consumer's and producer's surplus is very large. Assuming a constant proportion between profits and social surplus implies that, when we consider competition between two different firms, any divergence between x^* and the equilibrium value of x is attributable to distortions implied by R&D rivalry.

Although we make no explicit assumptions regarding the model which generates the values of p_k and s_k , our results will be given with reference to a parameter which relates the different values of p_k and s_k . Define

$$\rho \equiv \frac{1 + p_2/p_1}{s_2/s_1} \quad (1)$$

Furthermore, let Π_i be expected profits for firm i and S expected surplus. Our main result is the following.

Proposition 1 *At an interior symmetric equilibrium with both firms choosing $x = \hat{x}$, $\partial S/\partial x < 0$ iff $\rho > 1$.*

In words, Proposition 1 implies that, starting from any symmetric equilibrium solution and assuming that $\rho > 1$ (resp. $\rho < 1$), a small increase in x (a decrease in the riskiness of the portfolio) leads to a decrease (resp. increase) in social surplus. Therefore, if $\rho > 1$ (resp. $\rho < 1$), then the market is biased against (resp. in favor of) the riskier R&D project.

Proof of Proposition 1: Firm i 's expected profit is given by

$$\Pi_i(x_i, x_j) = f(x_i) [(1 - f(x_j))p_1 + f(x_j)p_2] +$$

⁴The private and the social optima need not be symmetric; in the case of an asymmetric solution, x^M and x^* should be interpreted as vectors.

$$\begin{aligned}
& +f(1-x_i)/\gamma [(1-f(1-x_j)/\gamma)\gamma p_1 + (f(1-x_j)/\gamma)\gamma p_2] \\
& = f(x_i) [(1-f(x_j))p_1 + f(x_j)p_2] + \\
& +f(1-x_i) [(1-f(1-x_j)/\gamma)p_1 + (f(1-x_j)/\gamma)p_2]. \quad (2)
\end{aligned}$$

Define $h(x_i) \equiv f'(x_i)/f'(1-x_i)$, where $f'(x) \equiv \partial f(x)/\partial x$. The first order condition for $\max \Pi_i$ can then be written as

$$h(x_i) = \frac{p_1 - (p_1 - p_2)f(1-x_j)/\gamma}{p_1 - (p_1 - p_2)f(x_j)}. \quad (3)$$

Specifically, at a symmetric equilibrium, we have

$$h(\hat{x}) = \frac{p_1 - (p_1 - p_2)f(1-\hat{x})/\gamma}{p_1 - (p_1 - p_2)f(\hat{x})}. \quad (4)$$

Let us now look at social surplus. In expected value, and imposing the constraint $x_i = x_j$, it is given by

$$\begin{aligned}
S(x) &= 2s_1f(x)(1-f(x)) + s_2f(x)^2 \\
&+ 2\gamma s_1f(1-x)/\gamma (1-f(1-x)/\gamma) + \gamma s_2f(1-x)^2/\gamma^2 \\
&= f(x)(2s_1(1-f(x)) + s_2f(x)) + \\
&+ f(1-x)(2s_1(1-f(1-x)/\gamma) + s_2f(1-x)/\gamma). \quad (5)
\end{aligned}$$

Upon some algebraic manipulation, we get that

$$\frac{\partial S}{\partial x} = \alpha \left(h(x) - \frac{s_1 - (2s_1 - s_2)f(1-x)/\gamma}{s_1 - (2s_1 - s_2)f(x)} \right), \quad (6)$$

where $\alpha \equiv f'(1-x)(s_1 - (2s_1 - s_2)f(x))$ is a positive factor.

Therefore, $\partial S/\partial x < 0$ if and only if the term inside brackets in (6) is negative. At the symmetric equilibrium level of x , $h(x)$ is given by (4). Therefore, the condition for $\partial S/\partial x < 0$ at $x = \hat{x}$ becomes

$$\frac{p_1 - (p_1 - p_2)f(1-\hat{x})/\gamma}{p_1 - (p_1 - p_2)f(\hat{x})} < \frac{s_1 - (2s_1 - s_2)f(1-\hat{x})/\gamma}{s_1 - (2s_1 - s_2)f(\hat{x})}, \quad (7)$$

which can be simplified to yield

$$[f(\hat{x}) - f(1-\hat{x})/\gamma][p_1(2s_1 - s_2) - s_1(p_1 - p_2)] > 0. \quad (8)$$

Now, from (2) we can conclude that, in equilibrium, $f(\hat{x}) > f(1-\hat{x})/\gamma$, that is, the probability of discovery is bigger in the low-risk project. In fact, if that were not the case, then firm i could increase its profits by choosing $x_i = 1 - x_i$. Therefore, the condition for $\partial S/\partial x < 0$ at $x = \hat{x}$ becomes

$$p_1(2s_1 - s_2) - s_1(p_1 - p_2) > 0, \quad (9)$$

which can be shown to be equivalent to $\rho > 1$. ■

The intuition for the result can be understood with reference to what Mankiw and Whinston (1986) designate as "the business stealing" effect.⁵ In fact, the marginal benefit of investing in a given R&D project is in part derived from a transfer of profits from the rival firm. Now, usually this business-stealing effect is considered to be the reason for distortions in the rate of R&D (cf Loury, 1979). Proposition 1 states that business stealing also implies distortions in the *composition* of R&D.

To see this, consider Figure 1, which plots the private and the social marginal benefit from R&D investment in a given project as a function of the rival's probability of discovery in that project (θ).⁶ The marginal benefit curves are drawn consistently with the assumption that $\rho > 1$. Therefore, we will provide the intuition for the market solution to be biased against the riskier R&D project. There are two things to notice in the figure. First, the private marginal benefit is greater than the social marginal benefit. This is the reason why the equilibrium rate of R&D would likely be greater than the social optimum rate.⁷ Second, and most important, the social marginal benefit falls to zero more rapidly than the private marginal benefit.

Now take two different projects with two different values of θ , θ_1 and θ_2 . Although the private marginal benefit exceeds the social marginal benefit in both cases, the distortion is greater for the project with a probability of success closer to one (c/d is greater than a/b). Finally, this explains why the privately optimal R&D portfolio would put too much weight on the project with a greater probability of success, the less risky project ($c/d > a/b$ implies $c/a > d/b$).

■ **Factors determining the value of ρ .** As we mentioned before, our results require no specific assumptions about the model of market competition. Instead, the results are presented in terms of the value of ρ . We will now argue that the crucial condition $\rho > 1$ corresponds roughly to Mankiw and Whinston's (1986) assumption that there is business stealing between rival firms in the product market. To do so, we consider several possible models of product market competition.

⁵In fact, as we shall see, the condition $\rho > 1$ corresponds approximately to their assumption that entry implies business stealing. Notice that although Mankiw and Whinston (1986) model entry, not R&D competition, our model can also be thought of as a model of contingent entry into a new market.

⁶For simplicity, the figure is drawn under the assumption that γ is close to one; otherwise, we would have to consider different marginal benefit functions for each project. In addition, the curves are drawn as linear and parallel, which however needs not be the case.

⁷This first fact does not necessarily follow from our model. It would be consistent with Loury's (1979) or Mankiw and Whinston's (1986) framework, for example. The only reason for mentioning it here is to contrast the effect of business stealing on the *rate* and on the *composition* of R&D.

Figure 1: Private (Π') and social (S') marginal benefit from investing in R&D as a function of the rival's probability of success.

1. To begin, consider the case when the products discovered by each firm are independent. In this case, we have $p_1 = p_2$ and $s_2 = 2s_1$, which yields $\rho = 1$.
2. Now suppose products are perfect substitutes. It can be shown that the collusive, the Cournot, and the Bertrand solutions imply $\rho = 1.5$, $\rho = 39/32$, and $\rho = .75$, respectively.
3. A stylized model of the new drug approval process in the U.S. is that when two drugs with the same therapeutic use apply for FDA approval, only one of them is approved in a "reasonable" length of time.⁸ In the case of an extremely "strong" approval regime, only one of the two drugs is approved, each with probability 50%. The value of ρ is then 1.5.
4. Finally, we should consider the possibility of some kind of non-price competition when evaluating the values of p_k and s_k . Many authors argue that much of the advertising and promotion budget in pharmaceutical firms takes the form of rent-seeking activities.⁹ In the extreme

⁸For example, Wellcome's AZT, an AIDS drug, was approved in a record four months after submission. However, other applications for similar drugs were not given the same priority (cf *The Economist*, January 30, 1988).

⁹According to *The Economist* (January 27, 1990, p. 75), Glaxo's Zantac, an anti-ulcer drug, "was only a slight improvement on Tagamet, an earlier hit drug from Smith-Kline Beckman." However, by means of an expensive advertising campaign, sales of Zantac

Table 1: Values of ρ under different models of product market competition.

	Assumption	ρ
1	Independent products	1.00
2	Homogeneous product	
	Collusion	1.50
	Cournot	1.22
	Bertrand	0.75
3	"Strong" approval system	1.50
4	Rent-seeking	3.00

case when monopoly profits are competed away by means of (socially wasteful) rent-seeking activities, we get a value of ρ equal to 3.

The different possible values of ρ (listed in Table 1) illustrate the idea that the condition $\rho > 1$ corresponds to the assumption that investment in R&D implies business stealing from the rival firm in the product market.

3 Extensions

In this section, we consider two possible extensions of the basic model, one allowing for different types of equilibria and another one changing the structure of the model itself.

■ The first extension considers the possibility of asymmetric equilibrium solutions. Let $\bar{x}$ and $\underline{x}$ ($\bar{x} > \underline{x}$) be the equilibrium values of x .

Proposition 2 *At an interior equilibrium $(\bar{x}, \underline{x})$, $\partial S / \partial \underline{x} < 0$ iff $\rho > 1$.*

Proof: The proof proceeds in a way very similar to that of Proposition 1. From the low- x firm's first-order condition, we get

$$h(\underline{x}) = \frac{p_1 - (p_1 - p_2)f(1 - \bar{x})/\gamma}{p_1 - (p_1 - p_2)f(\bar{x})}. \quad (10)$$

Writing social surplus as a function of $\underline{x}, \bar{x}$, taking the derivative with respect to the first argument, and simplifying, yields

$$\frac{\partial S}{\partial \underline{x}} = \alpha \left(h(\underline{x}) - \frac{s_1 - (2s_1 - s_2)f(1 - \bar{x})/\gamma}{s_1 - (2s_1 - s_2)f(\bar{x})} \right), \quad (11)$$

where $\alpha \equiv f'(1 - x)(s_1 - (2s_1 - s_2)f(\bar{x}))$ is a positive factor.

reached \$2.4 billion in 1989, while Tagamet's sales were only \$1 billion.

The proof now proceeds in the same way as that of Proposition 1. Notice that the argument for $f(\hat{x}) > f(1 - \hat{x})/\gamma$ can be extended to $\underline{x}$ in the case of an asymmetric solution, but not to $\bar{x}$ —hence Proposition 2 only applies to $\underline{x}$. ■

■ The second extension we consider consists of changing the structure of the model itself. So far, we have assumed the two projects available to each firm to be independent (apart from the fact they draw from a common budget). However, it is often the case that firms have to choose among alternative projects leading to similar ends. For example, having the pharmaceutical industry in mind, Grabowski and Vernon (1987) consider two qualitatively different types of R&D, “pioneering” and “imitative” R&D. In terms of our model, we may consider the low- and the high-risk projects as projects leading to small and to large product improvements, respectively (or “development” and “research” projects, respectively). Formally, the change to be introduced consists of the assumption that if some large improvement is achieved, then the payoff to any small improvement is zero (regardless of the firm who obtained such improvement). The following result is then obtained.

Proposition 3 *Consider the modified basic model presented above. If γ is sufficiently large, then, at an interior symmetric equilibrium with both firms choosing $x = \hat{x}$, $\partial S/\partial x < 0$ iff $\rho > 1$.*

Proof: Firm i 's expected profit is given by

$$\begin{aligned}\Pi_i(x_i, x_j) &= (1 - f(1 - x_i)/\gamma)(1 - f(1 - x_j)/\gamma) \cdot \\ &\quad \cdot f(x_i) [(1 - f(x_j))p_1 + f(x_j)p_2] + \\ &\quad + f(1 - x_i)/\gamma [(1 - f(1 - x_j)/\gamma)\gamma p_1 + (f(1 - x_j)/\gamma)\gamma p_2] \\ &= (1 - f(1 - x_i)/\gamma)(1 - f(1 - x_j)/\gamma) \cdot \\ &\quad \cdot f(x_i) [(1 - f(x_j))p_1 + f(x_j)p_2] + \\ &\quad + f(1 - x_i) [(1 - f(1 - x_j)/\gamma)p_1 + f(1 - x_j)/\gamma] p_2. \quad (12)\end{aligned}$$

Solving the first-order conditions and imposing the symmetry condition $x_i = x_j = \hat{x}$, one gets

$$\begin{aligned}h(\hat{x}) &= \frac{p_1 - (p_1 - p_2)f(1 - \hat{x})/\gamma}{(1 - f(1 - \hat{x})/\gamma)^2 [p_1 - (p_1 - p_2)f(\hat{x})]} - \\ &\quad - \frac{(1 - f(1 - \hat{x})/\gamma)f(\hat{x}) [p_1 - (p_1 - p_2)f(1 - \hat{x})]/\gamma}{(1 - f(1 - \hat{x})/\gamma)^2 [p_1 - (p_1 - p_2)f(\hat{x})]}. \quad (13)\end{aligned}$$

Social welfare is given by

$$\begin{aligned}
S(x) &= (1 - f(1 - x)/\gamma)^2 [2s_1 f(x)(1 - f(x)) + s_2 f(x)^2] \\
&\quad + 2\gamma s_1 f(1 - x)/\gamma (1 - f(1 - x)/\gamma) + \gamma s_2 f(1 - x)^2/\gamma^2 \\
&= f(x)(2s_1(1 - f(x)) + s_2 f(x)) \\
&\quad f(1 - x)[2s_1(1 - f(1 - x)/\gamma) + s_2 f(1 - x)/\gamma]. \quad (14)
\end{aligned}$$

After some algebraic manipulation, we get that

$$\begin{aligned}
\frac{\partial S}{\partial x} &= \alpha \left(h(x) - \frac{s_1 - (2s_1 - s_2)f(1 - \hat{x})/\gamma}{(1 - f(1 - \hat{x})/\gamma)^2 [s_1 - (2s_1 - s_2)f(\hat{x})]} + \right. \\
&\quad \left. + \frac{(1 - f(1 - \hat{x})/\gamma)f(\hat{x})[s_1 - (2s_1 - s_2)f(1 - \hat{x})]/\gamma}{(1 - f(1 - \hat{x})/\gamma)^2 [s_1 - (2s_1 - s_2)f(\hat{x})]} \right), \quad (15)
\end{aligned}$$

where $\alpha \equiv f'(1 - x)(1 - f(1 - \hat{x})/\gamma)^2 [s_1 - (2s_1 - s_2)f(\hat{x})]$ is a positive factor.

For high values of γ , (15) is approximately equivalent to (6), and the proof proceeds in a way similar to that of Proposition 1. ■

4 Final remarks

The results in this paper suggest, contrary to most of the previous theoretical literature and in accordance with conventional wisdom, that competition may induce a bias against risk-taking in R&D. Policy measures which favor long-term, relatively more risky R&D projects, may therefore have a role to play.

In fact, going back to the case of the pharmaceutical industry, one may argue that this was precisely one the (few) merits of the 1962 U.S. drug amendments. In substance, the 1962 Kefauver Act requires proof of improved efficacy in addition to testing for toxicity, that is, increased stringency and delay times for FDA approval of new drugs. The facts are that, since 1962, there has been a drastic decrease in the number of New Chemical Entities (NCEs) introduced in the U.S. market despite the fact real R&D expenditures has steadily increased in the same period.¹⁰ Some authors claim that, although the total number of new drugs has decreased since 1962, the number of new drugs providing significant improvements in efficacy has not decreased. To quote from Simmons (1974): "the major change that has occurred ... is that the percentage of significant drugs approved has increased ... while the number of 'me-too' drugs, i.e. drugs similar to and with no advantage over those already available, has declined." (p. 102)¹¹ This is consistent with, although

¹⁰See, for example, Figure 1 in Thomas (1990).

¹¹This is by no means the only or the main interpretation. See Peltzman (1973) and Baily (1983) for the most popular views.

it does not imply, the interpretation that the 1962 amendments have improved the allocation of resources between "large improvement" and "small improvement" projects. In fact, one can show, based on Proposition 3, that by raising a uniform tax on all projects the equilibrium value of x decreases towards a socially better level, assuming that $p > 1$.¹²

There are several possible extensions of the model presented in this paper, besides the ones developed in Section 3. These include the case of an n -firm oligopoly; R&D portfolios comprising more than 2 projects; projects with a continuum of outcomes (as opposed to success/no success). We believe, however, that the intuition of the "relative business stealing" effect would extend to these cases as well.

¹²Obviously, this is not to say that raising a uniform tax is the best policy. In fact, the informal "improvement rule" currently used by the FDA is an example that better can be done. According to this rule, new drugs which are seen to imply greater improvements with respect to existing therapy tend to be approved in shorter periods of time. The FDA currently classifies drugs in four categories, AA, A, B and C, by decreasing order of importance. In the period 1985-88, the average approval lags were 12, 25, 29 and 36 months, respectively. (Personal communication from John Willeben, Pfizer Pharmaceuticals.)

References

- Bagwell, Kyle, and Robert W. Staiger (1990). "Risky R&D in Oligopolistic Product Markets," Discussion Paper No. 872 (CMSEMS, Northwestern University), January.
- Baily, Martin (1983), "Research and Development Costs and Returns: The U.S. Pharmaceutical Industry," *Managerial and Decision Economics* 4, 107-121.
- Bhattacharya, Sudipto, and Dilip Mookherjee (1986), "Portfolio Choice in Research and Development," *Rand Journal of Economics* 17, 594-605.
- Cohen, Wesley M., and Richard C. Levin (1989), "Empirical Studies of Innovation and Market Structure," in R. Schmalensee and R. D. Willig (Eds), *Handbook of Industrial Organization*, Amsterdam: North-Holland, 1059-1107.
- Dasgupta, Partha, and Eric Maskin (1987), "The Simple Economics of Research Portfolios," *Economic Journal* 97, 581-595.
- Dasgupta, Partha, and Joseph B. Stiglitz (1980). "Uncertainty, Industrial Structure, and the Speed of R&D," *Bell Journal of Economics* 11, 1-28.
- Grabowski, Henry and John Vernon (1987), "Pioneers, Imitators, and Generics: a Simulation Model of Schumpeterian Competition," *Quarterly Journal of Economics* 102, 491-525.
- Klette, Tor, and David de Meza (1986), "Is the Market Biased Against Risky R&D?," *Rand Journal of Economics* 17, 133-139.
- Link, Albert N. (1982), "An Analysis of the Composition fo R&D Spending," *Southern Economic Journal* 49, 342-349.
- Link, Albert N. (1985), "The Changing Composition of R&D," *Managerial and Decision Economics* 6, 125-128.
- Mankiw, N. Gregory, and Michael D. Whinston (1986), "Free Entry and Social Inefficiency," *Rand Journal of Economics* 17, 48-58.
- Mansfield, Edwin (1981), "Composition of R&D Expenditures: Relationship to Size of Firm, Concentration, and Innovative Output," *Review of Economics and Statistics* 63, 610-614.
- Peltzman, Sam (1973), "An Evaluation of Consumer Protection Legislation: The 1962 Drug Amendments," *Journal of Political Economy* 81, 1049-1091.

Reinganum, Jennifer F. (1989). "The Timing of Innovation: Research, Development, and Diffusion," in R. Schmalensee and R. D. Willig (Eds), *Handbook of Industrial Organization*, Amsterdam: North-Holland, 849-908.

Scott, John T., and George Pascoe (1987). "Purposive Diversification of R&D in Manufacturing," *Journal of Industrial Economics* 36, 193-205.

Simmons, Henry E. (1974). "The Drug Regulatory System of the United States Food and Drug Administration: A Defense of Current Requirements for Safety and Efficacy," *International Journal of Health Services* 4, 95-107.

Thomas, Lacy Glenn (1990). "Regulation and Firm Size: FDA Impacts on Innovation," *Rand Journal of Economics* 21, 497-517.