FORMAL ENTREPRENEURSHIP THEORY IN ECONOMICS: EXISTENCE AND BOUNDS

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EXECUTIVE SUMMARY

Theoretical analysis often can penetrate difficult economic problems in circumstances where common sense is an unreliable guide to decision making. This paper provides some new theoretical problems related to entrepreneurial decisions and behavior. For example, it investigates the optimal timing of the introduction of an innovation. Typically, in practice, innovation is a continuous process. The longer the delay in the transfer of a new product from the R&D facilities to manufacturing and marketing, the more the product is likely to be improved. But that delay also gives competitors an enhanced opportunity to get there first. This paper shows how this trade-off can be analyzed systematically, and yields some surprising results about the optimal decision on the timing of the introduction of the new product.

1. THE ISSUE

The entrepreneur is the specter who haunts our economic models. It seems to be taken for granted in the literature that, even if entrepreneurs are not in complete control of our economic destiny, they influence its direction as few, if any others, are able to do. But having acknowledged this, implicitly or explicitly, normally no more is done to incorporate the entrepreneur's role into the mainstream models of value theory or the theory of the firm. This supposedly key person is rarely mentioned, and construction of the models simply proceeds without him or her.

Yet there *does* exist a body of entrepreneurship theory in economics. It even provides a rich store of insights pertinent both for understanding of behavior and for formulation of policy. On the other hand, by the very nature of its subject, severe limitations do circumscribe

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what the theory is able to do. There are things that one can reasonably hope to obtain from such a theory, and it does in fact provide such results. There are other things it probably cannot be expected to do, for reasons I hope to explain, and these limitations account both for the degree of disappointment that analysis of the subject has elicited and for the entrepreneur's absence from the standard formal analyses of microeconomics.

This paper has three purposes: first, it will seek to describe the reasons that some sides of entrepreneurship do not lend themselves to the sort of formal theoretical analysis that has been provided by the economic literature for other inputs of the productive process. Second, it will deduce from those observations just what an economic theory of entrepreneurship can and cannot reasonably be expected to accomplish. Finally, it will seek to show, with the aid of some illustrations, that a body of theory of entrepreneurship is not mere aspiration for the future—but that it exists, that it is being expanded, and that it works.

It should be emphasized that the discussion that follows is deliberately circumscribed because of limitations of the author's knowledge, to exclude the contributions, actual and prospective, of sociologists, psychologists and specialists in business management, to the understanding of what the entrepreneur does and what it is that makes him/her tick. There is, no doubt, much to be learned from these disciplines, but their contributions are of necessity excluded from the following discussion. One consequence is that none of the material that follows pretends to teach anyone how to be a better entrepreneur. But it is hoped, nevertheless, that the material has practical applicability in another arena—encouragement and enhancement of the entrepreneur's contribution to productivity growth and competitiveness of the economy.

2. A FEW REMARKS ON DEFINITION

Ivan Bull's very helpful paper on the theory of entrepreneurship (1991, pp. 1–3) reminds us of the profusion of definitions that have been offered for the term. He is clearly right in concluding that " . . . the search for a definition need not impede the search for a theory of entrepreneurship." In good part, this is so because many of the definitions that he cites are better considered to be complementary rather than competitive, each seeking to focus attention on some different feature of the same phenomenon. It is surely appropriate for two authors to differ in the aspects of the entrepreneur that they find it useful to emphasize, and the choice of one author need constitute no impediment to the pursuit of a slightly different side of the subject by the other.

There are, however, two uses of the term "entrepreneur" which, though both legitimate, are entirely different in their substance. One uses the term to refer to someone who creates and then, perhaps, organizes and operates a new business firm, whether or not there is anything innovative in those acts. The second takes the entrepreneur as the innovator—as the one who transforms inventions and ideas into economically viable entities, whether or not, in the course of doing so they create or operate a firm. The entrepreneur of Cantillion or Say is of the first variety, whereas that of Schumpeter is clearly of the second. As Schumpeter defined his subject " . . . the function of entrepreneurs is to reform or revolutionize the pattern of production by exploiting an invention or, more generally, an untried technical possibility for producing a new commodity or producing an old one in a new way . . . [this] requires aptitudes that are present in only a small fraction of the population . . ." (1947, p. 132). For convenience, I will refer to the former as the firm-organizing entrepreneur, and the latter as the innovating entrepreneur.

Both types of entrepreneur are important for the performance of the economy, but they differ profoundly in their roles, the nature of their influence, and the type of analysis their role

requires. There are plenty of entrepreneurs of each variety. The person who opens a new grocery or a new fast-food restaurant is simply repeating, in essence, what has been done a thousand times before; yet that individual's act is entrepreneurial in the first of the two senses. The many persons who have worked doggedly within their corporations, first to convince their managements of the economic promise of an invention, and have then struggled, typically for years, to transform that invention into a viable product, are entrepreneurs of the second variety (for a profusion of examples, see Diebold 1990).

Most of what will be said here focuses upon innovating entrepreneurship. It is the innovating entrepreneur of whom we think when we are concerned about economic growth and progress in productivity. For it is widely agreed that achievement in this arena is heavily dependent on constant discovery and employment of new and more effective ways of doing things and the introduction of new and better products. We will also see that it is the innovating entrepreneur, and not the firm organizer, whose role is inherently difficult to describe and analyze systematically, and who is really absent from the standard models of the firm. The role of the organizer of a firm, though indisputably enterprising, is at the same time very close to the position of the manager. The activities of management, though rarely mentioned explicitly in most formal models of the firm, are nevertheless very much present and can even be taken to constitute the central focus of the analysis.

3. LIMITS TO ANALYSIS OF THE ROLE OF THE INNOVATING ENTREPRENEUR[1]

The reason we have such difficulty in describing and analyzing the role of the innovating entrepreneur is all but obvious. By definition, that individual's acts *cannot* be mere repetition of what has been done before. They must entail the introduction of something unprecedented and unexpected. In contrast, an input of any other type is likely to be used today in much the same way as it was yesterday, and the logic of decisions on its use does not undergo constant change. For example, when management considers whether to borrow additional funds, and if so, how to use them, it repeats calculations that it has probably carried out a thousand times before. The calculation of discounted present value and other associated considerations has remained fundamentally unchanged for decades if not for centuries. One can readily describe the process, one can represent it formally, and one can even determine the requirements of optimality in the decisions.

In contrast, the work of the innovator makes fascinating reading just because it always entails something different from what has happened before, and because the story is always full of surprises. We can, of course, describe *ex post*, what some entrepreneur did at some point in the past. But that description can depict only an activity that was entrepreneurial then, though it is such no longer. We know only that whatever it is that the innovating entrepreneur is doing today, it must differ from what his/her ancestor did before.

Not being in any sense routine, much of the innovating entrepreneur's decision process is beyond systematic calculation. It must proceed on the basis of what Kirzner (1985, p. 7) has referred to as "alertness," on instinct, hunch, and inspiration. The work of the innovating entrepreneur has been likened to the task of the military strategist operating on the field of battle, where there is enormous advantage to surprise, where one must be prepared to adapt quickly to unanticipated developments, and where instinct is the guide on which one is ultimately forced to depend.

[1] Much of the material in this section is based on Baumol (1968).

The theory of the firm has based its results almost entirely on the premise of optimization. Firms are taken to hire the profit-maximizing number of workers, to retain optimal quantities of inventory, to apportion their capital optimally among the company's various products—those that constitute its most profitable product line. Mathematicians have provided to economics a set of powerful tools for the analysis of optimal decisions, including the differential calculus, mathematical programming, and the theory of games. Economists, in turn, have put those tools to good use in deriving illuminating theorems about the profit-maximizing behavior of the enterprise. A number of these have provided results that were surprising, and they have proved useful in application as tools of consulting and management science.

But that is precisely why the innovating entrepreneur has been barred from the formal economic theory of the firm. Because it must constantly change, we have difficulty in providing any sort of general description of what he/she does, except in the broadest and most vague of terms. This, in turn, precludes any useful translation of such a description into the language of mathematics. And that largely rules out systematic optimization calculations. The range of options available to the entrepreneur at any given time is largely unknown, and the consequences of any choice among them is unexplored. Thereby, the basis for any calculation of optimality is entirely removed. Thus, there simply is no room for the innovating entrepreneur and his reliance on hunch and instinct, in the world of the theory of the firm where every actor's move is assumed to be controlled rigidly by the dictates of sophisticated optimality calculations.

These same observations also indicate why it is so difficult for a school of business to train students to be innovating entrepreneurs. The schools, too, can equip themselves to teach what entrepreneurship was in the past, but that may be as useful as a course on the strategy of Gustavus Adolphus in the Thirty Years War would be at West Point. Indeed, the very act of teaching what an entrepreneur did yesterday, or of describing it in a text book, tends to transform it from an innovative act of entrepreneurship into a routine act of management. This statement is not intended to denigrate the task of management, which is clearly of crucial importance, but to differentiate between this activity and that of the entrepreneur.

All of what has just been stated about the innovating entrepreneur is in marked contrast to the position of the firm-organizing entrepreneur, who is very much present in the model of the firm, or is at least represented by a caricature, dehumanized and transformed into a calculating robot. The entrepreneur's decision on whether to launch a new firm is described formally in terms of a comparison of the present values of the stream of anticipated revenues and costs, of course, after suitable adjustment for uncertainty. Decisions on the purchase and allocation of resources of the firm are clearly analyzed in every model of the enterprise, as is every other major decision of the firm-organizing entrepreneur. Though one may well conclude that the models oversimplify and rigidify those decisions, one can hardly argue that the firm-organizer's problems have been ignored by the theory. Rather, it is difficult to think of any such problem that the theory either leaves out entirely or is utterly incapable of handling. Professor Coase's classic discussion of the firm (1937) addresses itself to what the existence of a firm can achieve, and so deals implicitly with the achievement of the entrepreneur who organizes a new business. The theory of contestable markets deals with decisions both on the subject of entry and those that arise thereafter, in the simplest and perhaps least realistic of worlds in which the market functions perfectly. The messier problems of internal organization and contracting where markets are less perfect are addressed in Professor Williamson's transactions-cost analysis (1985).

Thus, the firm-organizing entrepreneur by no means lacks theoretical treatment. Decision problems are considered extensively in the current models of the business enterprise.

Despite the fact that the entrepreneur is never mentioned by name, he/she is very much present in all those models. For he/she is represented, whether realistically or not, as the personification of the very act of optimality calculation. Invariably optimal decisions are attributed to him/her and, if in reality, his/her decisions are not always even approximately optimal, this representation does not lose its pertinence entirely, because it can serve as a guide for improvement of those decisions.

For reasons implicit in the preceding paragraph, firm-organizing entrepreneurship *can* be taught in the business curriculum. One can teach what the prospective entrepreneur must consider before deciding to launch a new business. Here one can teach not only the principles that emerge from the economist's models but also a variety of other pertinent considerations, such as legal restrictions, the influence of unions and politics, and a host of other vital and relevant matters. The same can be said about the multitude of decisions that will confront this entrepreneur once the firm is in operation. Because the theory of the activities of the firm-organizing entrepreneur not only exists but also flourishes, there is no lack of materials on the subject to impart to the student.

It is to be noted, again, that there is a close resemblance between the firm-organizing entrepreneur and the member of management; indeed, it is by no means clear that there is anything to be gained by seeking to distinguish between the two. For our purpose what is important is that what they do, characteristically, has often been done before by others if not by themselves, that these activities can to a considerable extent be transformed into routines, and that much of what they do can, consequently, be analyzed fruitfully with the aid of the tools of optimality calculation. As Schumpeter put the matter " . . . [as] innovation itself is being reduced to routine . . . so many more things can be strictly calculated that had of old to be visualized in a flash of genius" (1947, p. 132).

4. WHAT THEORY CAN USEFULLY SAY ABOUT THE INNOVATING ENTREPRENEUR

If the preceding arguments are valid, theory does not promise to be of help in telling us what the innovating entrepreneur does, or in providing a systematic body of analysis that will show how he/she can improve performance. There do remain at least two areas in which one can hope to learn more about innovating entrepreneurship. First, one can aspire to discover the attributes of the individual that are likely to lead a person to embark on an innovator's career, as well as those attributes that are associated with success in the undertaking. Second, one can seek to find out how current institutional arrangements or other social or economic phenomena affect the quantity of entrepreneurial effort, the directions it takes and the likelihood of its success, perhaps at the same time studying the reciprocal effects of entrepreneurial activity upon those institutional arrangements.

The first of these tasks, the discovery of the attributes of an entrepreneurial personality, is certainly promising. There is no reason to doubt that it can be carried out to some reasonable degree of approximation or that, when done, it will be valuable and enlightening. But the task seems to fall outside the purview of economic theory, both because it is primarily an empirical rather than a theoretical matter, and because it calls for the skills of the psychologist or the sociologist rather than those of the dismal scientist.

This leaves us with the second task as the prospective domain of economic theory in the study of innovating entrepreneurship, and it is here that pay dirt already has been hit upon and is likely to be hit upon again. When we speak of an innovating entrepreneur as a prime instrument of growth, we are already entering this arena, for that is a reference to an economic

consequence of the entrepreneur's activity. Once we probe further and investigate just how that activity serves to stimulate growth we proceed in greater depth with the second remaining task.

The Schumpeterian model, the deservedly best known foray into the theory of entrepreneurship, is a prime example. The model makes no attempt to deduce what the innovating entrepreneur does or how he/she can do it better. True, Schumpeter does provide a very generalized list containing five broad classes of innovative activity. But that portion of the work makes no pretense of constituting a piece of theoretical reasoning. Rather, it is a mere listing of the types of pertinent activity that the author has been able to think of. Theoretical analysis really enters the discussion when Schumpeter turns to the enhancement of profits made possible by innovation, which, in turn, constitutes a stimulus for imitation that finally brings the flow of innovator's profits to an end. This model is designed to show why the innovator must search constantly for yet other novelties if the flow of profits is to be held steady—why he/she is forced to keep running in order to stand still. Thus, the model leads us to abandon the view of the innovator's role that takes him/her to be a haphazard contributor of new products, processes, etc., who introduces such things intermittently and with timing that is determined fortuitously. Rather, he/she is seen now as a driven individual whose hand is forced by the pursuit of profits, and to whom a hiatus in the flow of innovations is not tolerable. The model focuses upon three relationships: 1) the effects of innovation upon profits; 2) the effects of innovation upon the activities of imitators; and 3) the effect of the behavior of profits on the activities of the innovating entrepreneur. Thus, every component of the structure of the model deals either with the consequences of entrepreneurial activity for other economic phenomena or with the reverse of such a relationship. The theory is fruitful and illuminating even though it is (necessarily) vague about what the individual entrepreneur does, and provides no calculus for the determination for what constitutes optimality in the entrepreneur's decisions.

The next section will offer some further illustrations that are rather less familiar, showing that theory can and does cast light upon the role of the innovating entrepreneur, even though it tells us little about what he/she does and provides little basis for advice on how to improve performance.

5. THEORY OF INNOVATING ENTREPRENEURSHIP: A FEW MORE EXAMPLES

The illustrations in this section are drawn from my just completed book on the theory of entrepreneurship.[2] My excuse for this egocentric course is that it will offer my audience concepts with which they are not yet familiar. With one exception, in what follows the results will be reported in terms that are literary rather than formal, and intuitive explanation rather than rigorous derivation will be stressed.

Example 1: Fluctuation in the Supply of Productive Entrepreneurs[3]

When the pace of productivity growth of an economy slows, one frequently hears part of the blame attributed to a falling off in the supply of entrepreneurs or a weakening of the spirit of entrepreneurship. This is spoken of in a way that suggests that there has been an unforeseen

[2] *Entrepreneurship, Management and the Structure of Payoffs*, to be published by MIT Press, 1993.

[3] For more on this see Baumol (1990).

break in social tradition and cultural pattern or even that the nation's genetic structure has undergone an unexplained mutation. The reverse explanation is offered for any sharp acceleration in the growth of another economy. Of course, such a discontinuous break in national character is not impossible, and may well occur from time to time. But it is hardly the simplest available explanation—the one favored by Occam's Principle. The first difficulty raised by this view is that it is hardly an explanation in itself, and that it merely puts off the task of accounting for the alleged break in cultural or genetic patterns. Second, as we will see, a simpler theoretical model can account for a sudden falling off or expansion in the supply of productive entrepreneurship. Finally, the cultural/genetic view of the matter condemns policy to impotence, at least until social and genetic engineering achieve a degree of competence and daring that they hardly aspire to, at least so far. We simply do not know how to go about modifying cultural or genetic influences in a way that promises to stimulate substantially the flow of entrepreneurial effort and ability.

The difficulty with this view of the subject is that it treats entrepreneurship as though it differed from all other inputs in a way that it clearly does not. In the analysis of any other input, the issue addressed perhaps before all others is the allocation of that resource among its alternative employment opportunities, with the recognition that in some occupations it will contribute more to production than to others. Theory emphasizes that what it refers to as "distortions" in the price of labor or land or any other input is likely to lead to inefficiency in its allocation—to its assignment to occupations in which its contribution to production is less than maximal.

It is not difficult to provide evidence that entrepreneurial talent also is subject to reallocation by changes in the relative prices it commands in different occupations. After all, there is every reason to believe that the primary objective of the typical innovating entrepreneur is the accumulation of personal wealth and not just contribution to the productivity of the economy for its own sake. If there is money to be made by improvements in steel production processes, one can be confident that persons with entrepreneurial talent will appear in that sector of the economy. But if a far greater return is offered to innovative devices for financial manipulation, entrepreneurial entry into that field will not be long delayed. Burton Malkiel and I are conducting a study of MBA students, their course selections and their compensation levels after their degree has been obtained. We firmly believe that the data will confirm that course selections closely followed the pattern of sharp changes of the relative rewards of different areas of concentration such as production management, advertising, and financial activities like "risk arbitrage." If this turns out to be so, it will constitute evidence for the view that when the supply of productive entrepreneurs declines this is likely to be attributable not to an autonomous contraction in the total number of innovating entrepreneurs, but to a change in the structure of rewards that has led the entrepreneurs to transfer their innovative talents from production to rent seeking or worse. This view of the matter clearly has the virtues of simplicity and plausibility, and it constitutes a denial of both the irrelevance of theory and the impotence of policy. It restores the relevance of the massive body of theory that devotes itself to the analysis of resource allocation, treating entrepreneurship, in this respect, as yet another resource subject to the allocating influences of the price mechanism. And it reminds the policy-maker that he/she possesses instruments that can effectively influence the allocation of entrepreneurial resources. Thus, for example, removal of the tax exemption of debt held for only short periods might have cut sharply into the profitability of junk-bond financing, and could have led to a flow of entrepreneurial talent from the design of leveraged buyouts to the improvement of manufacturing processes. This example of possible policy is not meant as a serious discussion of appropriate policy design.

It is intended only to suggest the sort of measure that is called to our attention by the theory that takes entrepreneurship to be an input allocable between more and less productive occupations by changes in the structure of prices and pecuniary rewards.

Example 2: Intertemporal Efficiency of the Market and Technology-disseminating Entrepreneurship

A rather mysterious feature affects the economic theory that supposedly explains the productive superiority of the market mechanism. All the empirical evidence on the market's accomplishments emphasizes its dynamic achievements—its stimulation of the flow of new products and processes that underlay the historically unprecedented growth in productivity and per-capita output of the last two centuries. Yet economic theory gives the market high marks primarily for its contribution to static efficiency in its allocation of resources, which economists from Adam Smith to Arrow and Debreu have made the focus of their analysis. In contrast, the theory almost suggests that free enterprise constitutes a serious impediment to at least one of the primary requirements of intertemporal efficiency. Although it is clear that maximal growth requires rapid dissemination of technological advance so that all producers can make use of the new products and processes as quickly as possible, the standard depiction of the innovating firm is that of a hoarder of new ideas that uses patents, secrecy, and whatever other means come to hand to prevent or delay as much as possible the use of their ideas by others.

The facts suggest that if this is indeed one of the goals of the business firm it is, fortunately for society, a dismal failure in its pursuit of this purpose. Studies of the speed of technology transmission (see Mansfield 1985; Tilton 1971) suggest that innovations typically "leak out" to other firms and other economies in periods estimated to range typically from 1–2½ years. It is easy to provide a profusion of examples of the rapidity with which technology transfer occurs. But the strongest indication is the extraordinary similarity in the products and productive processes used by the leading firms in the world's industrial economies. German, Japanese, and American cameras, cars, and computers follow one another with startling speed in the range of features they offer, in the use of computers and robots in their production process, etc. These similarities would be virtually impossible to explain if technology transfer were a slow and unreliable process.

Then how does one account for the apparent failure of innovators to prevent the rapid diffusion of their ideas? Though it is undoubtedly not the entire story, the theory of entrepreneurship offers two components of such an explanation.

A. The Imitative Entrepreneur

Ever since the beginnings of the industrial revolution and undoubtedly earlier, there has been a group of innovative entrepreneurs who have found it profitable to allocate their talent to the innovative dissemination of technology. As Schumpeter implies, it is itself an innovative act to find a new place in which to use an invention, and frequently the resulting transfer also must be accompanied by product or process innovation as an item is adapted to a different climate or to a market with its particular consumer tastes, etc. Indeed, it has been common for some of the product modifications thereby introduced to be retransferred back as product improvements into the country where the initial innovation had occurred.

Economic historians document the movements of the peripatetic imitating entrepreneurs who came from England and made their fortunes by rapid dissemination of British innovations throughout Europe and North America. The DuPonts brought to the United States

the knowledge and skills of French chemistry, particularly in the making of gunpowder, and often the original innovators acted as their own dissemination agents, as when Fulton tried (but failed) to sell his steamboat (as well as his submarine and his torpedo) successively to Napoleon and to his British enemies.

The point is that there is money to be made by enterprising technology transfer, and some entrepreneurs have, consequently, allocated their efforts to the task. With capable and energetic individuals engaged in this lucrative occupation it is easier to see why the market has in fact achieved such a remarkable record in speed of dissemination.

Still, this view assumes that such transfer activity primarily serves to thwart the determined efforts of innovating firms to maintain the proprietary character of the new knowledge acquired by their own efforts. But there is both empirical and theoretical evidence suggesting that this view of the goals of the innovating firm is, at best, an oversimplification. Indeed, the second explanation for the market's record of rapid spread of technology that emerges from the theory of entrepreneurship is the argument that market forces, not only encourage firms (even those in direct competition with one another) to share their technological advances with each other, but that these market forces may often literally offer those firms no other option, and may provide liberal rewards to the innovative entrepreneur who organizes such an information exchange.

B. Technology-sharing Cartels

To see why the pressures of competition may force firms to share technology by means of reciprocal licensing of patents or other arrangements that are either more or less flexible than this, imagine an industry containing nine firms identical in size, offering identical products, with each company investing the same amount per year in cost-reducing R&D. The yield of such outlays is inevitably uncertain, but assume that for each firm the expected yield of the process innovations that emerge is a .5% reduction in unit cost from the level of the preceding year.

Suppose, now, that eight of the firms decide to constitute themselves into what I refer to as a "technology-sharing cartel" in which each firm makes available to each of the other members the results of its own research, expecting in return full access to the results obtained by others. The ninth firm, however, decides to stay out of the cartel and to retain proprietary control over whatever information its research yields.

A moment's thought shows that any member firm, call it A, will acquire an enormous competitive advantage over the holdout firm, X. First, though both firms' R&D activities will have the same expected yield, A will automatically acquire at zero cost what amounts to an insurance policy against failure of its own efforts in any particular year, because it will be privy not only to its own results but also those of its seven cartel partners, and the probability of failure of the efforts of all eight firms is clearly considerably lower than that of any one of them. Obviously, firm X benefits from no such insurance.

More important, the cost reduction expected by firm A will not be .5%, but will be closer to[4] .4% because A can make use of the inventions contributed by all eight cartel members. And in this scenario, the near 4% rate of reduction in cost is likely to be enjoyed by A year

[4] It is likely to be somewhat lower than that both because there may be some duplication of the research results obtained by different cartel members and because technology transfer is really not quite free. It takes time, it is likely to require special staff training, and entail the cost of getting rid of the "bugs" that almost always plague innovations during the period immediately following their introduction.

after year. In contrast, holdout firm X can expect a cumulative rate of cost reduction of .5% a year. It should be obvious that, unless something else occurs to save it, firm X cannot hold out against this competitive pressure very long. It simply will find it increasingly difficult to match the constantly declining prices of its rivals, and will either be forced to join the cartel (if the cartel is willing, belatedly, to admit it) or it is apt to face insolvency.

A moment's consideration will confirm that there is nothing pathological about this scenario. While it need not hold universally, for reasons that space prevents me from discussing here, it should be clear that the story has wide applicability. Thus, it should not be surprising that empirical researchers such as von Hippel (1988) have confirmed that there is, indeed, a considerable amount of technology-exchange activity among firms.

Thus, the cartel-organizing entrepreneur contributes in this way to the efficiency of the market as a mechanism of technology transfer, and thereby helps to account for the intertemporal efficiency of the market mechanism. There is a good deal more to this portion of the theory of entrepreneurship. For example, the theory has provided materials on the stability properties of such cartels, and on their consequences for economic welfare. But enough has been said here to offer some flavor of the theoretical analysis, and to demonstrate that the theory exists and offers some illuminating insights.

Example 3: Routinization of Innovation and Optimality in its Timing

The spectacular success of the work of the innovating entrepreneurs in the last century has simultaneously increased the dependence of the firm on continuity in the stream of inventions, at least in a number of industries characterized by rapidly evolving technology. For reasons made clear by Schumpeter, both in order to prevent the erosion of profits as a consequence of the incursions of imitators and to keep up with rival enterprises that have a record of successful imitation, firms have increasingly sought to reduce to a minimum the uncertainties of the innovation process. More and more they have established R&D divisions whose task it is to ensure a more-or-less steady flow of innovation. Special budgets are dedicated to the purpose—the magnitude of these funds and their allocation being decided by the company bureaucracy, and their administration entrusted to persons who are managers more than entrepreneurs. The expanded role of routinization of the innovation process is documented, and the data indicate, for example, that well over half the new patents in the U.S. emerge from such sources rather than the basements and garages that are the stuff of popular views of the invention process. One implication is that the success of the activities of the innovating entrepreneur has served to elevate the position of management in the innovation process. A second consequence is that the pertinence of optimality calculations has partially been restored. I will end this section with a concrete illustration of such a calculation—one dealing with the optimal timing of the introduction of an innovation to the market.

What few nonspecialists recognize about the innovation process is that the moment that someone finds it appropriate to shout "Eureka!" is normally the point at which the major R&D effort first begins. It typically takes years from this date before the novel item has been improved to a point where it constitutes an economically viable product. "It is not unusual for several hundred times more man-hours to be required for development than for invention" (Diebold 1990, p. 18). Elimination of the problems, reduction of costs, and the other steps required for development, constitute a continuous process. By delaying the introduction date, a better product can be obtained—one that elicits fewer customer complaints and is less vulnerable to competition. However, delay postpones the flow of benefits to the company from the sale of the new product and increases the risk that a rival will beat it to the punch.

When, then, is the best innovation-launching date, in view of this trade-off between the rewards of speed-up and delay?

The problem of optimal choice of introduction date is formally identical to another problem that is familiar to all of us—just when should one buy a new computer, given the fact that tomorrow cheaper and better models will almost certainly be available? We will see next that mathematics can supply the answer, at least in theory. It will also be shown that optimization analysis can help us to answer the following and more difficult question. Suppose that there is an increase in the pace of the development process for our innovation (in the rate of technical progress in computer models). Will that mean that the innovation should now be introduced earlier than it would have been before, because an acceptable product will have been obtained earlier? Or should the introduction date be delayed, because a little additional time will offer incremental returns greater than before? We will see that the answer is somewhat surprising.

The entire discussion will be framed in terms of the optimal timing of the purchase of a computer, because it is easier to grasp intuitively. However, it is clear that exactly the same logic and results apply to the optimal timing of an innovation.

Here I will deal only with the simplest case, the one *in which the only effect of progress is to reduce cost and, hence, purchase price.* This restriction permits direct quantification of the rate of technical progress. The sole purpose of the product in question is assumed to be the (constant) stream of revenues that it yields to the purchaser.

We use the following notation:

R = the flow of revenues per unit of time, before the purchase

S = the same after the purchase date (where $S > R$)

Ce^{-wT} = the purchase price of the improved product at time T

r = the (continuously compounded) rate of interest (discount)

w = the rate of cost reduction through technical progress

T = the purchase date

B = the present value of the net benefits to the buyer of purchasing and using the computer.

Then, the consumer's objective is to maximize

$$B = \int_{t=0}^{T} Re^{-rt}dt - Ce^{-(r+w)T} + \int_{t=T}^{\infty} Se^{-rt}dt, \tag{1}$$

that is (by straightforward integration) to maximize

$$B = R/r + (S - R)/re^{rT} - Ce^{-(r+w)T}. \tag{2}$$

Thus, the first-order maximum condition becomes

$$B_T = (R - S)e^{-rT} + (r + w)Ce^{-(r+w)T} = 0 \tag{3}$$

where we write B_T for the partial derivative of B with respect to T. As is to be expected, equation (3) simply tells us that the equilibrium requires the marginal opportunity cost of delay, in the form of foregone gain, $S - R$, to equal the associated marginal cost-reduction yield achieved through continuing improvement in technology, as well as through postponement of expenditure. Equation (3) is our desired formula, implicitly giving the optimal computer purchase date, T.

Let us turn, next, to the critical issue—does speeding up the rate of technical progress hasten or postpone the optimal purchase date? To answer this we must find the response of T, the optimal purchase date, to a change in w. The answer is obtained through the usual procedure of comparative statics. Rather than describing the familiar calculations here, I will merely report the answer they give, and use two graphs to provide an intuitive explanation.

The curious implication of the mathematical analysis is that the rise in w calls for postponement of the optimal purchase date of the product if that date is relatively early in a regime of slower technical progress, and for a hastening of that purchase date if the date was relatively late under such a regime. Let us try to find an intuitive explanation for this apparently curious result.

Here, the geometry of the matter is of some help. Figure 1 is a graph of B (equation 1), the total benefit the consumer derives from a purchase of the novel item, as a function of the date the purchase is made. The graph only suggests the asymptotic approach of the benefits curve to the horizontal axis as one moves toward the right—asymptotic behavior as the cost of the product approaches zero with the compounding of cost reduction over time that is crucial for the explanation we seek. In the case shown, the selected rise in the value of the improvement rate, w, leads to a slight rightward move in the highest point of the curve and, hence, to an increase in the optimal value of T.

However, insight into the matter is offered only in Figure 2, which plots (3), the curve of *marginal* benefits of waiting, taken as a function of T, that is, it shows the behavior of B_T, the partial derivative of B with respect to T. It also shows the effect on that marginal benefit curve of a change in the value of w. We see that a rise in w has two consequences.

First, it raises the vertical intercept of the B_T curve, that is, it adds to the initial benefits

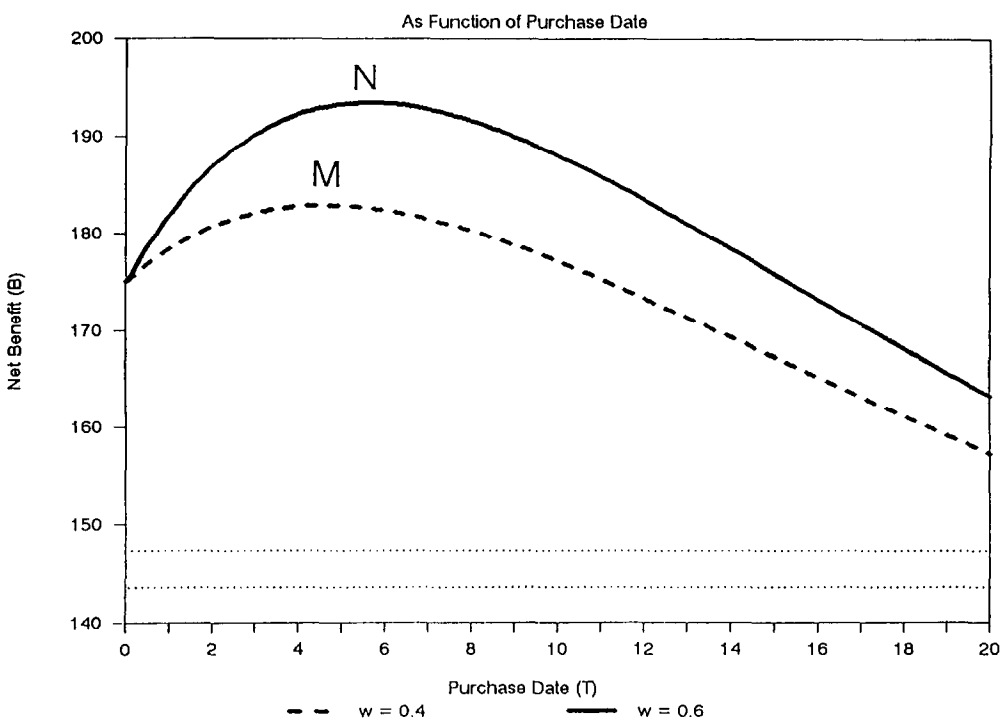

FIGURE 1 Net purchase benefits.

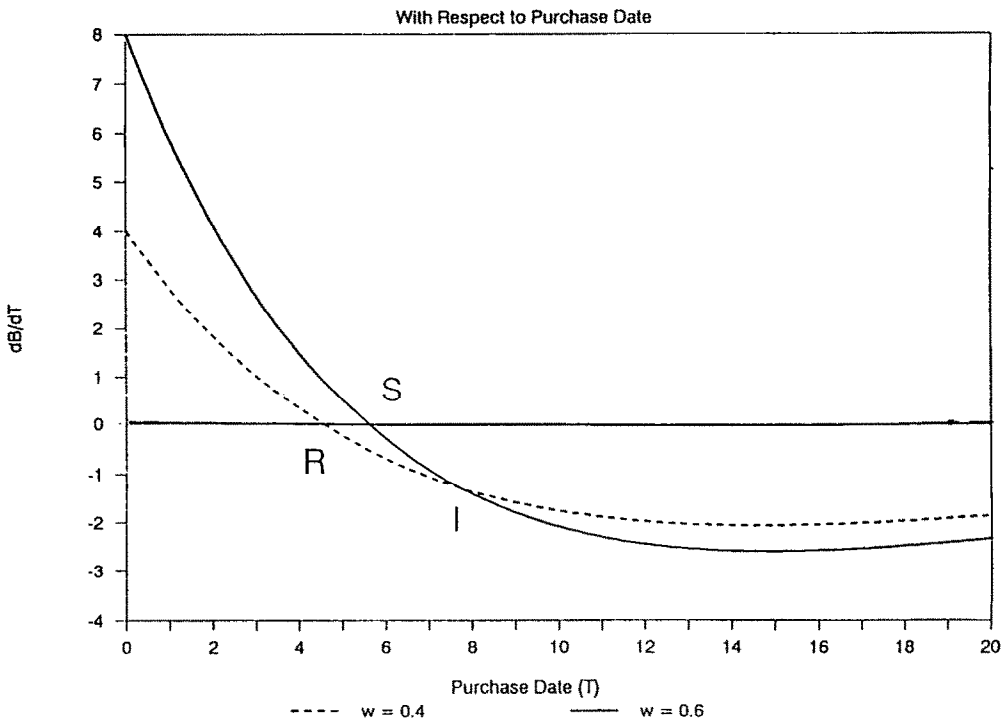

FIGURE 2 Derivative of net benefits.

of delay—the marginal benefit of a unit addition to the elapse of time before buying, by offering the consumer a less costly product as a reward for waiting, with the product's marginal reduction in price greater than that corresponding to a more modest value of w.

Second, the rise in w must ultimately *reduce* the height of the marginal benefits curve, B_T, by ensuring that the cost of the product, having approached zero sooner, must begin to level off at a lower value of T, meaning that there remains relatively little more to be gained through further postponement of the purchase date. The initial heightening and later lowering amounts to a rotation of the curve.

The net effect of the initial raising and later lowering of the benefits curve when there is a rise in w is that the curve corresponding to the higher value of w must at some point, I, intersect the marginal benefits curve for the lower w. Now, that means that if the optimal value of T, corresponding to the first-order requirement $B_T = 0$ (point R or S) lies to the left of I, as in the diagram, then the rise in w will increase the reward of additional waiting before buying. Thus, the optimal point, corresponding to the intersection of the B_T curve with the horizontal axis, will move to the right (the move from R to S). However, if the optimal point had been to the right of I, then the effect of the rise in the value of w would have been the reverse, because for high values of T, the marginal reward of additional waiting is thereby reduced.

Put more simply and intuitively, a speeding up of technical progress increases the marginal (cost-saving) return to delay in the introduction of an innovation (the purchase of a computer) if the optimal introduction date is relatively early. However, later on, as the total cost approaches zero asymptotically, there is little more to be gained by additional waiting;

indeed, there is now a reward for acting sooner than before. That is the reason for the curious result on the effect of an enhanced pace of technical progress, all obtained with the aid of a standard optimality (and comparative statics) analysis.

5. CONCLUSION

More illustrations of theoretical analysis of the work of the entrepreneur are easily provided, but I believe that more than enough have already been offered to make the point.

I think it has been demonstrated here that theory of entrepreneurship *does* exist, and that it is powerful and illuminating. I have argued that there are limits to what it can be expected to do. However, once those limits are understood and respected, one can proceed to carry the theoretical analysis further, and to mine it for further illumination on the role of the entrepreneur.

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