8 SMALL FIRMS: *Why* MARKET-DRIVEN INNOVATION CAN'T GET ALONG *Without* THEM

Synopsis

William Baumol[1] has provided striking evidence indicating that private innovative activity has been divided by market forces between small firms and large, with each tending to specialize in a different part of the task.[2] Even though the preponderance of private expenditure on research and development (R&D) is provided by the giant business enterprises, a critical share of the innovative breakthroughs of recent centuries has been contributed by firms of very modest size. These radical inventions then have been sold, leased or otherwise put into the hands of the giant companies, which have then proceeded to develop them—adding capacity, reliability, user friendliness and marketability more generally—to turn them into the novel consumer products that have transformed the way Americans live. Baumol has referred to this division of labor as the "David-Goliath partnership," the value of whose combined products clearly exceed the sum of the parts.

To the extent that the facts confirm this characterization, it is evident that the small enterprises have made and continue to make a critical contribution to the market economies' unprecedented growth and innovation accomplishments. Without breakthroughs such as the airplane, FM radio, and the personal computer, all introduced by small firms, life in the industrialized economies would be very different today. Moreover, without these breakthrough inventions to build upon, the big companies would be confined to a much more restricted body of ideas to which to devote their development activities.

In recounting these broadly accurate tendencies, the author was not previously able to provide a tenable explanation. This left open the possibility that the observed division of labor was merely a historical happenstance, an accidental

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1 This chapter was prepared under contract with the Office of Advocacy by William J. Baumol, who expresses appreciation to Dr. Ying Lowrey of the U.S. Small Business Administration.

2 Baumol, 2002.

development. If that were so, it could imply that the breakthroughs were not necessarily something only the small firms could have provided. Then they would not have been indispensable players of that role and the oligopolies might just as easily have taken their place.

This paper seeks to show that the division of innovative labor is no accident. It is the market mechanism that assigns each type of firm to its differentiated job. It is the market mechanism that assigns the search for radical inventions to the small enterprises and their subsequent development to the large. The author describes how the market does so, and how it prevents either group from a massive invasion of the other's terrain. If, as the evidence indicates,[3] the free market is of critical importance for America's unparalleled flood of innovation, and if widely and rapidly adapted innovation is the primary key to that growth, then it will follow from the analysis that small firms are indeed indispensable components of the process and that rapid and sustained growth cannot get along without them.

First, Baumol reviews some of the evidence indicating that such a division is indeed a reality.

The Specializations of Large and Small Firms in Reality

Radical Invention and Incremental Improvements: The Role of Small Firms

For ease of thinking, it is convenient to divide up inventions into two polar categories: revolutionary breakthroughs and cumulative incremental improvements. Of course, many new products and processes fall into neither extreme category, but are somewhere in between. Still, it will become clear that the distinction is useful. Moreover, there are many examples that clearly fit into one of these categories or the other quite easily. For instance, the electric light, alternating electric current, the internal combustion engine, and a host of other advances must surely be deemed revolutionary, while successive models of washing machines and refrigerators—with each new model a bit longer lasting, a bit less susceptible to breakdown, and a bit easier to use—constitute a sequence of incremental improvements.

The relevance of the distinction should be evident, given the fact that the working and organization of R&D in the large business enterprise tends characteristically to be bureaucratic, with management deciding the R&D budget, staffing, and even the projects to which the R&D division should be devoting its efforts. The inherent conservatism of the process naturally leads to the expectation that these firms will tend to specialize in the incremental improvements and tend to avoid the risks of the unknown that the revolutionary breakthrough entails. The latter, rather, is left most often to small or newly founded enterprises, guided by their enterprising entrepreneurs. Though that is to be expected, the degree of asymmetry in the apportionment of this specialized activity between large and small firms in reality is striking. The U.S. Small Business Administration Office of Advocacy has prepared a chart listing breakthrough innovations of the twentieth century for which small firms are responsible *(Table 8.1)*, and as will be seen, its menu of inventions literally spans the range from A to Z, from the airplane to the zipper. This remarkable list includes a strikingly substantial share of the technical breakthroughs of the twentieth century. Besides the airplane, it lists FM radio, the helicopter, the personal computer, and the pacemaker, among a host of others, many of enormous significance for the U.S. economy.

A more recent study, also sponsored by the U.S. Small Business Administration's Office of Advocacy, provides more systematic and powerful evidence to similar effect.[4] The report examines technical change through patenting and it defines small firms as "businesses with fewer than 500 employees." Perhaps most notably, the study finds that "…a small firm patent is more likely than a large firm patent to be among the top 1 percent of most frequently cited patents." Among other conclusions, in the words of its authors, this study reports that,

- Small firms represent one-third of the most prolific patenting companies that have 15 or more U.S. patents.

3 See Baumol, 2002b.

4 See U.S. Small Business Administration, Office of Advocacy, 2003. Quoting the press release describing the study, "A total of 1,071 firms with 15 or more patents issued between 1996 and 2000 were examined. A total of 193,976 patents were analyzed. CHI [the firm that carried out the study] created a database of these firms and their patents. This list excluded foreign-owned firms, universities, government laboratories, and nonprofit institutions."

Table 8.1 Some Important Innovations by U.S. Small Firms in the Twentieth Century

Air Conditioning	Link Trainer
Air Passenger Service	Microprocessor
Airplane	Nuclear Magnetic Resonance Scanner
Articulated Tractor Chassis	Optical Scanner
Cellophane Artificial Skin	Oral Contraceptives
Assembly Line	Outboard Engine
Audio Tape Recorder	Overnight National Delivery
Bakelite	Pacemaker
Biomagnetic Imaging	Personal Computer
Biosynthetic Insulin	Photo Typesetting
Catalytic Petroleum Cracking	Polaroid Camera
Computerized Blood Pressure Controller	Portable Computer
Continuous Casting	Prestressed Concrete
Cotton Picker	Prefabricated Housing
Defibrillator	Pressure Sensitive Tape
DNA Fingerprinting	Programmable Computer
Double-Knit Fabric	Quick-Frozen Food
Electronic Spreadsheet	Reading Machine
Freewing Aircraft	Rotary Oil Drilling Bit
FM Radio	Safety Razor
Front-End Loader	Six-Axis Robot Arm
Geodesic Dome	Soft Contact Lens
Gyrocompass	Solid Fuel Rocket Engine
Heart Valve	Stereoscopic Map Scanner
Heat Sensor	Strain Gauge
Helicopter	Strobe Lights
High Resolution CAT Scanner	Supercomputer
High Resolution Digital X-Ray	Two-Armed Mobile Robot
High Resolution X-Ray Microscope	Vacuum Tube
Human Growth Hormone	Variable Output Transformer
Hydraulic Brake	Vascular Lesion Laser
Integrated Circuit	Xerography
Kidney Stone Laser	X-Ray Telescope
Large Computer	Zipper

Source: The State of Small Business: A Report of the President, 1994, prepared by the U.S. Small Business Administration, Office of Advocacy, 1995, 114.

- Small firm innovation is twice as closely linked to scientific research as large firm innovation on average, and so is substantially more high-tech or leading edge.
- Small firms are more effective in producing high-value innovations—the citation index for small firm patents averaged 1.53 compared to 1.19 for large firms.
- Small patenting firms are roughly 13 times more innovative per employee than large patenting firms. A small firm patent is at least twice as likely to be found among the top 1 percent of highest-impact patents as a patent from a large firm.[5]

One is, then, led to the plausible conjecture that most of the revolutionary new ideas of the past two centuries have been, and are likely to continue to be, provided more heavily by independent innovators who, essentially, operate small business enterprises. Indeed, the small entrepreneurial firms have come close to monopolizing the portion of R&D activity that is engaged in the search for revolutionary breakthroughs.

But having demonstrated the vital role of the small enterprises, does it follow that there is little left for the large enterprises to do? This concern may, moreover, be exacerbated when it is recognized that the bulk of the country's R&D spending is contributed by large enterprises. According to data gathered by the National Science Foundation,[6] in 2000, 46 percent of total U.S. industrial R&D funding was spent by just 167 companies, each of which employed 25,000 or more workers; that is, nearly half the business expenditure on R&D was provided by 167 giant firms of the more than 30,000 U.S. firms that engaged in such activity. Does it then also follow that the giant companies are spending a great deal to achieve very little? These concerns are misplaced, the author maintains.

5 U.S. Small Business Administration, 2003, 2.

6 National Science Board, 2000, 24.

The Significance of Aggregated Incremental Improvements by Large Firms

As noted, the type of innovation in which the giant enterprises tend to specialize is primarily devoted to product improvement, increased reliability and enhanced user friendliness of products and the finding of new uses for those products. The approach tends to be conservative, seeking results whose applicability is clear and whose markets are relatively unspeculative. The bureaucratic control typical of innovative activity in the large firm serves to ensure that the resulting changes will be modest, predictable, and incremental. These firms are not predisposed to welcome the romantic flights of the imagination, the entrepreneurial leaps of faith and plunges into the unknown that often lead only to disaster, but which alone are likely to open up new worlds. Nonetheless, the incremental contributions of the large firms' routine activity at least sometimes adds even more to economic growth than do the more revolutionary prototype innovations. Though each such small improvement may be relatively unspectacular, added together they can become very significant indeed. Consider, for instance, how little computing power the first clumsy and enormously expensive computers provided, and what huge multiples of such power have been added by the many subsequent incremental improvements.

A set of extreme examples of the contributions of the small, entrepreneurial firms appeared in Table 8.1. But one can easily obtain equally startling examples of the magnitude of the innovative contributions of large companies, whose incremental contributions can add up and compound to results of enormous magnitude. One such illustration is the progress in computer chip manufacture by the Intel Corporation, the leading manufacturer of this device that has brought to market successive generations of chips and transistors, on which the performance of computers is so heavily dependent. According to a recent report,[7] over the 1971–2003 period, the clock speed of Intel's microprocessor chips—that is, the number of instructions each chip can carry out per second—has increased by some *3 million percent*, reaching about 3 billion computations per second today. During the period 1968–2003, the number of transistors embedded in a single chip has expanded more than *10 million percent*, and the number of transistors that can be purchased for a dollar has grown by *5 billion percent*. These are no minor contributions. Added up, they surely contribute far more computing capacity than was provided by the original revolutionary breakthrough of the invention of the electronic computer. Of course, that initial invention was an indispensable necessity for all of the later improvements. But it is only the combined work of the two together that made possible the powerful and inexpensive apparatus that is so effective today.

7 John Markoff, "Technology; Is There Life After Silicon Valley's Fast Lane?," *New York Times*, Business Financial Desk, Section C, April 9, 2003, p. 1.

What Drives the Small Enterprise-Large Firm Specialization Pattern: The Role of Market Forces

The central contention here is that the division of innovative effort between small firms and large is neither accidental nor it easily terminated. On the contrary, strong market forces drive both actors toward these assigned roles and make it difficult for the entrepreneurs and firm managers to act otherwise. The distinction between the two explanations—historical happenstance versus market forces that induce or perhaps even enforce it—is important not only for research and understanding, but for policy as well, because it can help in anticipating whether this apparently efficient arrangement can be expected to continue with no deliberate intervention to preserve it, or whether some policy measures will be required for the purpose.

To begin to determine which of these two possible explanations is valid, it is necessary to provide a theoretical model, or at least a scenario with logical underpinnings that can account for the types of innovative activities in which the two classes of firms tend to specialize. Here one is driven to deal with "representative firms" in a sense even more amorphous than Marshall's,[8] because giant oligopoly firms are not all cut from the same cloth and entrepreneurial establishments are surely even less homogeneous in structure or behavior. Moreover, the explanation of the hypothesized division of labor between the two firm types will undoubtedly entail some shading at the edges, if it is to fit reality. At least some breakthrough technology has, of course, emerged from large and established corporations (such as the much-noted case of the

8 Alfred Marshall (1842–1924), a British economics professor at Oxford University, developed the economist's "analytical toolkit" with concepts such as price elasticity and the representative firm.

transistor, contributed by AT&T's Bell Laboratories and their special regulatory circumstances at the time), while the number of minor incremental improvements that have been contributed by new small firms is undoubtedly enormous.

It will be suggested here that there are nevertheless significant overall differences in the influences faced by the two types of enterprise, and that these differences can account for the division of innovative labor that one observes between them. Moreover, if these causal attributions are valid, it will follow that the specializations of the two types of firm are not markedly transitory but, on the contrary, can be expected to remain for a substantial period in the future.

What Drives the Pursuit of Breakthroughs by Innovative Entrepreneurial Firms?

The heterogeneity of enterprising behavior precludes any universally applicable scenario, particularly one that imposes a uniform response upon the entrepreneurial firms. In this respect, the story differs from that of the innovating oligopolists who, the author maintains, are normally driven in similar ways by powerful market forces toward their specialization in incremental improvement. For the small firm, several pertinent and important influences are also ingrained in the economic environment, but these are rather more amorphous, not stemming from a pure profit calculus or any market-imposed threat to their survival.

The focus here is on three mechanisms that characterize the relation between the market and the entrepreneurial firm. They can be suggestively referred to as: 1) the superstar reward structure; 2) the psychic rewards to innovative activity; and 3) the scarcity and cost disadvantage of large firm competition in the arena of breakthrough innovation. Each will be discussed in turn, but first an observation that relates to them all. As is to be expected, the market does provide clear incentives for entrepreneurs to undertake the hazards of radical innovation. But, paradoxically, each of the three mechanisms to be discussed entails *financial underpayment* of the average innovative entrepreneur. That is, it entails the expectation of financial returns lower than those to corporate employees with similar education and experience who provide comparable efforts.

A few preliminary words must also be said to avoid misunderstanding of just what it is that is to be explained. It is not the hypothesis here that a large percentage of entrepreneurs employ innovation in the new firms they create. On the contrary, the evidence, imperfect though it is, suggests that most new firms are virtual replicas of many firms already in existence, and there is nothing innovative about them. Second, there is no suggestion here that even among that relatively uncommon species, the innovative entrepreneur, the preponderant focus is on anything that can reasonably be deemed breakthrough innovations. Here again, casual empiricism indicates the reverse—that the bulk of the novelties they introduce are only slightly better mousetraps. So the claim is not that most entrepreneurs devote themselves to radical innovation or even to any innovation at all. Rather, the converse is proposed: that among the (rare) innovations that can be considered to be radical, a disproportionate share is provided by independent innovators and their affiliated entrepreneurs.

Thus, in what follows, it will be necessary to account, first, for the comparative paucity of breakthroughs that emerge from the sizeable labs and affiliated facilities of the large, established, and innovative firms. Second, why are a significant group of entrepreneurs and inventors, albeit a comparatively small one, willing to undertake the great uncertainties and the typically enormous personal effort that pursuit of this objective requires? The issue is not why there are so many that do so, but why there is a significant set of these adventurers at all.

Superstar Market Reward Structure, or the Multimillion Dollar Lottery

The most obvious incentive to which one can attribute the relatively frequent focus of independent inventors and their entrepreneur partners upon more radical ideas is, of course, the great wealth and enormous prestige that success in their undertaking appears to promise. Among inventor-entrepreneurs who are enduring legends are Eli Whitney, James Watt, Elias Singer, Thomas Edison, the Wright Brothers, and so on. Indeed, it is striking how familiar they are.

There is an immediate consequence: The enormous prestige and great financial rewards, *along with their rarity*, transform the innovative entrepreneur's activities into a lottery that offers just a few mega-prizes, like so many of the lotteries that now capture the headlines. An innovator's activity is like such a mega-lottery, or like the pursuit of an occupation that offers a limited number of superstar

positions. But the prize is available only to those who provide *breakthrough* innovations. A technological contribution that permits humanity to fly or to send messages through the air can elicit headlines, but a minor improvement in automobile door handles is hardly likely to compete. And just as multimillion dollar lotteries have a greater attraction than a thousand-dollar lottery of the local club, even though the latter's terms are better actuarially, the pursuit of breakthrough innovations surely has a very special attraction to the independent entrepreneur.

Monetary Compensation, Psychic Compensation

A very well-recognized attribute of lotteries is their built-in unfairness, as measured in actuarial terms. The average payout is sure to be less than the per-ticket-holder take of the lottery operator—that is why he is in the business. There is a somewhat similar loss prospect for the representative entrepreneur. In part, the willingness of innovators, like the buyers of lottery tickets, to accept these biased terms may be attributable to over-optimism or to sheer miscalculation. But that is hardly the end of the story. Each of these activities—innovative entrepreneurship and the purchase of lottery tickets—also provides an important payoff of a second sort. Both activities offer distinct psychic rewards, and not only to those who have already achieved success or who even have a real and substantial likelihood of success. The *prospects* of glory, of wealth and fame, are something of value even if they never materialize. They are, indeed, the stuff that dreams are made of. And for the entrepreneur, contemplation of imagined success is only part of the psychic reward. Reading the biographies of the great inventors, one must be struck by the fascination that the process of their work elicited, by the moments of triumph, and even by the pleasure of puzzle solving and experimentation, though punctured by frustration and exhaustion.

These observations find support in some significant economic data. There is systematic evidence[9] that the average earnings of self-employed individuals are significantly lower than those of employees with similar qualifications, and the same is presumably true, in particular, of self-employed innovative entrepreneurs. At least two studies support this hypothesis for innovative entrepreneurs. Thomas Astebro reports on the basis of a sample of 1,091 inventions that,

9 See, for example, Freeman, 1978.

"The average IRR on a portfolio investment in these inventions is 11.4 percent. This is higher than the risk-free rate but lower than the long-run return on high-risk securities and the long-run return on early-stage venture capital funds…the distribution of return is skew; only between 7 and 9 percent reach the market. Of the 75 inventions that did, six received returns above 1400 percent, 60 percent obtained negative returns and the median was negative."[10] Perhaps even more striking is the recent work of Nordhaus, who provides evidence showing how little of the efficiency rent goes to the innovator: "Using data from the U.S. nonfarm business sector, it is estimated that innovators are able to capture about 2.2 percent of the total surplus from innovation. This number results from a low rate of initial appropriability (estimated to be around 7 percent) along with a high rate of depreciation of Schumpeterian profits (judged to be around 20 percent per year)….the rate of profit on the replacement cost of capital over the 1948–2001 period is estimated to be 0.19 percent per year."[11]

Perhaps even more striking and more extreme is the phenomenon of open sourcing and shareware in computer programming. Here, a great and growing body of complex and valuable material has been painstakingly created, and much of it is evidently of enormous value in economic and other terms. Yet it has been created and offered to others with modest, if any, restrictions, and without financial reward. Thus, a much noted and much valued activity is produced with zero financial reward, a payoff evidently far below what the work could have elicited if performed inside an established business enterprise. But the enthusiasm of those involved seems equally manifest.

An explanation is readily available and follows immediately from the attributes of the activities just noted. The representative entrepreneur may indeed be underpaid in terms of financial reward alone. But his *total* payoff may be closer to what economic theory would lead one to expect, though part of the payoff takes a form other than money. It is as though he were being paid off in two different currencies: partly in dollars, partly in euros. In equilibrium, such two-coin payment recipients could clearly expect fewer dollars than someone

10 Thomas Astebro, 2003, 226.

11 Nordhaus, 2004, 34. Using a cruder and more intuitive approach the present author also reached a very low figure for the returns to innovation that are not dissipated in spillovers (see Baumol 2002b, pp. 134–5).

similarly engaged whose contract calls for payment only in that one currency.[12] That this is how markets work is easily confirmed by casual observation.

The story pertains not only to the entrepreneur. It recurs throughout the economy. The fact that multimillion-dollar lotteries are carefully and openly structured to be actuarially unfair means, as already noted, that the purchasers of tickets in such a lottery will on average and as a whole receive back less than they put into it. It is arguable that the masses of purchasers who endure long and time-consuming queues to grab up the tickets are not irrational but that they receive an adequate payment in another currency: the psychic rewards. That same scenario helps to explain, in another example, why despite the rigors of their training and the difficulties of their work, the typical earnings of dancers are so miserable.[13] One can easily think of other occupations with similar attributes.

And the reason is not just sheer willingness of the recipient of psychic benefits to be exploited in financial terms. The market mechanism enforces it, as Adam Smith pointed out: Given two occupations, one very distasteful and the other a source of great pleasure, if other things including payoffs and ability requirements were equal, one must expect the work force to shun the one and flock to the other, driving wages up in the former and depressing them in the latter as a garden-variety manifestation of supply and demand.[14]

12 This suggests one way in which it may sometimes be possible to place a monetary value on psychological enjoyment and even esthetic pleasure. A similar situation has been noted in other arenas. For example, there are data showing that the average financial return to investment in works of art is significantly lower than the return to investment in bonds, the difference being interpreted as the financial valuation of the esthetic yield of painting ownership. See Frey and Pommerehne, 1989.

13 Other areas where some element of nonpecuniary income is likely to exist include scientific research, academic occupations, and perhaps professional work more generally (Friedman and Kuznets, 1945, pp. 130–132). It may also arise among the self-employed in their enjoyment of freedom from control by superiors (Hamilton, 2000; Frey and Benz, 2003). This phenomenon and its relation to the work of innovators has long been recognized: "The knowledge of the man of science, indispensable as it is to the development of industry, circulates with ease and rapidity from one nation to all the rest. And men of science have themselves an interest in its diffusion; for upon that diffusion they rest their hopes of fortune, and, what is more prized by them, of reputation too" (Say, 1819, 1834, p. 82).

14 "The wages of labour vary with the ease or hardship, the cleanliness or dirtiness, the honourableness or dishonourableness of the employment…. A journeyman weaver earns less than a journeyman blacksmith. His work is not always easier, but it is much cleanlier…The exorbitant rewards of players, opera-singers and opera-dances, &c. are founded upon these two principles: the rarity and beauty of the talents, and the discredit of employing them in this manner. It seems absurd at first that we should despise their person, and yet reward their talents with the most profuse liberality. While we do the one, however, we must of necessity do the other" (Smith, 1776, Book I, Chapter X, Part I).

Entrepreneurs' Competitive Position and the Low Supply Cost of Psychic Benefits

Until now a critical role has not been assigned for the market mechanism in eliciting disproportionate allocation of entrepreneurial activity to breakthrough innovation. The market does play such a role. Psychic benefits are a very tangible reward to the recipient but are generally *costless to the provider*. This implies that an innovative entrepreneur who on average receives great pleasure but meager financial rewards from the activity may nevertheless be richly rewarded overall. But the low financial payment means that innovations obtained from this source are purchased cheaply in financial terms, giving this sector of the economy a marked competitive advantage. That is, the independent innovative entrepreneur will tend to be the economical supplier of breakthrough innovation to the economy. One of the virtues of markets and competition is their ability to move economic activities toward those suppliers who can provide them most economically. In the case at hand, it means that the low-cost psychic reward component of the independent innovator's compensation will make it more economical for the large firm, in considering its make-or-buy options, more generally to acquire its breakthroughs from others rather than seeking to provide them in-house. Firms are forced to do so for fear that if they do not, their rivals will. This, then, suggests one market-based reason (that is not mere happenstance) why a disproportionate share of radical innovation stems from the independent entrepreneur.

There is one more observation to be offered here. Why does this low-wage competitive advantage of the independent innovator-entrepreneur not extend also to the less radical innovations—the cumulative incremental improvements that are a giant firm specialty? At least part of the answer is the greater complexity and investment cost characteristic of the latter. A Boeing 777 is obviously far more complicated than the primitive device the Wright brothers made airborne at Kitty Hawk, and the transformation of the Boeing 747 into the Boeing 777 entailed an army of engineers and designers and an expenditure that made the outlays of the Wrights dramatically insignificant by comparison. This, too, is not accidental. By its very nature, this revolutionary invention, like so many before it, grew ever more complex as it was repeatedly modified and improved. Thus, the independent innovator was and continues to be at a marked disadvantage in the financing of incremental improvements of inventions that have reached an advanced stage of sophistication.

This completes the scenario seeking to describe how market forces drive the individual actor away from the small developments and toward the breakthroughs. Next, the other side of the story: the giant firm and its characteristic preoccupation with the small changes that are designed to provide only gradual improvement.

The Market's Enforcement of Large-Firm Caution

The tendency of large firms to be risk averse in their R&D activities is well recognized.[15] As a clear illustration of that attitude and its implication for the innovation process, the author has previously quoted the following observations by a member of management of one of the world's major high-tech enterprises:

> In established businesses, innovation is mostly shaped through small, incremental steps of additional features to augment basic functionalities. With short product lifecycles, time to recoup R&D investments is limited…. Success is relatively predictable through the execution of well-defined innovation processes and in-depth knowledge of their markets in the respective business units.[16]

One may well want to ask what drives these firms to such fear of risk, and their consequent preference for the unexciting incremental development. After all, they are apparently better established and more firmly financed than the entrepreneurial firms, and should therefore be in a better position to cope with risk. Particularly if the attempted breakthrough is just one item in a substantial portfolio of current R&D activities, should that not provide a degree of protection?

Preliminary consideration suggests that there are two features of pursuit of a breakthrough that make a difference. First, given today's state of communication and publicity activities, it is the attempted breakthrough that is apt to attract public attention, and that of investors and prospective investors in particular. Second, breakthrough efforts are unlikely to produce a modest success.

15 See, for example, Kaplan and Henderson, 2005, 18–29.

16 A. Huijser, PhD., executive vice president and chief technology officer, Royal Phillips Electronics, the Hague, September 2003.

The outcome is all too likely to be one extreme or the other. Embarkation on such an activity is a decision like that before the hero of *The Lady or the Tiger*: the choice between two portals, behind one the lady of his dreams, behind the other a hungry man eater. But the subject requires more extensive treatment, particularly in showing the powerful role played by the market in assigning the R&D tasks to the giant oligopoly enterprise.

The Usual Suspects

A variety of explanations from different sources are described in Kaplan and Henderson.[17] For example, they cite some well known and striking cases in which the large firms simply overlooked such opportunities, as when Xerox neglected the computer mouse or when IBM delayed its adoption of the personal computer. The observations are valid, but are hardly general. An overlooked breakthrough is indeed an avoided breakthrough. But no structural reason seems to lead one to expect errors of foresight to be more frequent in big companies and therefore to explain their avoidance of the search for breakthroughs. More convincing is the argument based on Schumpeter's creative destruction—if the prospective invention is likely to be a substitute for some of the firm's currently profitable products, those products can be rendered obsolete by a radically superior substitute. This can be threatening to the large firm that fears cannibalization of its own successful products. The entrant without such vested interests has a clear advantage here. Other possible and previously offered explanations include a propensity of large firms to consider only options not far from the range of their current experience and conservatism imposed by the demands of their larger customers. The management of large firms may meticulously seek to avoid technological changes that threaten obsolescence of their own specialized knowledge, even where those changes promise to benefit stockholders, and managerial ingrained habits of mind may make them unreceptive to novelty. Older firms organized appropriately for one generation of technology may find that the same organization handicaps their use of newer techniques. These hypotheses are all very suggestive, and given that complex phenomena discussed here never have a single and simple explanation, they must be taken seriously. But they nevertheless must be considered with at least one reservation. It does not seem plausible that any of them affects

17 Kaplan and Henderson, 2005

any preponderant set of large firms in the same way, and what is examined here appears to be a widespread attribute of R&D in giant enterprises as a body. The hypothesis here is that there are *systematic* forces that impel large firms in general to avoid the search for radical technological change, noteworthy exceptions though there may be.[18]

All of these ascriptions of the characteristic pattern of innovative specialization of the giant enterprises appear to have some validity. But there are also powerful market forces that more systematically drive the big firms toward marked conservatism in their innovative activities, consistently favoring the incremental improvements.

The Innovation Arms Race and the "Pauper Oligopolies"

Perhaps the most compelling force that can drive a firm to avoid risky undertakings with vigilance and determination arises when the enterprise is continually close to the edge. The lack of protective margin means that even a moderate failure can drive it over that edge. It will be argued next that this is a primary force that leads the enterprises with the largest R&D undertakings to employ those resources as conservatively as is possible.

This bald assertion is surely implausible. For it claims that some of the largest and most powerful of the enterprises in the economy are characteristically, if not actually, short of funds, and certainly are endowed with no overabundance. And this is not a matter of mismanagement or dangerous market conditions, but is the result of a critical component of their activities, indeed, of the very mechanism that ensures the vigor and magnitude of their innovative activities. It is part of what the author elsewhere describes as the free-market innovation machine.

The heart of the matter is the nature of the competitive strategy that has become standard in the high-tech sectors of the economy. It is clear that since early in the 20th century, in these arenas, innovation has become the firm's principal weapon of competition. Continual improvement in products and processes, preferably a bit ahead of one's rivals, has become the primary instrument in the struggle for market. So much so, that successful and continuous investment in R&D is often a matter of life and death, with loss of market to the firm that falls behind in attractiveness of product or efficiency of production. Because no firm dares to be last and all strive to be first, the result must be a unceasing stream of market-attracting innovations, turned out dependably on a dedicated assembly line. This, evidently, helps to explain the explosion of innovation and the speed of its utilization and introduction into the market that is the most spectacular accomplishment of the free market economies.

But, paradoxically, rather than providing an abundance of revenues, this process also tends to impose scarcity of finances upon the firms involved. The reason is simple. While the resulting revenues can, indeed, be abundant, there is reason to be sure that the need for spending will easily keep pace. The point is that what is going on in this process is accurately described as an innovation arms race—a battle in which innovation is the principal weapon, and in which no combatant dares fall behind. And the history of arms races confirms that they can be expected to impoverish the participants. It is on these grounds that historians have described medieval monarchs as the "pauper kings." Whenever one of them raised the ante by acquiring more troops or better military equipment, his rival had no alternative but to match and even raise the outlay. And so, even Phillip II of Spain, perhaps the wealthiest monarch of Renaissance history, was eight times driven into bankruptcy.

An analogous situation is faced by the modern oligopolist in an innovating industry. In the innovation arms race, each firm must seek to be second to none. And as a result, most of them are bound to find themselves frequently under substantial financial pressure. They will, indeed, be the "pauper oligopolies." Of course, a few will beat the game, but others will be fortunate if they can receive a minimally viable financial rate of return over the long run.[19]

18 Bell Labs and the transistor is, of course, a prime example, but it is easily arguable that this was a very special case. AT&T, the parent company, was then regulated to determine prices essentially on a cost-plus basis, allowing the firm to recoup costs that could be shown to have any legitimacy, *plus a "fair rate of return"* on such outlays. Thus, the underlying pure research was virtually guaranteed to bring in something like normal profits. But the current author was there, consulting both with Bell Labs and the company headquarters, and knows that even so, top management was worried about continuation of such questionable outlays.

19 There is, indeed, no rarity of large firms in financial trouble. The causes do vary from case to case, but the examples, including airlines, automobile manufacturers, and telecommunications firms, are striking. An easy exercise is to make a list of the firms that were mightiest perhaps a half century ago, and confirm how many of those mighty have fallen.

And in that position, no management will willingly dare to undertake the risks that invite serious trouble. They will only devote precious resources to innovative projects for which reasonably reassuring market and technical information is available—the incremental product improvements.

The Marginal Investor

Even if the firm is in the unusual position of having an abundant financial margin and substantial reserves, the pressures it faces are not altogether different from those just described. But here those pressures emanate from the financial position of the firm's investors rather than from that of the company itself. Risky projects pose a special threat to stockholders, particularly to those whose investment is recent. The stock prices of the high-tech firms are closely tracked by the financial success of their innovative performance. A firm with a record of steady and dependable introduction of a succession of improved models of their products can expect their revenues to be enhanced by this performance. But the resulting rise in security prices will automatically bring down the rate of return to new investors to a level commensurate with competitive earnings elsewhere. That is, the working of the market ensures that recent buyers of the company's stocks would have had to pay stock prices sufficiently high to eliminate the prospect of excessive rate of return. This means that failure to perform up to the standards of its past will lead to investor disappointment, falling stock prices and rates of return to those stockholders below the current overall market lever. It is not uncommon to encounter cases in which even a delay beyond the promised date of introduction of an announced new model leads to a sharp drop in stock valuation. This can invite stockholder revolt, and it can hurt incumbent management even more directly through the effects on the employee stock options they are often granted. That is sufficient to force even very successful managements to be conservative in their choice of R&D projects. Radical inventions, by their nature, are far more likely to be failures, if not in terms of workability, then perhaps via heavy cost overruns or delays in the appearance of a viable model. Risk-averse management, whose stock offers new investors no more that the lowest rate of return currently permitted in comparable competitive markets, simply cannot afford to take such chances.

Outsourcing of Breakthroughs

A final part of the story has already been noted. Because of the comparatively low financial remuneration of the representative entrepreneurs described earlier, these entrepreneurs become a source of a low-wage, low-cost search for breakthrough innovations. This makes it more profitable for the large, established firm to buy rather than to make such service. The incentive is no different than that for the outsourcing of computer programming to India. The large firm is thereby given an incentive to outsource this activity, choosing to acquire the resulting intellectual property from the entrepreneurs in the market for inventions, rather than incurring the higher costs of doing the job of producing them itself.

There seems to be no reason to expect the market forces just described to be very transitory. If they are indeed enduring, it follows that the current division of innovative labor between small and large firms will continue. There is also no reason to believe that this will be damaging to the public interest.

The Bottom Line: What Entrepreneurs and their Small Firms Contribute

Given the enormous value of some of the revolutionary inventions that have been brought to society by entrepreneurs, the value of this group to the community hardly requires further evidence. Though they are not by themselves the entire engine of economic growth, they are an indispensable component of that mechanism. Their work underlies the incredible changes in the sources of the power that turns the wheels and drives the vehicles, as well as the more than dramatic upheavals in the means of communication and in the techniques of preservation of information—the three elements that can be said to be most responsible for the historically unprecedented growth of prosperity of much of the modern world. But this is well understood, and all that is added to this observation here is that this contribution of the entrepreneurs shows no evidence of slackening. That, indeed, is one of the central implications of the discussion of this paper.

But two other broad types of contribution, also of substantial importance, are not quite so obvious. One is directly related to the innovation process and to the discussion here, while the other is somewhat further afield but, nevertheless,

can draw some illumination from the discussion. One relates to the allocation of resources among prospective R&D projects, and the other to the promise of a career in entrepreneurship as a route out of poverty.

Entrepreneurs and the Task of "Picking Winners" among Prospective Breakthroughs

All too often, the importance of growth for a nation's economy has enticed governments into providing support for particular innovative projects that they favor or even to entire arenas of innovative activity that they consider the wave of the future. The trouble is that the governments have not proven too successful in the task of picking winners, that is, in selecting projects where such government funding will have the highest payoff. They have, indeed, made a few felicitous choices, but the failures have hardly been rare. Yet this is not a shortcoming of government alone. Others have shown their ability to forecast anything except the future. Laughter is all too easily elicited by dramatic misjudgments of the future by businessmen who apparently should have known better (but only in hindsight). There is the prediction by the CEO of IBM that some day the sale of computers might reach five machines per year, the failure of Western Union to recognize the prospective market for the telephone, and some other striking examples have been cited earlier. The moral is not that the individuals in question were particularly dense, but that the future is impenetrable. This is not a matter of risk that can be dealt with via probabilistic approximations and actuarial calculations. Rather, the prospects for a contemplated breakthrough innovation are characteristically enveloped in uncertainty.

How then are choices to be made in the allocation of society's R&D resources in this critical arena? Government has little qualification for the task and big business will not do it. It is only the innovative entrepreneur who is prepared to take on the burden. The task is performed largely by trial and error, using what little information and what large doses of experience and intuition are available to the entrepreneur, because there is no other way. And the process entails a heavy cost to many of the entrepreneurs—those whose guess is wrong. But the basic point is that in undertaking this task, the allocation of so critical a portion of society's R&D resources, the entrepreneurs make an enormous contribution to the general welfare, often at their own expense. It is a job that needs to be done, no one else will do it, and imperfect though the selection turns out to have been in hindsight, no one else could have done it any better.

Entrepreneurship, Educational Requisites, and the Path from Poverty

Innovative entrepreneurship has yet another virtue. It is an avenue to escape from poverty. The prototype is perhaps the immigrants who became itinerant peddlers, including Messrs. Levi and Strauss, who observing a market need, invented blue jeans and made their fortunes. There are no ethnic or cultural prerequisites. The large body of African-American patent holders is described in a number of books and a mere listing of their patents takes up 75 pages.[20]

Three attributes of entrepreneurial activity facilitate its role as conduit from the ghettos and other enclaves of poverty. The first and most obvious is that it requires no consent of an employer. At least in the United States, where some minimal licensing requirements are all that impede the process, for all practical purposes, all entry requires is the determination to do so.[21] Second, there are opportunities that require very little sunk capital, and many an entrepreneur has, indeed, started on a shoestring. The third attribute, which seems not to receive the attention it deserves, is its education requirement: virtually zero. The successful entrepreneur obviously needs to be clever and, indeed, sometimes requires some wisdom. But the great success stories are populated by school dropouts and avoiders of advanced education. Both Edison and the Wright brothers were active entrepreneurs and not just inventors. Edison dropped out of school at age 12 and the Wrights never attended high school. Other examples abound, all illustrating that advanced education is hardly an inescapable job requirement or indispensable for good performance as an entrepreneur. This is important because education is time-consuming and expensive, at least in terms of income foregone, even when government pays the bill. Society's islands of poverty are also aggregations of uncompleted education.

20 See Sluby, 2004, 204–278.

21 Unfortunately, practices elsewhere can be very different, and the resulting barriers to entry may well be suspected as a handicap to growth for the entire economy. "It takes two days to start a business in Australia, but 203 days in Haiti and 215 days in the Democratic Republic of Congo…. There are no monetary costs to start a new business in Denmark, but it costs more than five times income per capita in Cambodia and over thirteen times in Sierra Leone. Hong Kong, Singapore, Thailand and more than three dozen other economies require no minimum capital from start-ups. In contrast, in Syria the capital requirement is equivalent to fifty-six times income per capita…" (study by the International Finance Corporation of the World Bank quoted in Friedman, 2005).

Lack of education is often a handicap that cannot be overcome by those who seek jobs with any degree of promise for the future in established enterprises. But it does not close the door to exercise of entrepreneurship, and that is no negligible virtue.

Concluding Comment

This paper has gone beyond the observation that breakthrough advance in technology is predominantly a small firm specialty. There is a good deal of evidence that this has been the case for over a century and that it continues to be so today. True, the giant oligopolies provide the overwhelming preponderance of R&D expenditures, but in general those outlays are carefully directed to projects with minimal risk, which are therefore apt to yield non-negligible improvements, but improvements that typically are only incremental. This paper has inquired into the influences that can account for this division of labor and has offered a number of observations that indicate that the phenomenon is hardly an accidental occurrence. More important, the analysis, if supported by the evidence, indicates that this distribution of the task of technological advance can, with a degree of confidence, be expected to continue.

This underscores the contribution of the innovative entrepreneurs to the growth of the economy and the welfare of society. Three such contributions are emphasized here. The first, the focus of the article, is the entrepreneur's provision of the radical innovations that underlie the profound changes, since the Industrial Revolution, in the way Americans live. Second, it has been noted that the innovative entrepreneurs as a group carry out the task of selection of the projects to which the resources available for the search for radical breakthroughs are allocated. This is a task critical for the future of the economy, but it is a task from which others shrink because of the great uncertainties it entails. Finally, recalling the evidence that innovative entrepreneurs have often succeeded, and succeeded spectacularly, with little formal education, it has been pointed out that this serves to reduce further the naturally low barriers to entry into the activity. That, it turn, helps to fill a need critical for society: an attractive and promising avenue toward prosperity.

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