CHAPTER 3
MANAGEMENT IN FIRMS AND ORGANIZATIONS

Entrepreneurial Energy. Its Creation and Capture – a Policy Perspective of Economics and Innovation. Part I: Theory and History[*]

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Abstract. This perspective-research paper addresses the common misperception that government funding for research violates free market principles.

Sections I-IV focus on theory. They examine generally accepted free market economic principles that are relevant to innovation. They use descriptive economics to define “entrepreneurial energy”, to identify the stages that an innovation passes through, and to distinguish between an innovation’s public and private good stages. They conclude that a proper free market system requires government funding of basic research, which plays a central and complementary role with privately funded research and commerce.

Sections V-VI illustrate the theories presented in Sections I-IV by applying them to the histories of the electronics and the biotechnology industries.

Key Words: entrepreneurship, innovation, basic research, research funding, public goods, private goods, microelectronics, biotechnology

JEL Classifications: H11, H41, L63, M13, O31, O38

I. Introduction

> Indeed, we need look back half a century, to times which many now living remember well, and see the wonderful advances in the sciences and arts which have been made within that period.
> – Thomas Jefferson, Report: University of Virginia, Aug. 4, 1818[1]

If Thomas Jefferson were living in the US around 2000, he would probably have been very proud of its prosperity, coined the “New Economy”.After all, he was an architect of the US free market system within which the New Economy blossomed.

Even so, he might have been wary of the most publicized explanations of how the New Economy came to be, since he would probably not have considered globalization, monetary policy, increasing returns to scale technology, right-sizing and the like to be its most important drivers. These are crucial support, but he would probably have recognized that the New Economy was primarily generated through the tremendous waves of innovation that were brought forth by an extraordinary period of entrepreneurial energy. Moreover, as one of America’s first great innovators and leaders of free market policy, he would be able to point to his own words to unravel the

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[1] Appleby, Joyce and Terence Ball (eds.), “Jefferson - Political Writings,” Cambridge University Press, 1999.

creation and capture of this entrepreneurial energy, these most important but least understood elements of innovation.

Entrepreneurial Energy

Entrepreneurial energy is the force that combines human incentives, values, and abilities with institutional capability to drive innovations from their earliest roots as scientific principles to the ultimate product advances that provide value, create industries and propel an economy forward.

Jefferson's words provide a useful guide through entrepreneurial energy because they emphasize its four key elements: 1) entrepreneurs have an unflagging power to drive innovation forward, 2) institutions must play their complementary roles, 3) the free market system is critical for energizing innovators, but 4) innovation is based on economic complexities too great for it to comply with the simplest free market thinking.

It is the last point that can be unraveled to allow the creation and capture of entrepreneurial energy to be understood and renewed. It can be understood and renewed because, on their way to becoming value creating products and processes, innovations travel through distinct stages during which they take on specific economic natures. Some of these economic natures respond to a pure profit motive and are best handled by the private sector. But others do not respond as well to profit motives and require support from publicly funded institutions such as research universities. Unraveling these stages and their natures, and handling them accordingly, better positions the economy to continue being driven forward by entrepreneurial energy and innovation.

Approach and Organization

The following analysis, which is used for unraveling these natures, is based on an "inside/outside" approach – it gives weight to the lessons learned inside of industry as well as to the economic frameworks that are meant to shed light on these realities. By using this approach the real progress that industry has achieved is not obscured by analytical limits set by measurement problems of textbook economics. It challenges frictionless economics to ensure that the limits to innovation and progress be no more modest than those of industry's advancing capability.

Sections I-IV establishes the critical distinctions between "public goods" and "private goods," how simple free market views of innovation are undermined by not taking these properly into account, and how public and private good natures operate during an innovation's journey from entrepreneurial energy's creation to its capture.

Sections V-VI provides examples from today's trademark industries, electronics and biotechnology, to demonstrate the government's and private sector's roles in the process of advancing the economy by creating and capturing entrepreneurial energy.

Recognizing how entrepreneurial energy is created and captured through this process is a step towards allowing Jefferson's period of "wonderful advances" to continue without limit.

II. Inside Innovation: Private and Public Goods

> It would be curious then, if an idea, the fugitive fermentation of an individual brain, could of natural right, be claimed in exclusive and stable property. If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea, which an individual may exclusively possess as long as he keeps it to himself; but the moment it is divulged, it forces itself into the possession of every one, and the receiver cannot dispossess himself of it. Its peculiar character, too, is that no one possesses the less, because every other possesses the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me. That ideas should freely

> spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them, like fire, expansible over all space, without lessening their density in any point, and like the air in which we breathe, move, and have our physical being, incapable of confinement or exclusive appropriation. Inventions then cannot, in nature, be a subject of property. Society may give an exclusive right to the profits arising from them, as an encouragement to men to pursue ideas which may produce utility, but this may or may not be done, according to the will and convenience of the society, without claim or complaint from anybody.
> -Thomas Jefferson to Isaac McPherson, Monticello, Aug. 13, 1813[1]

Deep within these words, Jefferson raises the fact that there are two kinds of economic natures within innovation, one for its "public good" dimensions and the other for its "private good" dimensions. Public and private goods first require some definition and examination.

Private Goods

Private goods are what we usually think of when we think of our economy and markets. They are the things that we buy – our computers, our food, much of our property. They are distinguished by the fact that they are *rival*. I will have less of the good if somebody takes some from me. If you eat my food, then there is less for me to eat. If you use my computer, then I will have less access to it. When you gain, I lose. Private goods are also *exclusive*. It is reasonably easy for me to keep you from eating my food or using my computer. I have property rights over these goods and I can keep you from sharing in them.

Private industry is best suited for efficiently producing private goods because of the profit motive, Adam Smith's "invisible hand." This is because I have enough control over who acquires the exclusive and rival private good that I produce, that I can capture sufficient value for my efforts – its value is *appropriable*. Because the good is exclusive, nobody gets access to it unless if I decide that I am being offered enough in return for it. Because it is rival, I know that when I put one unit on the market, only one unit will be used – once a loaf of bread is bought, only one loaf can be eaten and anybody who wants more bread has to pay me or another bread producer. As a result, I am motivated to invest in and produce the goods that are the most valuable to society, allowing me to maximize my profits while society maximizes its value.

Although more abstract, another private good is the right to put a product on the market. If I have all of the rights to market a product, I have all of the value derived from the profits of the product. If you gain access to these market rights, then I lose some expected profit value. When you gain, I lose. Consequently, the market rights are rival. They are also exclusive if I can keep others from marketing my good. Regardless of what is best for society, there is a tradeoff between your value and mine, making these market rights a rival and exclusive private good.

This is what Jefferson was referring to when he said, "Society may give an exclusive right to the profits arising from them, as an encouragement to men to pursue ideas which may produce utility." He was referring to the fact that since profits are rival, patents are necessary to also make them exclusive in order to preserve the entrepreneurs' incentive to produce the innovations that are of most value to society. Jefferson hedged his support of patents because without competition, producers can use monopoly power to raise prices excessively in efforts to further increase profits. However, he recognized that for better or for worse, market rights over innovations are rival and must be treated accordingly. Since a free market is based on property rights that give people control over their rival goods, at least some of this monopoly power must be tolerated. Without these property rights, few private people or firms would be willing to invest in producing market-creating innovations, forcing economic progress to a screeching halt.

[1] Ibid.

Public Goods

The bulk of Jefferson's quote addressed public goods. In contrast with a private good, a public good is one in which I lose nothing when others acquire it – it is *non-rival*. Spreading the good around imposes no cost on anyone. When you gain, I do not lose. In addition, once the good is provided, it is very difficult for me to keep it from diffusing freely to others – it is *non-exclusive*.

National defense is an example of a public good. I am protected by an army that is strategically stationed overseas. If somebody moves to my country, that person is equally protected, but my protection is not diminished (non-rival). When you gain, I do not lose. Furthermore, I cannot restrain my new neighbor from being protected by the army if I am to be protected (non-exclusive). Once the army has been provided, we all benefit from it at no cost to one another while being unable to keep one another from this benefit.

As Jefferson points out in detail, an idea, such as a scientific principle, is another example of a public good. It is perhaps the truest public good. Once I let my idea out, I cannot keep it from spreading, but I do not lose the idea when others acquire it. Because I lose nothing as others gain, it is *non-rival*, it would be inefficient to exclude anybody from the idea since denying people access to my idea would reduce the idea's value to society.

But relying on me to make the investments that produce the ideas that can be freely spread as such is also in error – I will not voluntarily invest nearly enough because I would be losing from the investments even while society was gaining. The loss created by this conflict is magnified to the extent that my idea may generate more ideas that may eventually lead to products that society values but do not profit me.

Because of this, public goods generally do not respond as well as private goods do to Adam Smith's invisible hand of the profit motive. Since a public good's value diffuses freely across society, no producer can capture its value – the value is *non-appropriable*. This would lead me to pay for only a little of the public good, or even better, to wait for other people to pay for it since I would get as much value from their investment as from my own.

This is especially true when the investment needed for providing the public good is billions of dollars and the payoff is distant and uncertain. As a result, relying on the profit motive to produce public goods would lead to too little investment.

Because the profit motive leads to under-investment in public goods, the solution is to compel everybody who benefits from the public good to contribute to funding its production. For this reason, it is generally understood that public goods are most efficiently provided by the public sector – national defense is only one of many examples. Providing public goods is one of the most important, if not the most important, basic functions of a government in a free market.

Efficient Production of Private and Public Goods

In practice, the distinction between private good and public good production is that private goods are efficiently produced by the private sector and public goods are efficiently produced by the public sector. This allows free market principles to be fully leveraged by requiring the private sector to maximize (private good) profits by maximizing value to society, but allows key (public good) resources to be provided by the government when they would otherwise not be provided.

Part II considers how the government can efficiently allocate its investments in public goods. This is a very important issue that cannot be neglected, but it does not impact the conclusion about the private and public sectors' roles.

Table 1

Public and Private Goods

Type of Goods	Nature	Examples	Efficient Producer
Private Goods	Exclusive and rival Responds to profit motive	Food Market rights	Private sector
Public Goods	Non-exclusive and non-rival Does not respond to profit motive	National defence Scientific principles	Public sector

III. Traditional "Free Market" Views About Innovation

I have sworn upon the altar of God, eternal hostility against every form of tyranny over the mind of man.
-Thomas Jefferson, as quoted on the Jefferson Memorial

Entrepreneurial energy is sparked by inspirations, the fundamental ideas on which value-creating innovations can be developed and built. Fragile, elusive and seeking reward, these inspirations should be extremely sensitive to the incentives of a free market. As Jefferson might warn, very little tyranny of misplaced government involvement could drive away these inspirations and all of the entrepreneurial energy that would follow. Is this not one of the main reasons that the great centers of entrepreneurial energy have been so few, and the freest of markets have enjoyed their greatest concentrations?

The most effective system for creating and capturing entrepreneurial energy must be consistent with free market principles. However, the innovations' public and private good dimensions defy simple free market analysis, as is demonstrated by the following examples of common but flawed views about the creation and capture of entrepreneurial energy.

– 1: Intellectual property protection should be minimized because it protects a public good, undermining the value of innovation by creating monopolies that reduce the diffusion and adoption of new ideas.

This view, which minimizes the role of property rights, appears to be very appealing within a conventional free market frame of mind. In fact, economic theories repeatedly reach this conclusion and economists frequently favour similar positions.

This is not surprising because economic modelling of intellectual property protection tends to be formed by the thinking that an innovation is a change in technology, which is basically an idea, which is a public good. It is then easy to show that restricting access to the innovation is inefficient because an idea, a public good, could be spread to many people without it being taken from any others. With this basis, the models naturally reach conclusions that confirm the position that intellectual property protection protects a public good and should be aggressively minimized.

However, this argument is greatly flawed. More than anything, it illustrates the impact of misinterpreting an innovation's public and private good dimensions are frequently misunderstood, undermining analyses and conclusions. In fact, just looking at the patent law (at least in the case of the US) demonstrates that the view that intellectual property protection protects a public good is not only wrong, it is *doubly* wrong.

Patent laws such as those in the US provide the patent holder with a limited monopoly of a specific product that the idea made possible. The monopoly profits that a patent provides are very much unlike an idea because if you get some of my market, I will certainly have less profit (like as is the case for a private good). But in exchange for receiving this limited monopoly over a particular application, the patent law stipulates that I must fully and clearly divulge the underlying idea (a public good) in the patent application to the public. This places the innovation's dimension that can be costlessly replicated, the idea, into the public domain, increasing access through which it can inspire any and all other applications (more creation of more entrepreneurial energy to be captured).

Hence, the view that patents protect a public good is doubly wrong – the patent law provides property rights that *protect the private good dimension* (profits from market rights to a specific application) in exchange for *unprotecting the public good dimension* (the idea).

Because the standard costs of monopoly are significant, intellectual property does need to be limited. But the key point is that economic theories that are based on conventional assumptions do not capture an innovation's public and private dimensions correctly, and this leads them to support excessively low intellectual property protection.[1]

– 2: The private sector should be given all of the incentive and responsibility for innovation.

Although this is a very different position, one that maximizes the role of property rights, it also appears to be very appealing within a conventional free market frame of mind. It seems to make perfect sense as a way of using the free market to allow entrepreneurial energy to operate efficiently and generate great waves of innovation.

By making private industry responsible for all facets of innovation, the reasoning goes, the best competitors within private industry would be allowed to reap the rewards of innovation. This would drive them to produce the innovations that would be of greatest value to society. Hence the great profits of firms such as Intel. Additionally, keeping the government out of the innovative process is sensible because the government lacks the information and profit incentive that private industry uses to ensure that the most profitable lines of research are followed.

But again, this view is flawed. It assumes a simple path from entrepreneurial energy's creation to its capture in which everything that is needed will be provided by a profit incentive. It assumes that innovation and entrepreneurial energy are wholly based on private goods.

This is false because the early steps of innovation, the creation of entrepreneurial energy, have largely public good natures. The basic research breakthroughs that create technological platforms for the innovations are ideas. If they are true breakthroughs, they are generally very remote from any eventual profits or any other private good dimension. Further, once the breakthrough is made, it can be freely diffused across the economy. They are classic public goods, non-appropriable and non-responsive to profit motives. Neglecting breakthrough basic research's public good nature would stifle the entire innovative process by withholding the most important resource for innovation from private industry, the scientifically advanced technological platform.

Actually, it is very fortunate that basic research breakthroughs can be freely diffused as public goods because this diffusion gives life to the breakthrough's true potential. Perhaps an application or two is immediately apparent, but for a true breakthrough, the idea needs years of fermentation and a wide variety of perspectives for its true value to even be identified. The diffusion, itself, transforms basic research breakthroughs from scientific principles to entrepreneurial energy, which in turn leads to competition for creating products of value and maximizing profits.

There is a textbook argument that if there ever are profits to come from basic research breakthroughs, then private companies would still make the investments. That may be so, if one firm were able to perform so much basic research that it could be assured of achieving a sufficiently large number of breakthroughs. But this expense would be enormous. Rather than putting the tremendous resources into basic research with the hopes that some breakthroughs and trade secrets will eventually pay off in some way, private firms are justified in putting their resources into more applied research or development with targeted shorter-term goals. It is sensible for them to focus on capturing, rather than creating, entrepreneurial energy.

In contrast, if sufficient public basic research investments are made and basic research breakthroughs are achieved, there will be a much greater technological platform for private firms to leverage through investing in their profit-driven applied research. Evidence presented in Part II

[1] Scalise, "What Kind of Good Does Intellectual Property Protection Protect?", mimeo.

supports this, demonstrating that US private industry has dramatically increased its focus on more applied research investment following the US public sector's great investment in breakthrough basic research through the middle of the twentieth century.

This is the essence of creating entrepreneurial energy (the technological platform created through basic research breakthroughs) that can be captured (profitable short-term applied research). Greater technological platforms enrich the entrepreneurial energy that private firms can invest in capturing.

These are two examples of 'pure free market' views that would stifle innovation through failing to recognize the economic complexities of free markets and innovation. Both of these views fail because they do not recognize the interplay between private goods and public goods in the creation and capture of entrepreneurial energy. Recognizing both natures is critical because public and private good dimensions of entrepreneurial energy's creation and capture depend on one another, as the following framework demonstrates.

The Path to Innovation – From Principles to Profits

> The fact is, that one new idea leads to another, that to a third, and so on through a course of time until someone, with whom no one of these ideas was original, combines all together, and produces what is justly called a new invention. – Thomas Jefferson[1]

This fact that Jefferson raises is an important one, the very process of entrepreneurial energy's creation and capture. Before culminating in a useful invention, the seeds of that invention, the basic research breakthrough, may first have to pass through many people. It may have to pass through many people because it may have to satisfy many stages of refinement, with people in each stage chipping away and molding it step by step into a valuable product.

This molding may be linear, such as finding a useful application for a principle. However, the molding is likely to be highly complex such as when the innovation must evolve with other technologies to combine into a single more powerful technology. One example of this "convergence" is that of semiconductor technology, the ARPNET, the personal computer, telecommunications technology and other ideas combining "all together" to become the Internet.

As previously pointed out in an Arizona Republic editorial:

> "With this complexity, the 'course of time' that can separate the breakthrough "new idea" from the pay-off "inventions" can be years, or even generations. Paul Krugman has pointed out that the Industrial Revolution, which first had an economic impact around 1840, was based on the spinning jenny that was invented in the 1760's (an 80 year lag). Similarly, electric power was a driver of innovation and prosperity in the 1920's, yet had been introduced in the 1880's (a 40 year lag). The jet engine was critical to the post World War II boom, but its key technologies had been created during the Great Depression (a 20 year lag). 2 The semiconductor has provided value through its enabling technology for computation and communication since the 1950's, but its value to the community soared in the 1990's when it formed the basis of the unanticipated Internet."[3]

Generalized Framework

While the paths that innovations must travel can be long and sometimes difficult to trace, they are formed by two main stages. In general, an innovation first travels through a period of entrepreneurial energy creation in which public goods are created through activities such as break-

[1] Appleby, Joyce and Terence Ball (eds.).
[2] Krugman, Paul, "Peddling Prosperity".
[3] This paragraph was published by Scalise within an opinion piece in The Arizona Republic newspaper, 8/22/00.

through basic research. If the necessary investments and breakthroughs are made during this first stage, the innovation can then proceed through the stage of private good emergence and entrepreneurial energy capture in which activities such as applied research, development and product/process design generate value and profits.

This framework is somewhat generalized because the research process is too complex for sharp, universal distinctions to be drawn among all categories of research for all innovations. Basic research is sometimes blurred into other forms of research and sophisticated development is often referred to as basic research. Additionally, some stages may repeat many times, allowing more and more innovations to result from a given basic research breakthrough, and development can even lead to more research. Also, some activities are referred to both as research and development, such as pre-competitive research, which is sometimes called exploratory development.

However, exploration of these generalized stages and their typical components demonstrate the natures and interactions of innovation's public and private good components that drive entrepreneurial energy.

Public Goods and the Creation of Entrepreneurial Energy

Entrepreneurial energy is created through ideas that revolutionize the technological platform and provide the opportunity for many new innovations. As a result, creating true entrepreneurial energy is generally achieved through basic research breakthroughs. In its 1997 working paper, "Government Funding of Scientific Research," The National Science Board describes research as follows:

> "Research is the search for new knowledge and concepts that unify and extend that knowledge. The work, stimulated by theoretical or practical questions, is conducted in the context of existing knowledge and paradigms…Typically, research is designed to answer specific questions to fill gaps within the existing body of knowledge or to test the paradigm itself. Work which is intended to confirm or refine an existing paradigm may, in fact, contradict it, thus opening the way for a scientific revolution…An investigator may or may not have specific, practical applications for the results of his/her work when designing the research. However, extensive history has documented the fact that the most important applications and policy implications are not envisioned at the time of the research. This fact is most especially true of work that leads to new or greatly modified paradigms."

These principles, that research focuses on knowledge and is remote from applications, underlie breakthrough basic research's public good nature that dominates the creation of entrepreneurial energy and starts the innovation process.

Basic Research Breakthroughs

Usually discoveries of deep scientific principles, these basic research breakthroughs can propel technological standards forward, or they can even produce the foundation for entirely new areas of technology and industry.

The quantum mechanics and early transistor basic research that launched semiconductors and all of the subsequent electronics industries are examples of this. These breakthroughs create entrepreneurial energy by providing the fodder for many innovations. Great luck notwithstanding, all innovations and waves of innovation can be traced back to basic research breakthroughs. An innovation's most recent ancestor may be in incremental technical advance, marketing or one of many other factors. But ultimately, the innovation probably owes its existence to some basic research breakthrough.

This basic research phase has pure public good properties. The basic research breakthroughs, the scientific principles, are ideas. As ideas, they are highly non-exclusive and non-rival.

Can basic research have the properties of a private good? The idea itself cannot be rival or exclusive. Only some refinement or application of the idea, and perhaps the generated profits, can be rival or exclusive. However, as the examples in Sections V and VI point out, the basic research stage is very remote from the eventual products that can be marketed for profits. They are scientific inquiries that usually do not reveal their value potential at the time of discovery. The private good refinements and applications occur in later stages. The NSB description even proposes that the most important applications of greatly modified paradigms are only recognized long after the breakthrough. This implies that the greater the breakthrough, the less its value is anticipated, the more remote it is from its eventual private good payoffs, the more it starts as just an idea.

Because basic research breakthroughs are public goods, far too little basic research investment will occur if the government does not participate appropriately. If public funding of the public good basic research is neglected, there will be too little resource to spark the profit-seeking steps that follow, and entrepreneurial energy will fade as the technological platform is exhausted. For this reason, institutions such as the publicly funded research university system have been created to provide conducive environments for achieving basic research breakthroughs.

Private Good Emergence and the Capture of Entrepreneurial Energy

If an economy has succeeded in creating entrepreneurial energy through basic research breakthroughs, then the private sector has the opportunity to capture it. Entrepreneurial energy is captured through completing the innovation’s research and carrying out its development. The National Science Board describes development as follows:

> “Development is the process by which a new product or process is brought into being or improved based largely on existing knowledge and theory.”

In contrast with research, development is closely associated with a complete product or process, the ideas’ embodiment that generates value or profit. This reflects that private goods are emerging while entrepreneurial energy is being captured, and the innovation is continuing to move through its path towards being a product.

A critical point to note is that applied research or development, which used to be thought of as less sophisticated than basic research, is now often exceedingly sophisticated. In practice, this often causes some of the most important applied research and development to be miscategorized as basic research.

The stages of capturing entrepreneurial energy typically include some or all of the following.

Pre-Competitive Research

The innovation's next phase in its journey from idea to invention is likely to be pre-competitive research, also called exploratory development. This stage translates basic research principles into the conceptual building blocks of marketable products. This stage begins to capture the entrepreneurial energy.

Through refinement, the esoteric idea has started to take on a private good dimension because it has started to generate categories of potential products. However, there is still substantial uncertainty about the ultimate innovations or products, leaving only distant and uncertain prospects for profits. As such, it is still little more than an idea. This results in a dual nature in which the innovation is still a public good, but one that has private goods struggling to get out.

The innovation’s emerging private good nature disqualifies the government from being the appropriate driver at this stage. Similarly, because the innovation is still little more than a public good, a non-rival and non-exclusive idea, individual firms may be disinclined from performing the pre-competitive research.

However, the free market does provide an efficient solution for supplementing the private firms' investment in pre-competitive research. Since the innovation has started to generate a potential product area by the time that it has reached the pre-competitive stage, an industry or subsector can probably be identified that could anticipate receiving value from the idea's ultimate form. As such, pre-competitive research can be carried out by industry consortia or joint ventures, formed by the firms that can expect to share in the value of refining the idea. These organizations balance the needs of public goods (all who will benefit from it are compelled to contribute) and private goods (investments are made voluntarily according to the profit motive). This is an efficient free market solution to the pre-competitive research stage.

Applied Research

The innovation's next phase is typically applied research, also called development. During this stage, the conceptual building blocks are arranged to identify and provide parameters for feasible marketable products – the technological framework's applications become the focus. The innovation is still nothing more than an idea, but the entrepreneurs have now greatly narrowed their targets and can expect it to soon yield profitable products. Private companies can carry out this stage because the promise of profits is emerging more forcefully, and, as such, the private good dimension has taken on real substance.

Product/Process Design

Once the innovation has been sufficiently developed into an area of potential products, the next stage is typically product design, the optimal arrangement of the technology base for constructing a marketable product or process.

At this point, the innovation has achieved a balance of private and public good qualities. The design yields a marketable manifestation (private good) of the refined idea (public good). It is this stage that generates patents. Through the patent law's design, entrepreneurial energy is captured by the firm, but the refined idea is diffused to recreate entrepreneurial energy as other embodiments may be inspired. This stage may occur many times to the extent that the basic research breakthrough created a rich technological platform. Inspirations for new designs can come from the patent application, engineering, marketing or many other places in addition to applied research.

By providing a patent system, the government plays a key role in increasing the public good dimension's efficiency. Its private good dimension's efficiency is also enhanced by leaving the rest of the innovation to the private firm.

Production and Marketing

The final step is production and marketing, the invention's payoff. This is the point at which entrepreneurial energy's creation provides explicit value through its impact on the market and entrepreneurial energy is fully captured. As such, the stage's nature is essentially that of a private good and is best handled by private firms without government's involvement.

The US was extremely effective in bringing innovations through this maze during the 20th Century. This is because by design, luck or even the sheer necessity of war, the US succeeded in generating a good environment for creating and capturing entrepreneurial energy. Basic research was supported by the public sector and the private sector was given profit incentive to combine "all together" to produce the innovations that drove the economy forward.

Table 2

Components of the Creation and Capture of Entrepreneurial Energy

	Basic Research	Pre-Competitive Research	Applied Research	Product Design	Manufacturing and Marketing
	Creation	Creation / Capture	Capture	Capture	Capture
Economic Nature	Public good	Entwined public and private goods	Private good separating from public good	Separable public and private goods	Private good
Optimal Venue	Publicly funded	Industry funded	Privately funded	Privately funded	Privately funded

This generalized process, with focus on innovation's public and private good dimensions, provides a useable framework for entrepreneurial energy's creation and capture. This is evidenced by the examples of the semiconductor industry's development and the many electronics industries that it spawned, and of biotechnology.

V. Entrepreneurial Energy's Creation and Capture: The Semiconductor (and the world of electronics)

> And it cannot be but that each generation succeeding to the knowledge acquired by all those who preceded it, adding to it their own acquisitions and discoveries, and handing the mass down for successive and constant accumulation, must advance the knowledge and well-being of mankind, not infinitely, as some have said, but indefinitely, and to a term which no one can fix and foresee.
> –Thomas Jefferson, Report: University of Virginia, Aug. 4, 1818[1]

The transistor was invented in 1947 at AT&T's Bell Telephone Laboratories by William Shockley, John Bardeen and Walter Brattain. This pivotal moment provided the "nerve cell" of the Information Age[2] and ignited the semiconductor industry. However, it was only one of many pivotal moments on the path of creating and capturing the semiconductor industry's entrepreneurial energy.

This path dates back to the scientific awakening in the days before Jefferson, took a sharp turn in the early twentieth century with the evolution of quantum mechanics, was driven forward by the demands of World War II and, with Bell Labs' mediation, culminated in the world of electronics during the second half of the twentieth century.

Its complex path provides an example of how publicly funded institutions create entrepreneurial energy through creating public goods, allowing private industry to capture this entrepreneurial energy through competing to create private goods (A detailed history of the semiconductor industry's history and the science that led up to it is presented in Michael Riordan's and Lillian Hoddeson's Crystal Fire-The Invention of the Transistor and the Birth of the Information Age; the author wishes to emphasize that this section supports the effort to focus on economic principles by interpreting Riordan's and Hoddenson's research of the semiconductor industry history, and does not present any original research of the history of the electronics industry.).

The following analysis focuses on the semiconductor industry's entrepreneurial energy creation. Its capture is of equally great importance, however much has already been written about this (at least implicitly) while underplaying the public good investments that came first. To balance this, the analysis sets out to demonstrate how public investments in basic research break-

[1] Appleby, Joyce and Terence Ball (eds.), "Jefferson - Political Writings," Cambridge University Press, 1999.
[2] Riordan, Michael and Lillian Hoddeson, "Crystal Fire - The Invention of the Transistor and the Birth of the Information Age," W.W. Norton & Company, 1997, (1998 paperback edition).

throughs created the entrepreneurial energy that was captured through private competition in the semiconductor industry.

Creating a Public Good and Semiconductor's Entrepreneurial Energy - Basic Research: Academic Breakthroughs in Quantum Mechanics

Before the transistor could be invented, ushering in the world of electronics, the electron first had to be found and understood. This was a great challenge since the very idea of an electron conflicted with the way the world was understood to work up through the end of the nineteenth century. However, between the late nineteenth century and World War II, a network of great physicists took the long stride forward by uncovering the secrets of quantum mechanics and the electron through basic research breakthroughs. This basic research progress generated the semiconductor technology's scientific platform.

These great basic research breakthroughs (the original "quantum leaps") occurred through a *public good process*. It was a public good process because it revolved around ideas, esoteric ideas that were very remote from profits or any other exclusive/rival property. It was also a public good process because it fed off of its public good nature; the free diffusion of ideas allowed the physicists to combine their talents, with each making irreplaceable contributions that allowed others to take the next steps forward. So great of a pool of talent was needed, in fact, that these breakthroughs were achieved through the combined efforts of European universities, where many of the early theoretical breakthroughs were made, and US universities, where largely experimental research guided the breakthroughs' impact.[1] Through this public good process, quantum mechanics became the public good kindling for entrepreneurial energy because its ideas opened up great new areas of understanding that could then lead industry to compete for the profits from a whole universe of new private goods.

The basic research breakthroughs' public good, entrepreneurial-energy-creating features made the university system the ideal setting for achieving the breakthroughs. Universities were (and are) better suited than private industry for achieving these scientific breakthroughs for several reasons.

First, the university system is not constrained by private industry's measures of performance and reward system. Profit-seeking stockholders are reasonable to demand that investment choices return profits, for which time to payoff and risk are great negatives. As the NSB pointed out, a true breakthrough's potential can rarely be recognized and rationally acted on in advance, so it is understandable why stockholders would not fund such research – even if its eventual payoff does turn out to be greater than they could ever hope. In contrast, universities are judged primarily on their ideas' abilities to stand the test of time for advancing science, rather than on their likelihood of making an immediate profitable impact. This positions universities to be more efficient in pursuing the most valuable breakthrough basic research, regardless of the payoff details.

This is at the heart of breakthrough basic research's public good nature. It produces ideas. While it is easy to appreciate a true breakthrough's contributions to industry in retrospect, there is rarely much defensible justification in advance for investing in the breakthrough since its value is typically not recognized until after the investment. This was very true for the electron, *the* building block of the semiconductor and modern technology. After Cambridge University's Joseph John Thomson discovered the electron in 1897,[2] he would often toast, "To the electron – may it never be of any use to anybody."[3] And for years, it wasn't. Thomson's scientific inquiry led him to one of history's great breakthroughs, but would not have provided a business plan that justified private funding. It was just an idea, a public good, that came to be through public investment.

Second, the most brilliant minds are most productive when information flows freely among them. The university system allows this by not having industry's disincentives to informa-

[1] Ibid.
[2] Ibid.
[3] Ibid.

tion flow, allowing the idea to become fully realized science and the public good potential to be maximized. The university system's vast, complex intellectual resources are unimpeded in focusing their independent yet combined attack on a line of discovery, discovery that can then energize competition in the private sector. In contrast, as competitors in private industry, the best minds would be working against one another in relative isolation. This does not make sense when the target is an esoteric idea, a public good that is elusive and very remote from any private good or profit.

This free information flow was very important for quantum mechanics' progress. For example, German physicist Max Planck, was hesitant to even propose the basics of quantum mechanics,[1] the user's manual for the electron. It is understandable why he may have been reluctant to risk overturning the direction of technology. Advancing quantum mechanics further required the contributions of a network of scientists that included no less than Albert Einstein, Ernest Rutherford, Neils Bohr, Werner Heisenberg, Wolfgang Pauli, Rene Descartes, Christian Huygens, Thomas Young, Augustin Fresnel, Erwin Schroedinger, Arnold Sommerfield, James Clerk Maxwell and many others.[2] Planck knew the demands that were raised by his new ideas, and was fortunate that the world's resources were ready to contribute. With only limited interaction and support, he may have decided that the effort was futile and chosen not to even explore the issue.

The pre-World War II academic scientific community laid out the scientific framework that made the semiconductor industry possible through their scientific inquiry and free interaction. Although there initially was little apparent application for Thomson's "useless" electron and the quantum mechanic theories that explained its behavior, the scientific breakthroughs had unleashed the electronic industry's basic force. With more progress, these academic investments – these public investments in public good creation – would create the entrepreneurial energy that would find a "useful" home in its own electronics industries.

Creating Entrepreneurial Energy and a Public Good

World War II Advances Technology and Strengthens the Government's Commitment to Basic Research

World War II could have been a dark age for science since many of the greatest scientists were pulled off of their research to assist with urgent military needs. However, it was a valuable stage for the semiconductor industry because World War II caused many of these great scientists to cooperate on developing radar technology. This was valuable because advanced radar technology relied on the semiconductors silicon and germanium for detecting radiation, and the hurried work that was done in the US and Great Britain led to breakthroughs in understanding these elements.[3] The new understanding, again achieved through the public goods method (idea-centered, publicly funded, broad collaboration), guided the previous quantum mechanics breakthroughs yet closer to the transistor.

Similarly important, Vannevar Bush, who coordinated the scientists' wartime achievements as Director of the Office of Scientific Research and Development, delivered a report to President Truman at the close of the World War II urging him to aggressively promote scientific research. Citing the scientists who contributed to the war efforts and the importance of the radar in gaining advantage in battle, he proclaimed,

> "It has been basic United States policy that Government should foster the opening of new frontiers…It opened the seas to clipper ships and furnished land for pioneers. Although these frontiers have more or less disappeared, the frontier of science remains."[4]

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[1] Ibid.
[2] Ibid.
[3] Ibid.
[4] Ibid.

Bush focused on basic scientific research, stating:

> "New products, new industries and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. This essential, new knowledge can only be obtained through basic scientific research.[1]

Hardly a better environment could have existed for ensuring that the semiconductor's basic scientific platform would be fully realized. And Bell Labs was well prepared to participate in this realization and to accept any assistance that the government might provide.[2]

Creating Entrepreneurial Energy and a Public Good - Basic Research at Bell Labs After the War

Consistent with Bush's vision, the decade after the war was a critical and productive time for the semiconductor industry's development. The wealth of recent basic research in the scientific community started to be organized into the basic ideas that would underlie the semiconductor as a profitable good – the industry's primary public goods became fully realized, as did its entrepreneurial energy.

Many of this period's most important breakthroughs occurred at Bell Labs where Schockley, Bardeen and Bratain worked intensively to create the first, crude transistor in 1947. This basic scientific research led to their shared Nobel Prize in 1956, in which they were credited,

> "The summit of Everest was reached by a small party of ardent climbers. Working from an advance base, they succeeded. More than a generation of mountaineers had toiled to establish that base. Your assault of the semiconductor problem was likewise launched from a high altitude camp, contributed by many scientists. Yours, too, was a supreme effort - of foresight, ingenuity and perseverance - exercised individually and as a team. Surely, supreme joy befalls the man to whom those breathtaking vistas from the summit unfold."[3]

Key to Bell Labs taking the role of shepherding quantum mechanics into the transistor was the fact that there were three ways in which Bell Labs was operating as a public good producing research institute.

First, Bell Labs chose to pursue basic scientific research. Bell Labs acted on this commitment by hiring the ablest physicists and paying them to perform breakthrough research worthy of a world-class research university.[4]

The closely related second factor was that Bell Labs had a very open, collaborative culture, which was very similar to the research university system's cooperative culture. On the research level, open interaction was encouraged with other laboratories around the world, including corporate laboratories as well as university laboratories. Similarly, publishing research was a top priority – a job was not completed until its results were published and even the patent process was not allowed to interfere with rapid publication.[5] As a result, Bell Labs greatly increased the effective pool of intellect that it was able to tap, accumulating a great wealth of knowledge. The benefits of this were similar to the benefits of the multi-continental university research collaboration that developed quantum mechanics.

Third, and perhaps most fundamental, AT&T's regulated monopoly status positioned it to benefit from the US government's commitment to basic research. Although AT&T was a privately-

[1] Ibid.
[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Ibid.

owned firm, some of which was subject to competitive forces, its regulated status provided Bell Labs with access to (effectively) public financing. This was conducive to supporting collaborative, world-class research and being a "unique institution" with unrivaled scientific and technical resources.[1]

Bell Labs had access to (effectively) public financing because AT&T and its local telephone companies were regulated monopolies and, as such, had tariffs set by the Federal Communications Commission and state regulators. AT&T's rates could be raised or lowered with government approval according to what was required to achieve the guaranteed rate of return on its costs. These costs included not only the cost of providing telephone service, but also the costs of most research performed in Bell Labs.

This made Bell Labs' research unit economically more similar to a federally funded research institution than to a standard private research lab. In a federally funded research institution, the government provides money acquired from the public through taxation to provide the money necessary for performing research. Increases in regulated tariffs are economically the same as this. If AT&T claimed that it had a research opportunity that would lead to worthwhile long term results (such as the transistor) and the FCC agreed to raise tariffs accordingly, then the increased tariffs are essentially a tax and the increased revenue are essentially tax funds that are provided directly to AT&T and Bell Labs.

This profoundly impacted the research that it had the financial opportunity and incentive to perform, enabling its collaborative commitment to basic research. Bell Labs had the financial freedom to target and refine the semiconductor public goods as they passed through the late basic research phase,[2] with the luxury of paying little attention to costs.[3] This allowed it to act on its vision to create a solid state substitute for vacuum tubes and provide a new technological basis for its industry.

Underscoring the importance of Bell Labs' research being (effectively) government financed, Bell Labs did not experience any significant competition from private industry in developing the transistor. Its most significant competition came from government financed academia, in particular Purdue University which may have been only months behind Bell Labs in developing a transistor.[4] This lack of private competition reflects the fact that the transistor had not yet proven that it was much more than a scientific curiosity with limited application, so it did not warrant much private investment. With Bell Labs and Purdue University at the front of the race, the first transistor can be seen as a public good development that required the public good method and was not likely to come from private industry, at least not at that time.

Creating Entrepreneurial Energy - AT&T's Attempts to Commercialize the Transistor Before Its Private Good Emerged

AT&T's initial attempts to commercialize the transistor were unsuccessful and further demonstrated that the 1947 breakthrough was on the public good level. This failure occurred despite the fact that AT&T tried to capture as much of the semiconductor's value as possible and, according to Riorden and Hoddeson, "swiftly brought its great resources to bear on the task of turning this scientific discovery into a practical device."[5]

But AT&T undermined its own efforts by being very secretive,[6] which was in conflict with the fact that the first transistor was a public good breakthrough – still more of an idea than a product. AT&T was prematurely acting like it possessed a private good by trying to exclude others from a rival market, although the transistor's great value would come from letting the ideas diffuse

[1] Ibid.
[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.

further, not from the initial physical embodiment or Bell Labs' vision of what they could make it into.

This secretive strategy was causing interest to fade and jeopardized the semiconductor industry's development. According to Riorden and Hoddeson, "People beyond AT&T were beginning to suspect that all the original enthusiasm over the transistor had been premature." Even a 1949 Consumer Reports article struck a skeptical tone, stating, "Current Bell System statements concerning the transistor are far more subdued and give a strong impression that it is under wraps…Very little is said of immediate practical applications. Such transistor difficulties as high noise level are stressed."[1]

AT&T was jeopardizing the semiconductor's completion of the public good phase since the world had not yet seen proof of the transistor's value, and even AT&T did not have the resources to uncover its value without contributions from all directions. As the NSB would warn, the transistor greatly modified the paradigm and, as such, its "most important applications and policy implications (were) not envisioned at the time of the research." As a result, the initial effort had little impact on the marketplace and transistors found very little use apart from some hearing aid and military application in addition to some uses within the Bell system.[2] As a private good, the transistor was not yet worth much and the public good's entrepreneurial energy was in danger of being at extinguished, at least for the time.

From Creating to Capturing Entrepreneurial Energy - *Spreading Bell Labs' Public Good*

But AT&T soon started to treat the transistor appropriately, as a public good. With strong encouragement from the government, AT&T dropped its secretive posture and started to allow the transistor technology to diffuse.

This diffusion, as well as the creation of the semiconductor industry and its entrepreneurial energy, received a great boost in 1951. Four years after Bell Labs invented the transistor, Bell Labs held a symposium to "provide up-to-date knowledge about the transistors for engineers wanting to explore their use in electronic circuits and systems."[3]

This symposium was partly instigated by AT&T's obligations to the public, as mandated by the government, consistent with its public financing. Its obligations to the public included those to the military whose contractors believed the transistor could revolutionize their equipment – but did not know how.[4] The obligations also included the specter of an antitrust suit, forcing Bell Labs to ensure that it did not appear to be withholding " 'proprietary information' that might be useful to the broader national interest."[5]

However, AT&T also recognized that this was in its own best interest because it had come to understand that it still possessed only a public good, an idea, and that the idea still needed to diffuse widely to create value as a private good. According to Riordan and Hoddeson,

> "(Bell Labs' director of research and later president, Mervin) Kelly and others clearly understood that the transistor was an extraordinary breakthrough and that keeping its technology under wraps was ultimately self-defeating. 'We realized that if this thing was as big as we thought, we couldn't keep it to ourselves and we couldn't make all the technical contributions,'
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> "(Bell Labs' transistor development group head, Jack) Morton reflected. 'It was to our interest to spread it around. If you cast your bread on the water, some-

[1] Ibid.
[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Ibid.

> times it comes back as angel food cake.'…Controlling the spread of the fire ignited by their pygmy amplifier proved impossible, however."[1]

AT&T's enlightened official position was summarized in a May 1951 memorandum: "One of our objects at present is to promote the development and application of the transistor first for direct military and Bell System applications and secondly, in the national interest, throughout the domestic economy."[2]

AT&T's primary possessions were still only the ideas that underlie the relatively bulky transistors and could lead to much more value through spurring other ideas. Without spreading the idea around, there is no telling what the semiconductor industry's course may have been and how much would have been lost through attenuated attention and entrepreneurial energy. But allowing the ideas to diffuse satisfied its public good nature, completed the initial entrepreneurial energy creation and pushed the transistor ideas into position to create an industry.

Capturing Entrepreneurial Energy - Semiconductor Private Good's Emergence and a New Industry

Letting the public good diffuse had dramatic results. As the mature public good diffused, it reached many firms that were ready to grasp it and make a profit, creating value in the process. The entrepreneurial energy was being captured as the public goods' diffusion brought forth private goods.

Even before 1951 was over, General Electric achieved the first major advance in transistor technology that did not occur within Bell Labs.[3] Fortune Magazine proclaimed 1953 to be "The Year of the Transistor." By 1954, annual transistor sales were approaching the 1 million mark. Most of these were still for hearing aids and military use, but dozens of companies were now investing in and racing for the semiconductor industry's future. These firms included established giants such as GE, RCA, and Raytheon as well as many small start-ups, such as Texas Instruments.[4]

The rate of entrepreneurial energy capture and progress only increased throughout the 1950s as the consumer potential was becoming clear, further re-firing the entrepreneurial energy's creation and capture. Little more than a start-up, Texas Instruments created the transistor radio industry, designing and building the first radios' circuitry.[5] Having accomplished this, TI was chosen to supply IBM with transistors for the first fully transistorized computer.[6] Soon, dozens of competing firms were driving down manufacturing costs,[7] allowing the transistors to dominate and even create markets including those for phonographs, dictating machines, pocket pagers, automobile radios and fuel injection systems, clocks, watches, toys, and satellites. Digital computers and next-generation telephone switching systems were on the horizon.[8]

The results of the industry's energy led Kelly to claim, "We are now further along in semiconductor electronics technology after one decade of work than we were in electron tube technology 25 years after de Forest's invention of the audio." Many other bold statements echoed this unbridled confidence, this entrepreneurial energy, foretelling the semiconductor industry's astounding performances and unprecedented rewards. Morton predicted, optimistically but insightfully, "It may well be that these solid state electronics extensions to man's mind will yet have a greater impact upon society than the nuclear extension of man's muscle…Perhaps the safest prediction one can make is that transistor electronics has a great future – that it will go in new direc-

[1] Ibid.
[2] Ibid.
[3] Ibid.
[4] Ibid.
[5] Ibid.
[6] Ibid.
[7] Ibid.
[8] Ibid.

tions we cannot foresee today at all."[1] These statements of great success and high expectations reflected the rich technological platform that the public good process had provided for industry to build off of.

However, it would not be AT&T, the creator of the entrepreneurial energy, that would capture it. It would be the new small hyper-dynamic firms, created through entrepreneurial energy and formed strictly to drive the semiconductor forward and capture profits. According to Reardon and Hoddeson, "During the 1960s, however, Bell Labs slowly began to lose its innovative edge…radical innovation had to come from elsewhere – from risk-taking Sun Belt semiconductor firms with little to lose and an industry to gain."[2]

The unbounded energy caused Bell Labs, with its (effectively) public funding and public goods research orientation, to give way to Schockley Semiconductor Laboratories, RCA and Texas Instruments, which gave way to Fairchild Semiconductor, which gave way to Intel, each capturing heightened entrepreneurial energy. In fact, soon after the integrated circuit's development, AT&T licensed hundreds of patents to Fairchild in exchange for two integrated circuit patents.[3]

Once profits were sufficiently close, the arena belonged strictly to private profit-seeking private firms. The industry was up and running, entrepreneurial energy was being captured through competition for advanced private goods, and the simplest of free market principles were dominating.

In contrast with the decline in interest during the late 1940s when AT&T was closely guarding the public good transistor ideas, the expectations for the private goods were becoming limitless, as was the entrepreneurial energy. This period, after 1951's diffusion of the transistor ideas, is the private good mirror of the scramble early in the century to uncover quantum mechanics.

During the first half of the century, scientific inquiry recognized the gap that existed in scientific understanding and exploited the public good nature of ideas to compete and advance knowledge by working freely off of one another's ideas with public support. During the second half of the century, private firms recognized that they had a new technological platform and exploited the private good nature of the goods that it could generate by trying to surpass one another's performance and capture profits. Public and private goods played their appropriate complementary roles in creating a new world of value.

Capturing Entrepreneurial Energy - The Semiconductor Industry and Electronics World in General

Little new can be said about how high tech products have changed the world. The value of the semiconductor is incalculable because its impact is so ubiquitous, in countless markets that would not even exist without it. These industries include personal computers and telecommunications (the industries that consume the most semiconductors), the Internet, computerized car parts, telecommunications, advanced aviation, video games, biotechnology equipment, advanced sound systems…

Looking back, the electronics world and all of the value that it has created traces through paths beaten by private profit seeking firms that captured entrepreneurial energy, intersect at the transistor and find their common root in the quantum mechanics breakthroughs of the early twentieth century whose public goods created entrepreneurial energy. Looking forward, this example demonstrates that investment in the public goods of basic research breakthroughs promises to continue to "advance the knowledge and well-being of mankind, not infinitely, as some have said, but indefinitely, and to a term which no one can fix and foresee."

[1] Ibid.
[2] Ibid.
[3] Ibid.

VI. Entrepreneurial Energy's Creation and Capture: Biotechnology

> Some of these have rendered the elements themselves subservient to the purposes of man, have harnessed them to the yoke of his labors, and effected the great blessings of moderating his own, of accomplishing what was beyond his feeble force, and extending the comforts of life to a much enlarged circle, to those who had before known its necessaries only. That these are not the vain dreams of sanguine hope, we have before our eyes real and living examples.
> –Thomas Jefferson, Report: University of Virginia, Aug. 4, 1818[1]

The semiconductor industry's experience was extraordinary – it may be the greatest example of private industry propelling an economy forward by capturing the entrepreneurial energy created through the public goods process. Despite being extraordinary, the semiconductor industry's experience is based on economic fundamentals and reflects the economic rule, not the exception. It is little coincidence that biotechnology, the other industry that is arguably opening the greatest frontiers for new industries, had a remarkably similar experience. The biotechnology industry was also enabled when the public goods process created entrepreneurial energy and a technology platform, which generated intense and value creating private competition.

The Capture of Biotechnology's Entrepreneurial Energy

Much attention has been focused on a branch of the latter portion of this experience, the great race to complete the first mapping of the human genome in 2000, in which the private start-up, Celera, challenged a formidable government-funded network (including the National Institute of Health, the Department of Energy, organizations within the British government and several private companies). The race's winner would take leadership in the sector, lead the creation of goods and services of extraordinary value to society, and receive profits that reflect this value.

Although the government network opened the genome-mapping race with a clear advantage that was based on its scale and earlier activities, the private Celera entered and made the tough decisions and savvy investments that allowed it to outperform the government network. As a result, Celera greatly sped the progress while finishing no worse than in a tie for the first mapping. This has been celebrated as a great example of private industry proving its innovative superiority to government organizations by using its incentives to capture entrepreneurial energy, to compete and drive progress forward in exchange for expectations of profits (private goods).

Public Goods Process That First Created Biotechnology's Entrepreneurial Energy

But this private capture of entrepreneurial energy is only the second half of the story. This would not have occurred without the first half, the public creation of entrepreneurial energy that occurred through the public goods process. Specifically, the roots of human genome mapping and the race are traced directly to the publicly funded basic research breakthroughs achieved around 1950 at Cambridge University, where James Watson and Francis Crick identified DNA's double helix structure and published their findings in the academic journal *Nature*.[2] The article's second paragraph referenced the publicly funded work of Pauling and Corey at the California Institute of Technology and acknowledged the importance of their collaborative spirit in allowing them to bring their idea to fruition.

Biotechnology's entrepreneurial energy creation and capture occurred through the same economic forces and public good process that enabled the transistor and eventual electronics in-

[1] Appleby, Joyce and Terence Ball (eds.).
[2] James Watson and Francis Crick, Molecular Structure Of Nucleic Acids - A Structure for Deoxyribose Nucleic Acid, Nature, 2 April 1953.

dustries. First, the enabling basic breakthroughs were significantly funded by the public. Second, the breakthroughs were achieved by researchers who competed with one another but within a collaborative environment. Third, the breakthrough received life through being published for public consumption because their discovery was a public good (concepts that were very remote from most of their commercial potential, so the researchers would maximize their benefit by allowing the public goods/ ideas to diffuse and develop through the public process). And fourth, after the public goods process refined the underlying ideas for years, private industry emerged to compete intensively to capture the entrepreneurial energy and profits through producing the most valuable products and services that they could innovate.

There are a wide variety of examples of the public goods process that creates and captures entrepreneurial energy, to render the elements subservient to man – although it is hard to imagine how any could be more powerful than electronics and biotechnology.

VII. Conclusion – Entrepreneurial Energy and the Payoff Economy

> You possess, yourself, too much science, not to see how much is still ahead of you, unexplained and unexplored.
> - Thomas Jefferson to John Adams, Monticello, June 15, 1813[1]

Jefferson would probably not call the recent times a "New Economy" – "new economy" applies to what he and his contemporaries created centuries ago. Rather, he might call it a "Payoff Economy," since it has been reaping the rewards of the basic research investments that were made through previous generations in accordance with the principles that were laid out at the time of the true new economy's creation.

The great danger of attributing this prosperity to a "New Economy" is that doing so masks the fact that basic research investments were made to bring forth this prosperity. Publicly funded basic research created the entrepreneurial energy that was captured, leading to this prosperity. It masks the fact that maintaining public commitment to these investments is required for sustaining prosperity. Most importantly, it masks the fact that these lessons, proven by the "Payoff Economy", can be applied and reapplied to sustain continuous waves of innovation, providing continuous waves of prosperity, which can keep the economy new.

> And where this progress will stop no one can say.
> -Thomas Jefferson to William Ludlow, Monticello, September 6, 1824[2]

Dysfunctional Managerial Behavior in the Workplace: Implications for Employees, Supervisors, and Organizations

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Abstract. This paper presents a review of the literature that describes and attempts to explain various manifestations of dysfunctional managerial behavior. Dysfunctional behavior includes questionable and sometimes erratic actions of people in the workplace. Codependency, a fairly stable pattern of behaviors, affects millions of people and is one possible explanation for

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[2] Ibid.
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