Ideias Fundadoras

Apresentação

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Edwin Mansfield faz parte do pequeno grupo de economistas neoclássicos americanos que se debruçaram sobre o estudo da inovação, seguindo a trilha aberta por J. Schumpeter. Nesse seleto grupo ele, sem dúvida, se destaca pela capacidade de desenvolver uma agenda de pesquisa sobre o processo de inovação, reunindo tanto aspectos conceituais e teóricos quanto instrumentais.

Desde muito cedo Mansfield se interessou pela economia da inovação. Contudo, sua contribuição à economia ultrapassa esse campo, já que ele é autor também de reconhecidos manuais de microeconomia, gestão e econometria. Seu trabalho no campo da economia da mudança técnica e da inovação se estendeu por um período de aproximadamente 40 anos. Sua obra nesse campo foi muito vasta e diversificada. Em um trabalho síntese que preparou no final de sua vida, ele reuniu nada menos do que 43 artigos que constituem suas principais contribuições ao campo (MANSFIELD, 1995).

Certamente ele foi um dos economistas da corrente neoclássica que deu uma das mais importantes contribuições à compreensão do processo de inovação. F. Scherer (2005) o considerava tão merecedor do Prêmio Nobel quanto R. Solow, contudo, atribui o seu não reconhecimento a um certo desconhecimento da sua produção científica, sobretudo de *papers*, sendo mais reconhecido por seus livros, o que o comitê do Nobel valorizava menos. Com efeito, ele publicou pelo menos quatro livros importantes no tema da economia da inovação (MANSFIELD, 1968, 1971, 1977, 1982). Ainda assim, Granstrand afirmou que, no campo da economia da tecnologia, Mansfield foi o autor mais citado em quatro dos anos que examinou (apud DIAMOND, 2003). Certamente ele teria merecido a premiação pela sua contribuição tanto no campo empírico quanto teórico da economia da inovação.

Apesar de pertencer à escola neoclássica, Mansfield foi se distanciando de sua família de origem por causa de seus métodos de pesquisa heterodoxos e pelas questões cada vez mais complexas que buscava desvendar. Essa evolução pode ser percebida pela sua trajetória intelectual. Inicialmente sua abordagem era essencialmente ditada pelos avanços obtidos por sua escola de origem, que, conforme relata Scherer (2005), tinha uma percepção muito abstrata do fenômeno da inovação.

As primeiras contribuições de Mansfield situaram-se no campo da teoria da difusão de inovações. A questão inicialmente colocada aos economistas era de medir o impacto causado pela inovação no sistema econômico. A difusão era justamente o processo de propagação do progresso técnico em que a inovação impactava a atividade econômica. O artigo mais citado em sua obra é o que trata da difusão tecnológica na indústria, publicado em 1961 (DIAMOND, 2003). As contribuições feitas por Mansfield enquadravam-se no contexto da visão hegemônica, que considerava a difusão um processo de reprodução mimética de uma tecnologia já desenvolvida. Todavia, o estudo teve o mérito tanto de formular um modelo matemático que foi testado empiricamente na indústria quanto de propor uma explicação às diferenças de taxa de difusão observadas entre tecnologias. A variável que explicava a maior taxa de adoção era a rentabilidade da nova tecnologia. Com isso, Mansfield tinha dado um salto no debate, ao passar de uma descrição meramente morfológica do fenômeno para uma modelização que incluía uma variável econômica na explicação do processo de difusão.

Entretanto, Mansfield sentiu certo desconforto com a forma como a teoria do *mainstream* tratava a inovação, devido à forma demasiadamente abstrata como a tecnologia e a mudança técnica eram abordadas pelos modelos que buscavam demonstrar qual seria a contribuição do progresso técnico para o desenvolvimento econômico. Segundo Mansfield, os estudos pioneiros realizados durante a década de 1950, que se apoiavam na abordagem econométrica da função agregada de produção, eram muito imprecisos em sua capacidade de descrever a relação entre tecnologia e economia. Esses modelos atribuíam qualquer mudança de produtividade, não explicada pelos demais insumos, à tecnologia. Não se lograva isolar nessa abordagem o que era progresso técnico de outros fenômenos como economias de escala, melhor *mix* de produtos, educação e saúde, entre outros (MANSFIELD, 1972).

É importante perceber o seu desencantamento com a abordagem convencional do fenômeno da inovação, que seria rotulada hoje de "externalista" e "linear", para compreender os motivos que o levaram a trilhar novos caminhos extremamente férteis. Segundo Mansfield, a teoria dominante não era capaz de captar a complexidade do fenômeno da inovação. Eventos como o *spillover* e o *fallout* da pesquisa pública para o setor privado não eram apreendidos, assim como a importância da pesquisa básica para o desenvolvimento econômico. A abordagem convencional não explicava as diferenças de esforços e de inovação entre empresas de diversos portes e os diferentes setores (MANSFIELD, 1972).

Em 1971, quando realizou sua palestra na NSF (National Science Foundation) sobre as contribuições da P&D para o crescimento econômico nos Estados Unidos, Mansfield definiu uma nova agenda de pesquisa, que buscava desvendar as ideias ainda simplórias e mecanicistas existentes até então sobre a inovação (MANSFIELD, 1972). Essa agenda estava dividida em três grandes blocos: a P&D; a mudança técnica; e o crescimento econômico e aumento de produtividade. Os temas dessa agenda continuam ainda muito contemporâneos. Pode-se afirmar que Mansfield tinha uma ideia muito clara da agenda de pesquisa no estudo da inovação e de sua relação com o dinamismo econômico, sendo que essa agenda o guiou em suas pesquisas ao longo de sua vida e da qual ele pouco se desviou. Uma comparação entre essa agenda e a síntese da sua obra mostra como Mansfield foi coerente com suas propostas iniciais de trabalho.

A inflexão que se desenhou em sua trajetória intelectual não foi sem consequências para a sua abordagem metodológica. A insatisfação com a forma abstrata e externalista dos modelos econométricos levou Mansfield a construir um novo método de pesquisa baseado no levantamento dos impactos econômicos da inovação. Tal como afirma Scherer (2005), a abordagem de Mansfield diferia profundamente daquela econômica convencional. Esse método apoiava-se no levantamento direto de informações junto às empresas. D. Teece (2005), que foi seu aluno, aponta que sua resposta metodológica às perguntas que surgiam sobre o processo de inovação baseava-se primeiramente na observação empírica para, a partir dela, construir alguma modelização teórica.

Hertzfeld (1998), analisando as metodologias de avaliação dos programas de P&D da Nasa, as separou apropriadamente em três abordagens: os modelos econométricos; os estudos microeconômicos; e os estudos de caso. Os estudos microeconômicos, aos quais pertencem os de Mansfield, caracterizam-se pelo levantamento direto das informações para medição dos impactos de determinada tecnologia.

Esse tratamento metodológico somente era possível, como bem lembrou Scherer (2005), porque Mansfield tinha acesso à nata das empresas industriais americanas, que realizavam P&D nos Estados Unidos, as quais tinham uma imensa boa vontade para responder aos seus complicados questionamentos. Tal abordagem juntava o levantamento de informações quantitativas com perguntas de ordem qualitativa para inferir alguns fenômenos. Essa hibridação foi frequentemente criticada por seus colegas, menos heterodoxos, que a consideravam, no mínimo, imprecisa e pouco rigorosa.

O texto que está sendo publicado pela *RBI* "Social and privates rates of return from industrial innovations" deve ser percebido como a sua primeira grande contribuição no *tournant* de sua trajetória intelectual. Esse trabalho foi escrito em parceria com seus estudantes da Universidade de Pensylvania, onde era professor de economia desde 1964. Não por acaso, ele é o primeiro *paper* apresentado na coletânea que resume suas contribuições. O texto representa o primeiro passo dado pelo autor na sua agenda utilizando o novo ferramental que ele havia construído a partir da crítica ao modelo vigente.

O desafio consistia em responder, primeiramente, à pergunta de qual era a importância das externalidades para as inovações realizadas na indústria. A pergunta que havia sido feita anteriormente era se existia um subinvestimento privado em P&D e se o apoio público à P&D executada pelo setor privado se justificava. Como Mansfield (1995) aponta, esse foi o primeiro estudo feito sobre a indústria que buscou medir o retorno privado e social de inovações. A partir das informações levantadas, foi possível afirmar que o retorno social de 56% era muito superior ao privado de 25% da inovação. Essa ideia não era nova, mas faltava uma comprovação empírica que Mansfield trouxe.

Do ponto de vista da credibilidade dos resultados, o artigo "Social and private rates ..." constitui uma certa unanimidade no meio dos estudiosos da inovação. A National Science Foundation se encarregou de replicar o trabalho. Um estudo foi realizado pela Robert Nathan Associates em 20 inovações, encontrando taxas superiores (70% e 36%), e outro pela Foster Associates em 20 inovações, obtendo taxas de 99% e 24% (DIAMOND, 2003). Confirmava-se tanto a rentabilidade quanto o desnível entre as duas taxas. As críticas aos estudos empíricos de Mansfield dirigiram-se para outros trabalhos (SCHERER, 2005).

As contribuições desse trabalho não se limitaram apenas à comprovação empírica da importância das externalidades na atividade inovativa da indústria. O estudo traça uma nova forma de enxergar o fenômeno da inovação. O aspecto mais destacável constitui a diferença setorial do processo de inovação, que já vinha sendo muito explorada por outros teóricos da inovação, como C. Freeman. A diferença de impacto das inovações entre setores era um dos aspectos já destacados por Mansfield em sua agenda traçada no início dos anos 1970. As 17 inovações estudadas, que pertencem a diversos setores da indústria, apresentam comportamentos muito diferenciados.

O artigo também inova ao indicar caminho para se medir o retorno social da tecnologia. Com efeito, a passagem da abordagem microeconômica do retorno privado para o social não poderia limitar-se à perspectiva da empresa. Além dos ganhos transferidos aos consumidores contabilizados no excedente social, era preciso também mensurar os prejuízos causados aos produtos deslocados pela inovação, assim como os ganhos obtidos por imitadores que comercializassem a nova tecnologia. É bom salientar que essa preocupação de abater também externalidades negativas causadas pela inovação foi bastante ampla e estendeu-se à questão ambiental. Assim, os custos de remoção do resíduo de um produto de limpeza foram abatidos dos benefícios sociais.

Os custos da inovação foram bastante retrabalhados por Mansfield. Esses gastos não deveriam incluir apenas os das inovações bem sucedidas, mas também os daquelas que haviam malogrado. Esses custos também foram ampliados para incluir os de comercialização e produção juntamente com os de P&D.

As inovações foram também separadas nas de processo e de produto. Nas de processo e de produto consumidas por outras indústrias, Mansfield e seus colaboradores buscaram mensurar os ganhos obtidos pelo lado da demanda, entrevistando uma amostra de empresas usuárias da tecnologia.

Mansfield ainda contribuiu para o avanço do entendimento do processo de inovação, não apenas descrevendo os desníveis entre os rendimentos sociais e privados, mas buscando identificar, a partir de uma análise de regressão aplicada em sua amostra, quais eram os fatores que favoreciam esse desnível. Tais análises o levaram a concluir que quanto mais relevante a inovação, mais ela era copiada pelos competidores.

Sem dúvida, o artigo abriu novas frentes de estudo. Mansfield questionava-se como a inovação transborda às demais empresas e quais fatores influenciariam esse processo. A apropriabilidade da inovação tornou-se um aspecto crucial para a agenda mansfieldiana. Questões como o tempo que uma inovação demorava para ser copiada pelos concorrentes dependendo do setor, ou até que ponto as patentes representavam uma efetiva barreira para que as demais empresas não copiassem uma inovação ocuparam os esforços de Mansfield nos anos posteriores, e constituem importantes desdobramentos das questões que foram inicialmente abertas pelo artigo apresentado neste volume da *RBI*.

Referências Bibliográficas

DIAMNOND, A. M. Edwin Manfield's contributions to the economic of technology. *Research Policy*, v. 32, p. 1607-1617, 2003.

HERTZFELD, H. R. Space as an investment in economic growth. In: LOGSDON, J. M. (Ed.). *Exploring the unknown*. Washington D.C.,: Nasa, v. III, 1998, p. 385-401 (The Nasa Histories Series).

MANSFIELD, E. Industrial *research and technological innovation*: an econometric analysis. New York: W.W. Norton, 1968.

_________. *Innovation, technology and economy*: the selected essays of Edwin Mansfiled. Aldershot, UK e Brookshield, US: Ed. Edwar Elgar, v. I e II, 1995 (Economist of the Twentieth Century).

_________. Introduction in Mansfield, E. *Innovation, technology and economy*: the selected essays of Edwin Mansfiled. Aldershot, UK e Brookshield, US: Ed. Edwar Elgar, v. I e II, 1995, p. ix-xxii (Economist of the Twentieth Century).

_________. Contribution of R&D to economic growth in the United States. *Science*, v. 175, p. 487-94, Feb. 1972.

_________. Technical change and the rate of imitation. *Econetrica*, v. 29, n. 4, p. 741-66, Oct. 1961.

_________. Contributions of new technology to the economy. In: SMITH, B. L.R.; BARFIELD, C. L. (Eds.). *Technology, R&D, and the economy*. Washington, D.C.: The Brookings Institution and American Enterprise Institute for Public Research, 1996.

MANSFIELD, E.; RAPOPORT, J.; SCHNEE, J.; WAGNER, S.; HAMBURGER, M. *Research and innovation in the modern corporation*. New York: Norton, 1971.

MANSFIELD, E.; RAPOPORT, J.; ROMEO, A.; VILLANI, E.; WAGNER, S.; HUSIC, F. *The prodction and application of new industrial technology*. New York: Norton, 1977.

MANSFIELD, E.; ROMEO, A.; SCHWARTZ, M.; TEECE, D.; VILLANI, E.; WAGNER, S. *Technology transfer, productivity, and economic policy*. New York: Norton, 1982.

SCHERER, F.M. Edwin Mansfield: an appreciation. In: LINK, A. N.; SCHERER, F. M. (Eds.). *Essays in honor of Edwin Mansfield*. The economics of R&D, innovation and technological change. New York, 2005, p. 1-7.

TEECE, D. J. Technology and technology transfer: Mansfieldian inspiration and subsequent developments. In: LINK, A. N.; SCHERER, F. M. (Eds.) *Essays in honor of Edwin Mansfield*. The economics of R&D, innovation and technological change. New York, 2005, p. 27-43.

SOCIAL AND PRIVATE RATES OF RETURN FROM INDUSTRIAL INNOVATIONS*

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I. INTRODUCTION

For many years, economic analysts and policy-makers have been interested in developing and obtaining better and more complete data concerning social and private rates of return from industrial innovations. It has long been recognized that information of this sort is essential if public policy concerning civilian technology is to be formulated rationally. Yet despite the work of Denison, Fellner, Griliches, Mansfield, Minasian, Peterson, Terleckyj, and others, existing knowledge in this area is far too weak to provide a reasonably adequate foundation for analysis and policy.[1] The purpose of this paper is to report the results of seventeen case studies, each of which estimates the social and private rate of return from the investment in a particular industrial innovation. The results of this paper, although subject to obvious limitations and shortcomings, should provide us with a somewhat better understanding of this topic. The studies described

* The work on which this paper is based was supported by a grant to Mansfield from the Office of National R and D Assessment of the National Science Foundation. The bulk of the basic data on which this study is based was collected by Beardsley, Rapoport, Romeo, and Wagner. A preliminary version of this paper was presented by Mansfield at the meetings of the Eastern Economic Association on October 26, 1974; at the National Bureau of Standards; in a paper at the 1975 meetings of the American Economic Association; and in a paper at the First U.S.–U.S.S.R. Symposium; at M.I.T.; at the RAND Corporation; and at the National Science Foundation. Also, he presented some of this material in his Schmookler Memorial Lecture at the University of Minnesota in 1975 on the Economics of Information (which took place in Leningrad in 1975).

1. For a summary of existing knowledge in this area, see E. Mansfield, "Contribution of R and D to Economic Growth in the United States," *Science*, CLXXV (Feb. 4, 1972), 477–86.

here seem to be the first attempts to make direct measurements of this sort in the industrial sector.

II. The Sample of Innovations

Our first step in carrying out this investigation was to contact a number of business firms in the Northeast and to try to persuade them to provide us with data bearing on the social and private returns from innovations that they had carried out. As would be expected, a substantial percentage of those who were contacted refused to cooperate because, despite our assurance that the data would be held in strictest confidence, they felt that such data were too sensitive to show outsiders. Those firms that were willing to cooperate were asked to pick one or more of their recent innovations more or less at random. Then many manweeks were spent gathering data concerning each innovation and its effects from the innovating firm, from firms using the innovation (if it was used by firms), and from other sources. These innovations occurred in a wide variety of industries (described below), and in firms of quite different sizes. Most of them are of average or routine importance, not major breakthroughs. Although the sample cannot be regarded as randomly selected, there is no obvious indication that it is biased toward very profitable innovations (socially or privately) or relatively unprofitable ones. The sample is described in Table I.

III. Estimation of Social Benefits: Product Innovations Used by Firms

As is evident from Table I, the innovations in our sample can be divided into three classes: product innovations used by firms, product innovations used by households, and process innovations. Based on an intensive study of each of the innovations in each of these classes, it appears that the same general kind of model is applicable to all of the innovations in our sample in a particular class. In this and the following sections we describe the model that is used to measure the social benefits in a particular period from product innovations used by firms.

In each case these new products resulted in a potential saving to users. For example, the product innovation in the primary metals industry resulted in a potential saving to makers of household appliances. Thus, each of these innovations could shift downward the supply curve of the industry using the innovation. How far downward

TABLE I

CHARACTERISTICS OF SAMPLE OF SEVENTEEN INNOVATIONS

Industry producing the innovation	Type of innovation	Nature of innovation	Type of user	Approximate date of innovation
1. Primary metals	New product	New type of metal that reduced cost of appliances	Firms	Late 1950's
2. Machine tools	New product	New computer controls	Firms	Early 1970's
3. Control systems	New product	New type of component	Firms	Late 1960's
4. Construction	New product	New material that cut cost of building	Firms	Mid 1950's
5. Drilling	New product	Reduced cost of drilling wells	Firms	Mid 1960's
6. Industrial equipment	New process	New type of drafting	Firms	Early 1960's
7. Paper	New product	New paper product that cut costs of users	Firms	Mid 1960's
8. Thread	New product	New type of thread that cut costs of garment makers	Firms	Early 1960's
9. Industrial controls	New product	New mechanism for doors	Firms	Early 1970's
10. Electronics	New product	New device that reduced costs of certain video tape operations	Firms	Early 1970's
11. Chemicals[a]	New product	New product that reduced costs of users	Firms	Late 1960's
12. Chemicals[a]	New process	Reduced costs of production	Firms	Mid 1960's
13. Chemicals[a]	New process	Reduced cost of certain aromatic chemicals	Firms	Late 1960's
14. Chemicals[a]	New process	Major process improvement	Firms	Early 1960's
15. Household cleaners	New product	New product that reduced cost of cleaning floors	Households	Early 1960's
16. Stain removers	New product	New stain remover	Households	Mid 1960's
17. Dishwashing liquids	New product	New product that cut costs of operating dishwashers	Households	Early 1960's

a. Chemicals are defined to include petroleum refining.

this supply curve will shift depends, of course, on the pricing policy of the innovator. If the innovator charges a relatively high price for the new product, the supply curve may shift only slightly. Indeed, if the innovator charges a high enough price, the supply curve will not shift downward at all.

Suppose that the innovator decides to set a price for its new product that yields a profit[2] to the innovator equivalent to r dollars per unit of output of the industry using the innovation (for example, r dollars per appliance in the case of the new type of metal). Also, suppose that the industry using the innovation is competitive and that its supply curve is horizontal in the relevant range. In particular, assume that, before the advent of the innovation, this supply curve was S_1 in Figure I, and the price charged by the industry using the innovation was P_1. After the advent of the innovation, this supply curve is S_2, and the price is P_2.

Under these circumstances, the social benefits from the innovation can be measured by the sum of the two shaded areas in Figure I. The top shaded area is the consumers' surplus due to the lower price (P_2 rather than P_1) resulting from the use of the innovation.[3] In addition, there is a resource saving, and a corresponding increase in output elsewhere in the economy, due to the fact that the resource

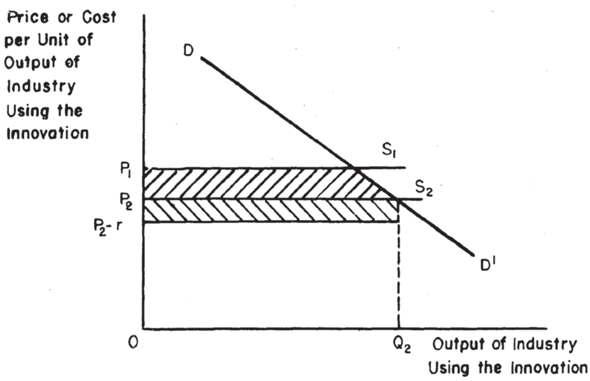

FIGURE I
Social Benefit from Product Innovation That Reduces the Costs of the Industry Using It

2. Profit here is defined to be gross of any depreciation on the investment in the innovation. Basically, it is a cash flow concept.

3. Of course, one problem in any model of this sort is that the concept of consumers' surplus is a controversial one. But as so many writers have pointed out, it is hard to do applied work in this area without adopting some such concept. See, for example, J. Currie, J. Murphy, and A. Schmitz, "The Concept of Economic Surplus and Its Use in Economic Analysis," *Economic Journal,* LXXXI (Dec. 1971), 741–99.

costs of producing the good using the innovation—including the resource costs of producing the innovation—are less than P_2Q_2. Instead, they are P_2Q_2 minus the profits of the innovator from the innovation, the latter being merely a transfer from the producers of the good using the innovation to the innovator. Thus, besides the consumers' surplus arising from the price reduction, there is a resource saving amounting to the profits of the innovator.[4]

However, two adjustments must frequently be made in this estimate corresponding to the lower shaded area in Figure I. First, if the innovation replaces another product, the resource saving cited in the previous paragraph does not equal the profits of the innovator (from the innovation), but these profits less those that would have been made (by the innovator or other firms) if the innovation had not occurred and the displaced product had been used instead. This is the correct measure of the resource saving. Second, if other firms imitate the innovator and begin selling the innovation to the industry that uses it, their profits from the sale of the innovation must be added to those of the innovator to get a full measure of the extent of the resource saving due to the innovation.

Based on this model, an estimate was made of the social benefit in each period from the investment in each of these innovations. For each innovation, the top shaded area in Figure I equals

$$(P_1 - P_2)Q_2\,(1 - 1/2\,Kn), \qquad (1)$$

where $K = (P_1 - P_2)/P_2$, and n is the price elasticity of demand (in absolute value) of the product of the industry using the innovation. To estimate $P_1 - P_2$, we obtained as much information as we could concerning the size of the unit cost reduction due to the innovation in the industry using the innovation. Based on interviews with executives of the innovating firm, executives of a sample of firms using the innovation, and reports and studies made by these firms for internal purposes, it was possible to obtain reasonably reliable estimates of $(P_1 - P_2)$.[5] And once we had an estimate of $(P_1 - P_2)$, it was simple

4. To put matters somewhat differently, the sum of the two shaded areas in Figure I can easily be shown to equal the social value of the extra output of the product (as measured by the area under the demand curve) plus the value of the resources saved.

5. We assume that the cost reduction experienced by the industry using the innovation is passed on to consumers. In view of the market structures of the industries in question, this seems to be a reasonable assumption. Also, the available evidence seems to support this assumption. But it is important to note that, if the cost reduction were kept by the industry using the innovation, the social benefit would equal this industry's cost saving due to the innovation plus the innovator's (adjusted) profits. Since the industry's cost saving must be greater than our measure of the upper shaded area in Figure I, our measure of social benefit would be conservative.

to compute K. Also Q_2 was generally available from published records. Rough estimates of n were obtained from published studies and from the firms. Since K is generally very small, the results are not sensitive to errors in n. Indeed, the expression in equation (1) can be approximated quite well in most cases by $(P_1 - P_2)Q_2$, which is the total savings to consumers due to the lower price, if they buy Q_2 units of the product of the industry using the innovation.

To estimate the additional resource saving from the innovation, which equals the bottom shaded area in Figure I (if the adjustments described in the paragraph before the last are unnecessary), the innovator's profit from the new product was obtained from detailed discussions with the firm's executives, as well as study of relevant financial records. For each year, the costs of marketing and producing the innovation, as well as the costs of carrying out the innovation (R and D, plant and equipment, manufacturing start-up, and marketing start-up),[6] were deducted from the innovator's revenues from the innovation. Note that the R and D costs were adjusted to allow for the fact that the innovator invested R and D resources in uncommercialized R and D projects. To make this adjustment, we obtained estimates from each of the innovating firms of the average number of dollars spent on uncommercialized R and D projects per dollar spent on a commercialized R and D project during the relevant period. Then we multiplied the innovator's R and D outlays (in each year) on the innovation by this number in order to get an estimate of the total R and D investment, including a prorated allowance for uncommercialized projects. In cases where the adjustments described in the paragraph before the last were necessary, estimates of the foregone profits from displaced products were deducted, and the profits of imitators were added, to the innovator's profits. These estimates were obtained from the relevant firms.

IV. Parallel Innovative Efforts, Time Horizon, and Rates of Return

In calculating the social rate of return, we must recognize that, besides the innovator, other firms or research organizations in the United States[7] may have invested resources (prior to the introduction

6. For discussions of the cost categories involved, see E. Mansfield and J. Rapoport, "The Costs of Industrial Product Innovations," *Management Science*, XXI (Aug. 1975), 1380–86; and E. Mansfield, J. Rapoport, J. Schnee, S. Wagner, and M. Hamburger, *Research and Innovation in the Modern Corporation* (New York: Norton, 1971).

7. We are concerned here only with the costs and benefits arising within the United States. Thus, we ignore the fact that some of these innovations resulted in significant

of the innovation in question) in R and D and related innovative activities aimed at innovations of essentially the same kind as this one. Clearly, it is not easy to obtain data on the extent of such investments, but fortunately the difficulties seem to be less than they might appear, for two reasons. First, only a limited number of organizations could reasonably have been expected to be doing R and D in the relevant area, and if they had been devoting any substantial amount of resources to such work in the relevant time frame, it is inconceivable that the current executives of these organizations (and all their competitors) would have been unaware of it. Second, since these innovations occurred some time ago, firms generally are quite willing to discuss whether they were carrying out work of the relevant kind at that time. Moreover, and this is particularly fortunate, our results are quite insensitive to errors in the estimated investment in R and D carried out by others. Even if the true social research expenditures were ten times our estimate, and the true social development expenditures were double our estimate, the results change remarkably little.

Based on interviews with executives of the innovating firm, as well as with other firms that could reasonably be expected to do (and be aware of) R and D of the relevant kind, it appears that, in most of the cases in our sample, no other firm or research organization was doing work aimed at roughly the same kind of innovation. Thus, in these cases, the private investment seems to be a good approximation to the social investment. In the remaining cases, other firms or individuals were engaged in R and D aimed at the same kind of innovation. In the cases where this R and D was *unsuccessful,* we obtained as accurate an estimate as possible of the cost of this unsuccessful R and D, and added this figure to the R and D costs described in the previous section to get an estimate of the total social cost of the relevant R and D carried out by the innovator and others.[8]

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social benefits in other countries, and we do not attempt to include whatever costs may have been incurred in other countries in an attempt to produce innovations of roughly the same kind. Also, each rate of return estimated here is on the investment in the innovation in question, given that previous investments in basic science, education, and so forth had already occurred. Clearly, the rates of return on the investments considered here were dependent on these previous investments.

8. Of course, some of the unsuccessful R and D directed at one innovation may be part of the uncommercialized R and D carried out by the innovator in the case of another innovation. Really, the social cost of an innovation should include a prorated share of the cost of uncommercialized R and D carried out by the innovator, excluding the cost of its uncommercialized R and D aimed at innovations where other firms beat it to the punch. But there is no way to estimate the latter cost, and our procedure clearly biases the social rates of return downward.

In the one case (among product innovations used by firms) where other firms or individuals were engaged (prior to the introduction of the innovation in question[9]) in R and D aimed at roughly the same kind of innovation, and where this R and D was *successful,* we must recognize that the innovator's investment resulted only in the innovation's availability at an earlier point in time, not in all of the social benefits from the innovation date up to the relevant time horizon. In other words, the proper comparison is between what would have occurred if the innovator had not carried out the innovation (but other firms were free to do so) and what in fact occurred. In this case, we obtained as accurate an appraisal as we could of the date when the innovation would have appeared if the innovator had not carried out the innovation, and we calculated the social benefits only during the period between the date when the innovation occurred and the date when it would have appeared if the innovator had done nothing.[10] Of course, it frequently is very difficult to estimate when the innovation would have occurred if the innovator had not carried it out. But in this particular case a realistic (if perhaps somewhat conservative) estimate is that the second firm to produce the innovation would have come up with it when in fact it did so, regardless of whether the innovator preceded it or not.

For most innovations these calculations were carried out for each year from the beginning of work on the innovation until 1973. Thus, our estimates of the social benefits are conservative, since all benefits after 1973 are ignored. But in some cases, this would introduce a serious distortion, since the innovation is relatively new. In these cases, forecasts were made of the consumers' surplus and the innovator's profits (adjusted for imitators' profits and for profits on older products) in each year up to 1980. These forecasts are based on firms' expectations concerning $(P_1 - P_2)$, Q_2, and the relevant profits in the next few years. They are intentionally very conservative, so whatever bias there is in the resulting rates of return should be downward.

Finally, having made the calculations described in this and the previous section for each year, we have an estimate of the net social benefits from the innovation for each year. Then we can compute the

9. Work of this sort that occurs after the innovation takes place is of a different kind. It is directed at *imitating* or *improving on* the innovation, and is not properly regarded as part of the work *producing* the innovation.

10. Note that this procedure assumes that, once the innovator is joined by another firm producing the innovation, they adopt a pricing policy that is just the same as the other firm would have adopted if it were the sole producer of the innovation. Needless to say, this may not be true, since there may be advantages stemming from competition between the two firms. However, we adopt this assumption because it results in a conservative estimate of the social rate of return and because any other assumption would have to be based largely on speculation.

internal social rate of return, the interest rate that makes the present value of the net social benefits equal to zero. In other words, it is the interest rate i that results in the following equality:

$$(2) \qquad B(t) + \frac{B(t+1)}{1+i} + \frac{B(t+2)}{(1+i)^2} + \cdots + \frac{B(t+n)}{(1+i)^n} = 0,$$

where $B(t)$ is the net social benefit year in t, t is the first year in which the net social benefit is nonzero, and $(t + n)$ is the last year in which the net social benefit is nonzero.

Finally, we also compute the private rate of return from the innovator's investment in each innovation. To do so, we calculate the cash flow to the innovator from the innovation during each year. This calculation involves the subtraction of all costs incurred by the innovator to carry out, produce, and sell the innovation (including the allowance described in the previous section for R and D on uncommercialized projects) from the innovator's revenues from the innovation. Also, profits that the innovator would have earned on products displaced by the innovation must be subtracted as well.[11] The time period over which these computations were made was generally up to 1973, but in some cases (as in the case of the social rate of return) it extended to 1980. Again, the forecasts in the latter cases are decidedly conservative. The net private benefits in each year, like the B's in equation (2), were deflated. The Consumer Price Index, which generally was used, is not ideal, but it seems very unlikely that the results will be affected in an important way by this choice of a deflator.

V. PRODUCT INNOVATIONS USED BY HOUSEHOLDS

In this section we turn to the model used to calculate the social benefits for product innovations used by households. Since all of the innovations of this type in our sample are meant to reduce the cost of some particular household activity, basically the same model will apply. Suppose that the demand curve for this activity is DD' in Figure II and that the innovation reduced the price of performing this activity from P_1 to P_2. Suppose too that the innovator makes a profit

11. In all but one case, it is assumed that the profits from the displaced product would have continued (up to the time horizon indicated below) at their previous level if the innovation had not occurred. This seems reasonable, based on the facts. But in the one remaining case, there is reason to believe that, if the innovation had not occurred, another innovation superior to this one would have occurred at a particular point in time afterward. Thus, we assume that the innovator would have earned nothing on the displaced product after this point in time. Of course, it also earned nothing on the innovation after this point.

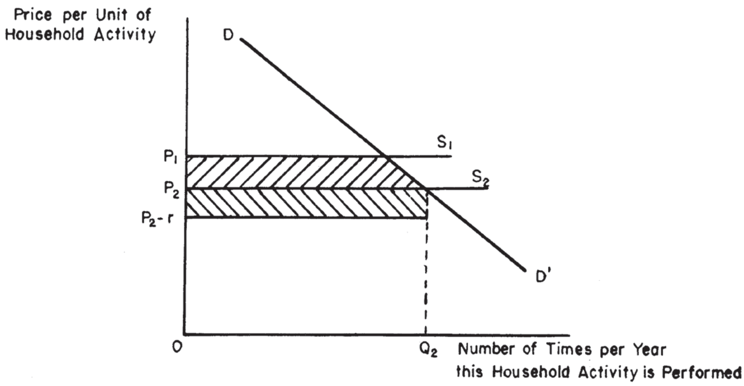

FIGURE II
Social Benefit from Product Innovation That Reduces the Price of a Household Activity

of r dollars every time this activity is performed using the product innovation. Then the social benefits from the innovation can be measured by the sum of the two shaded areas in Figure II. These two areas are exactly analogous to those in Figure I, and the methods used to estimate them are similar to those described above, except that no interviews were carried out with users. Instead, the results are based entirely on the estimates and findings of the firms. As in the previous sections, it is necessary to correct the R and D costs for uncommercialized projects, to estimate R and D costs incurred by firms and organizations other than the innovator, to deduct the profit from displaced products from the innovator's profit, and to include the profits of imitators.

However, not everything is the same as in previous sections. For one thing, one of these innovations, the stain remover, resulted in some environmental costs, since it increased the amount of a certain chemical that is put into our water supplies. As a rough measure of these costs, we used an estimate (obtained from an official of the Environmental Protection Agency) of the cost of removing a unit of this chemical from water, given that it occurs in a particular concentration. Then we multiplied this cost times the number of units of the chemical that is deposited in the water, given that consumers use the innovation to perform the relevant household activity Q_2 times per year. Finally, this estimate was deducted from the social benefit to correct, at least roughly, for the environmental costs. Note that this was the only innovation in our entire sample that resulted in any substantial environmental costs, so far as we could determine.[12]

In all but one of these cases, there is no reason to believe that, if the innovator had not introduced the new product, any other firm would have done so in the relevant time frame. But in the remaining case, a competitor introduced a similar new product only a short while after the innovator introduced its new product. In this case, we obtained estimates from the relevant firms concerning the quantity of its new product that the competitor would have sold each year if the innovator had not developed and introduced its new product. Then we deducted this amount from the actual combined sales of both new products to get the extra amount that was used each year because the new product was introduced earlier than it otherwise would have been, due to the innovator's actions. Then we calculated the consumers' surplus based on this extra amount. Also, we calculated the innovator's profit less the profit that would have been earned by the competitor on the share of the innovator's sales that the competitor would have gotten if the innovator had not introduced its product (and less the profit on products displaced in the remainder of cases). Based on these calculations, we computed the social rate of return.

Finally, as in the case of product innovations used by firms, we computed private as well as social rates of return. The calculations are entirely analogous to those described in the previous section. In all cases the calculations end with 1973.

VI. PROCESS INNOVATIONS

Next, let us turn to the model underlying our calculation of the social benefits from process innovations. In the case of three of the four process innovations included in our sample, there was no apparent effect on product prices. By lowering the costs of the innovators, these process innovations increased the innovator's profits. Also, since they were imitated (or used at nominal cost) by other firms, they soon increased the profits of other firms as well. The total decrease in costs (which equals the increase in profits) of all of the relevant firms is a measure of the social benefit of each of these innovations in a particular period. It equals the social saving in resources due to the innovation. For each of these innovations, we estimated the total reduction in costs on the basis of interviews with the relevant firms

12. Note that some of these innovations had positive environmental effects. However, since these benefits are hard to measure, we ignore them. Of course, whatever bias this introduces results in our estimates of the social rate of return being conservative.

and of studies and reports concerning the cost reductions due to the innovations and the extent of their utilization.

In the case of the fourth process innovation (the innovation in industrial heating equipment), the situation was different. In this case, the innovator shared the gains with its customers. As shown in Figure III, it reduced the price of its product from P_1 to P_2. Thus, the social

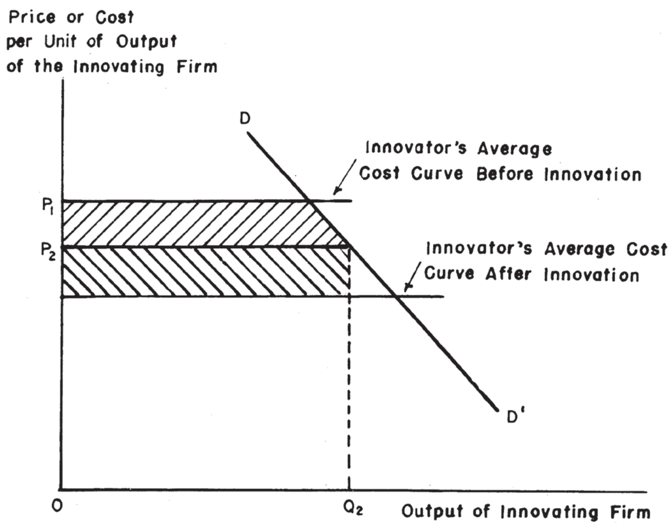

FIGURE III
Social Benefit from Process Innovation That Results in Price Reduction by Innovator

benefit equals the sum of the two shaded areas, the top shaded area being the consumers' surplus resulting from the price reduction, and the bottom shaded area being the profits to the innovator from the innovation. The situation is almost exactly the same as in Figures I and II.

For one of the process innovations, it was necessary to estimate the length of time that the innovator hastened the appearance and introduction of the new process. (In the other cases, there is no reason to believe that if the innovator had not introduced the innovation in the relevant time period, any other firm would have done so.) In this case other firms were doing R and D along somewhat similar lines, and there was some feeling among knowledgeable engineers and managers that the new process might have been developed and introduced about four years later than in fact occurred if the innovator had not done so. In this case we assume that the diffusion of the new process would have begun four years later (but that it would have proceeded at the same rate) if the innovator had not developed and introduced it. Then the social and private savings are computed by comparing the actual extent of use of the innovation with what it would have been under this assumption. In addition, the social rate of return based on the entire industry's investment in this sort of innovation is estimated, this estimate having the advantage that it is free of any such assumption about how quickly competitors of the innovator would have developed and introduced the innovation.[13] (The latter estimate, which is the lower of the two, is shown in Table II.)

TABLE II

SOCIAL AND PRIVATE RATES OF RETURN FROM INVESTMENT IN SEVENTEEN INNOVATIONS

Innovation	Rate of return (percent)	
	Social	Private
Primary metals innovation	17	18
Machine tool innovation	83	35
Component for control system	29	7
Construction material	96	9
Drilling material	54	16
Drafting innovation	92	47
Paper innovation	82	42
Thread innovation	307	27
Door control innovation	27	37
New electronic device	Negative	Negative
Chemical product innovation	71	9
Chemical process innovation	32	25
Chemical process innovation	13	4
Major chemical process innovation	56[a]	31
Household cleaning device	209	214
Stain remover	116	4
Dishwashing liquid	45	46
Median	56	25

a. Based on investment of entire industry. See Section VI.

VII. SOCIAL AND PRIVATE RATES OF RETURN

The results, shown in Table II, seem to have at least three implications. First, they indicate that the social rate of return from the

13. For two of the processes the calculations end with 1972 or 1973; for the other two, forecasts are used up to 1980 (and in one case, beyond).

investments in these seventeen innovations has been very high. The median estimated social rate of return is about 56 percent. Moreover, for a variety of reasons, these estimates are likely to be conservative lower bounds.[14] To put these results in perspective, recall that Griliches found that the internal social rate of return from hybrid corn—a very successful innovation—was 37 percent.[15] Clearly, the investments that have been made in industrial innovations have, on the average, yielded handsome social returns, if these innovations are at all typical.

Second, the results indicate that the private rates of return from the investments in these innovations have been much lower than the social rates of return.[16] The median private rate of return (before taxes) was about 25 percent. In interpreting this number, it is important to recognize the riskiness of this kind of investment (and the fact that these are pretax figures). This riskiness is evidenced by the enormous variation in the private rates of return in Table II. In the case of six innovations the private rate of return (before taxes) was less than 10 percent, while for five innovations, it was more than 40 percent.

14. For example, in many cases, we ignore all post-1973 benefits from the innovations. Throughout this study, we have tried to use estimates and procedures that, if biased at all, would be biased in this direction.

15. See his "Research Costs and Social Returns: Hybrid Corn and Related Innovations," *Journal of Political Economy,* LXVI (Oct. 1958), 419–31. The models used in Sections III and IV are in the same spirit as the one applied by Griliches. The principal differences are that we have extended the analysis to include the pricing policies of the innovator, the effect on displaced products, and the costs of uncommercialized R and D and of R and D done outside the innovating organization. Another noteworthy study of this kind is W. Peterson, "Returns to Poultry Research in the United States," *Journal of Farm Economics,* XLIX (Aug. 1967), 656–69. This study concludes that the average rate of return from the investment in poultry research was 18 percent.

16. Note that there is nothing in our procedures that makes it inevitable that an innovation's social rate of return exceeds its private rate of return. For a variety of reasons (such as investments in R and D by organizations other than the innovator, and the transfer of profits from the producers of displaced products to the innovator), the social rate of return can be less than the private rate of return—and in fact this turns out to be the case for four of the innovations in our sample. For a study of some of the factors associated with a firm's probabilities of success in R and D, see E. Mansfield and S. Wagner, "Organizational and Strategic Factors Associated with Probabilities of Success in Industrial R and D," *Journal of Business,* XLVIII (April 1975), 179–98.

One of the innovations was developed by a nonprofit organization. In this case the private rate of return is defined to be the rate of return to this organization and the licensees that produced and marketed the innovation.

When we compute a confidence interval for the proportions of innovations where the social rate of return exceeds the private rate of return, we find that the probability is 0.90 that this percentage lies between 60 percent and 92 percent. Thus, if we could treat our sample as randomly chosen, we could be quite confident that the social rate of return exceeds the private rate of return in the majority of cases. Also, a t-test indicates that the mean difference between social and private rates of return, which is 47 percent, differs significantly from zero at the 0.01 level. And so does a sign test, which does not assume normality.

Third, the results indicate that, in about 30 percent of the cases, the private rate of return was so low that no firm, with the advantage of hindsight, would have invested in the innovation, but the social rate of return from the innovation was so high that, from society's point of view, the investment was well worthwhile. We would also like to estimate the extent to which innovations with favorable social rates of return have anticipated rates of return that are so low that they are not carried out. Unfortunately, Table II cannot provide much information on this score for the obvious reason that all of these innovations were carried out. Also, expected and actual private rates of return may differ considerably.[17]

VIII. Factors Associated with the Gap Between Social and Private Rates of Return

Economists have long been interested in the sorts of innovative activity where the gap between social and private rates of return, if it exists, is particularly large. There has been considerable speculation on this score, but it seems fair to say that the current state of knowledge in this regard is extremely limited. Economic theorists have generally singled out three factors as being of considerable importance in determining the extent of the gap between the social and private rates of return from an innovation. The first of these factors is the market structure of the innovator's industry. If the innovator is faced with a highly competitive environment, it is less likely that it will be able to appropriate a large proportion of the social benefits than if it has a secure monopoly position or if it is part of a tight oligopoly. Of course, the extent to which the innovator is subjected to competition, and how rapidly, may depend on whether the innovation is patented. Moreover, another consideration of at least equal importance is how expensive it is for potential competitors to "invent around" the innovator's patents, if they exist, and to obtain the equipment needed to begin producing the new product (or using the new process). In some cases, like DuPont's nylon, it would have been extremely diffi-

17. However, a limited amount of evidence can be given on this score. We could obtain data for nine of the innovations concerning the approximate private rate of return expected from the innovation by the innovator when it began the project. In five of the nine cases, the expected private rate of return was less than 15 percent, indicating that these five projects were quite marginal; yet the average social rate of return of these five projects was over 100 percent! Unless there is a marked discontinuity of some sort, it would appear from this that there may be many projects where the expected private rate of return was a bit lower (with the result that they were not carried out), but where the social rate of return would have been quite high. (The rank correlation between the expected private rate of return and the social rate of return does not differ significantly from zero in this sample.) However, the very small sample and the crudeness of the analysis should be borne in mind.

cult to imitate the innovation (legally). In other cases, a potential competitor could obtain and begin producing a "me too" product (or using a "me too" process) at relatively little cost.

A second factor that economists have emphasized as a determinant of the size of the gap between social and private rates of return is whether the innovation is major or minor. (A reasonable measure of an innovation's importance (at least in our sample) might be the annual net social benefits derived from it.) According to R. C. O. Matthews, the "degree of appropriability is likely to be less . . . in major innovations than in minor ones. . . ," [18] since major innovations are more likely, in his view, to be imitated quickly. Similarly, on the basis of a model stressing the indivisibility of information, Kenneth Arrow concludes that "the inventor obtains the entire realized social benefit of moderately cost reducing inventions but not of more radical inventions." [19]

A third factor that is sometimes cited is whether the innovation is a new product or process. Thus, Matthews thinks that the degree of appropriability may be less for process innovations than for product innovations. On the other hand, Nelson, Peck, and Kalachek stress that new processes can often be kept secret and that it frequently is difficult for one firm to find out what processes another firm is using.[20] This, of course, suggests that the gap between social and private rates of return might be greater for products than for processes. Neither Matthews nor Nelson, Peck, and Kalachek present any evidence on this score.

Although most of these hypotheses seem quite plausible, the truth is that none of them have been subjected to any sort of systematic empirical tests. Based on the results presented in the previous section, it is possible for the first time to attempt some empirical tests of these hypotheses. These tests are made in two steps. First, we divide the sample into two groups, processes and products, to see whether the average difference between the social and private rates of return is different in one group than in the other. Second, looking at products alone (since there are too few processes to support such an analysis),

18. R. C. O. Matthews, "The Contribution of Science and Technology to Economic Development," in B. Williams, ed., *Science and Technology in Economic Growth* (London: Macmillan, 1973), p. 14.

19. K. Arrow, "Economic Welfare and the Allocation of Resources for Invention," in National Bureau of Economic Research, *The Rate and Direction of Inventive Activity* (Princeton: Princeton University Press, 1962), p. 622. Arrow's model bears a resemblance to ours in Section III, but he was interested in a somewhat different set of questions, and no attempt was made to use it as a basis for empirical work.

20. R. Nelson, M. Peck, and E. Kalachek, *Technology, Economic Growth, and Public Policy* (Washington: Brookings Institution, 1967), p. 161.

we assume that

$$D_i = \alpha_0 + \alpha_1 S_i + \alpha_2 P_i + \alpha_3 I_i + z_i, \tag{3}$$

where D_i is the difference between the social and private rates of return for the ith innovation, S_i is the annual net social benefit (in thousands of dollars) from the ith innovation three years after its initial introduction (a crude, but reasonable, measure of the innovation's importance), P_i is a dummy variable that equals 1 if the innovation is patented and 0 otherwise, I_i is an estimate of the minimum amount of money (in thousands of dollars) it would have cost any of the innovator's competitors to imitate legally and introduce the ith innovation, and z_i is a random error term. According to the hypotheses stated above, one would expect α_1 to be positive and α_2 and α_3 to be negative. Ordinary regression techniques were used to determine whether this was the case.

The results suggest that the difference between the social and private rates of return tended to be higher for products than for processes. (The average value of D_i was about 57 percent for products and about 21 percent for processes.) But this difference is not statistically significant. Turning to the estimation of the α's, we obtained data concerning I_i for each innovation.[21] Then, combining these data with the information concerning D_i, P_i, and S_i (which stems from the work in previous sections), we used least squares to estimate the α's, the resulting equation being

$$\underset{(0.46)}{D_i = 12.4} + \underset{(4.34)}{0.0313 S_i} - \underset{(1.87)}{0.0509 I_i}, \quad (R^2 = 0.67), \tag{4}$$

where the t-statistic of each of the regression coefficients is shown in parentheses, and P_i is excluded because its regression coefficient is not even close to being statistically significant. Despite the relatively small sample size, the estimate of α_1 is highly significant, and the estimate of α_3 is significant at the 0.05 level. Both have the expected signs.

Thus, the results seem to support the hypothesis that the gap between social and private rates of return tends to be greater for more important innovations and for innovations that can be imitated relatively cheaply by competitors. Apparently, when the cost of imitating

21. These estimates were obtained from the innovating firms. In each case executives of the innovating firm were asked to estimate the minimum amount that it would have cost a competitor to imitate the innovation (legally). In some cases the estimate of I_i was as high as \$2 million; in other cases, it was as low as \$3,000. Although these estimates are rough, the executives seemed to think that they were not very wide of the mark.

the innovation is held constant, it makes little or no difference whether the innovation is patented—which seems reasonable because whether or not a patent exists is of relevance largely (perhaps only) because of its effects on the costs of imitation. It is important to note that S_i and I_i can explain about two-thirds of the observed variation in this gap among the product innovations in our sample.[22] However, at the same time, it is important to bear in mind the smallness of the sample and its nonrandom character.

IX. Unemployment, Repercussions on Other Markets, and Future Changes in Technology

Before concluding, we must take up several additional factors that have not been mentioned explicitly in previous sections. First, new technology can, of course, result in prolonged and serious unemployment of particular kinds of labor. Recognizing this fact, we tried to determine whether there was any substantial unemployment (or change in job content) resulting from each innovation described in Section II. In no case could we find any evidence of an appreciable change of this sort: although labor requirements sometimes were reduced by the innovation, growth in output offset these reductions. Thus, in this sample at least, this factor does not seem of substantial importance. Obviously, however, it can be of importance in other cases; and in situations where it is of importance, one must adjust the social benefits, as calculated in previous sections, for the fact that (for a certain period of time) some of the resources saved by the innovation do not find employment elsewhere.[23]

Second, new technology can, of course, have an effect on other industries and markets besides the ones directly involved. For example, by reducing the cost and price of the product using an innovation, the innovation affects the outputs of goods that are substitutes or complements of this product. However, so long as the prices of these and other goods (other than the product using the innovation) are not materially affected, the effects of these output changes are already included in the measures specified above.[24] In our sample there is no

22. One innovation had to be excluded from the regression (and the t-test in note 16) because its private rate of return was incalculable, since the private net benefit in each year was negative. Note too that the ratio of I_i to the innovator's cost in carrying out the ith innovation was tried as an additional explanatory variable in equation (4), but it was not close to being significant. Apparently, the absolute, not relative, cost is what matters most.

23. See A. Schmitz and D. Seckler, "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester," *American Journal of Agricultural Economics*, LII (Nov. 1970), 569–77.

24. See E. Mishan, *Economics for Social Decisions* (New York: Praeger, 1972), Ch. 6.

evidence that any of these innovations had any appreciable impact on any price other than that of the good using the innovation (in Section IV) or of the household activity in question (in Section V) or of the good based on the one relevant process (in Section VI). Also, one must assume that inputs that were displaced from industries producing goods competing with the product using the innovation readily found employment elsewhere. There is no evidence that this was not the case.

Third, new technology can, of course, play an important role in suggesting and prompting further innovations. Without question, practically all of the innovations in our sample had this effect. Thus, since each of these innovations is instrumental in bringing about future innovations, each results in social benefits above and beyond what we have measured. However, each of these innovations may have been suggested, prompted, or aided by previous innovations, and there is no feasible way to estimate the extent to which there is a net understatement of benefits.

X. CONCLUSION

As everyone who writes on this subject is quick to point out, very little is known about the social and private returns from industrial research and technological innovation. The need for measurement in this area is acute and widely recognized. For example, the Council of Economic Advisers, in its 1972 Annual Report, stressed the need for further analysis "to show the benefits, costs, and processes associated with R and D." [25] Our purpose in this study has been to measure, as best we can, the social and private rates of return from a sample of innovations.[26] We believe that our results go far beyond anything heretofore attempted in this area. (Also, to check and extend our results, we obtained very rich and detailed data concerning the returns from the innovative activities from 1960 to 1972 of one of the nation's largest firms. The results bear out our present findings.[27])

25. Economic Report of the President, 1972, pp. 127–28.

26. Griliches, Mansfield, Minasian, and Terleckyj have estimated rates of return from nonagricultural R and D based on econometric studies where R and D is inserted into production functions. Where the results of these studies can be compared with this one, the results are quite similar. For example, see N. Terleckyj, *Effects of R and D on the Productivity Growth of Industries: An Exploratory Study* (Washington: National Planning Association, 1974).

27. For each year, this firm has made a careful inventory of the technological innovations arising from its R and D and related activities, and it has made detailed estimates of the effect of each of these innovations on its profit stream. We computed the average rate of return from this firm's total investment in innovative activities during 1960–1972, the result being 19 percent, which is not too different from the

Of course, proper caution should be exercised in interpreting our results. For a host of reasons, they can tell us little about the extent to which there is an underinvestment (or whether an underinvestment exists) in innovative activities of various kinds.[28] Our sample of innovations is not a random sample, the data sometimes are rough, and for a few of the innovations they are based partly on forecasts. Further, the models that we use are simplified in many respects.[29] For these and other reasons, our results should be treated with considerable caution. The measurement of social and private rates of return from investments in new technology is an extremely difficult business, which is one good reason why so few such measurements have been attempted. Nonetheless, it is important that we make the best estimates we can.

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median private rate of return in Table II. Also, we computed lower bounds for the social rate of return from the firm's investment, and found that they were about double its private rates of return. For further discussion of this study, see G. Beardsley's Ph.D. thesis, University of Pennsylvania; E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, and F. Husic, *The Production and Application of New Industrial Technology* (New York: W. W. Norton, 1977); and E. Mansfield, "Comments on Returns to R and D Expenditures in the Private Sector," Conference on Research in Income and Wealth, November 1975.

28. See E. Mansfield, "Federal Support of R and D in the Private Sector," *Priorities and Efficiency in Federal Research and Development,* Joint Economic Committee of Congress, October 29, 1976; his testimony before the House Committee on Science and Technology, published in *Federal Research and Development Expenditures and the National Economy* (Washington: Government Printing Office, 1976); and G. Eads, "U. S. Government Support for Civilian Technology: Economic Theory vs. Political Practice," *Research Policy* (1974).

29. An important point to bear in mind is that the models used here cannot cope with innovations whose effects cannot be regarded as a form of cost reduction. This limitation is likely to be much more important for very major innovations than for lesser ones.