Techonomics: Anticipating the Future

by Dr. H. Lee Martin, *Tennessee Alpha '78*

Give me a fulcrum on which to rest, and I can move the earth.
—ARCHIMEDES, 287-212 B.C.

WHAT'S HAPPENING? Globalization, mass-customization, virtual companies, virtual stores, jobless recovery, outsourcing, off-shoring, tax relief, wireless world, world-wide web, just-in-time delivery, virtual warehousing, shortened product-life cycles—the lexicon of the new economy is expanding rapidly. We see it happening in all that we do, where we do it, and how we organize to compete effectively. In the span of 100 years we have seen the transition from the agricultural economy to the industrial/manufacturing economy to the information economy. So what lies ahead? Techonomics, my term, provides a thought process to evaluate and anticipate future trends.

My grandfather grew up across the classroom from the people he would compete with for life.
My father grew up across the country from the people he would compete with for life.
I grew up across the world from the people I would compete with for life; only they knew it and I didn't.
—SOURCE UNKNOWN

My six-year-old came home recently from a brief shopping trip to Wal-Mart with a simple, telling question, "Do they make everything in China?" Seems that he had just discovered the "Made in …" labels on each product, and he did his own unscientific survey. I might have asked a similar question as a kid, "Do they make everything in Japan?"

This article describes the foundation of a thought process called techonomics for analyzing technology-driven trends in the economy enabling you to spot, evaluate, and capitalize on future business opportunities. The fundamental assumptions and key laws will be introduced; a method for developing your own techonomic metrics is provided and applied to several business sectors.

The techonomic representation measures the cost of fundamental resource metrics over the passage of time, providing insight into trends and discontinuities brought about by technological advancement. Because we live in a world of limited resources, it is important for individuals, businesses, and nations alike to be able to discern among numerous opportunities for resource deployment—to find the great opportunities among a myriad of good options. The objective of techonomics is to provide a rationale to aid in this discernment.

The cause and effect relationship in the physical world has been understood for centuries. Simply stated:

For every action there is an equal and opposite reaction. —ISAAC NEWTON, 1643-1727

Techonomics considers technology as the fundamental driving force in modern business producing an observable economic result. For generations, the concept of supply and demand put forth by Adam Smith in *The Wealth of Nations* has framed our understanding of free markets. Because of advances in technology, we are now capable of overproducing many manufactured consumer items, and traditional market theories fail to provide an adequate framework for understanding rapidly changing economic trends. It is no longer sufficient to provide a product at a price that the market will bear—it must be provided at a price and quality level determined by a much better informed customer. To compete in a free market with increasingly perfect information availability, business must recognize the impact of technology and embrace its use in best practices.

Technology today is a major cause of:
- New product and business opportunities,
- Lower barriers to entry,
- Streamlined organizing principles,
- Improved and ubiquitous communication methods,
- Massive wealth creation for individuals and nations,
- Nonlinear access to the majority of the world's information, and
- Fundamental changes in how we live and work daily.

The reaction of the new economy is seen in:
- Expanding number of companies,
- Increased competition,
- Exploding diversity in product offerings and reduced product cycles,
- Effective global networking,
- Increased outsourcing,
- Digital everything: cheap, smart, feature-packed, and small, and
- AAA reach—serving anyone, anywhere, anytime *instantly.*

We are surrounded by insurmountable opportunities.
—POGO

So what is *techonomics*? A definition is in order. The techonomic premise is that *tech*nology advancement causes major economic changes in business and society. Only through economic success in the marketplace do businesses succeed and then perpetuate, and their products reach the masses. Supporting the old adage "follow the money," the properly timed introduction of new technologies drives the flow. It is not sufficient to be able to make something work. To be a successful business, offerings must compete in the marketplace on the basis of cost and quality. After a need is filled, the economics of the resulting product, process, or service relative to competition will ultimately determine society's acceptance and marketplace success. Technology advancement creates new business opportunities, while economic reality determines the long-term viability of opportunities. Combining those two thoughts into a definition results in techonomics.

Techonomics is the study of trends in business and society resulting in observable economic change caused by the advance of technology.

Traditional economics has been guided by studying fundamentals of supply and demand to determine the distribution and pricing of goods and services. The role of technology to supply goods in increasing quality at decreasing costs, to provide globally networked systems for new organizational models, and to affect mass awareness instantly must be understood in the analysis of the 21st-century economy.

FUNDAMENTAL ASSUMPTIONS AND LAWS OF TECHONOMICS

Viewing technology advances as the major "cause" of economic change, techonomics relates the key technology advancements to their economic effects on business and commerce. The cause-and-effect relationship of certain key technologies transcends the nuances of various markets and gives a stable foundation upon which to understand significant trends in the economy. A handful of fundamental assumptions supports the applicability of techonomics to anticipating future trends.

- *Increasing knowledge:* For techonomics to have impact, the universe of knowledge must be increasing. In times of rapid knowledge expansion, techonomic trends exhibit a greater impact on the economy.
- *Relatively free market with competition:* A free market is required for the competitive economic opportunities provided by technology advance to be embraced. In a contrived market, rational business practices give way to governmental regulation or monopolistic control.
- *Knowledgeable participants:* Knowledgeable participants acting in their best interest are the driving force behind adoption of best practices. Free to select among the possible providers, informed individuals and businesses are the catalysts for change.
- *Cost metric:* Techonomic metrics represent the cost of a measurable provision over the passage of time, providing insight into trends and discontinuities brought about by technological advancement. Rapid changes in these metrics are the indicators of significant pending market opportunities. Cost is commonly measured in monetary terms, but can also be related to labor, material content, or other measurable quantities fundamental to the market being observed. Techonomic metrics are tracked as a function of time to observe when technology advance causes performance shifts in the market being considered.

The first three laws of techonomics broadly develop a philosophy that is both observable and universally applicable. These three laws have been selected as the foundation of techonomics because they are caused by exponentially accelerating technological advance compounded with reducing costs over an observable period of time. They are causing major shifts in fundamental business practices today.

The first three laws of techonomics are:

1. Moore's Law
Law of Computational Ubiquity,
2. Metcalfe's Law
Law of Global Information Network, and
3. Coase Law
Law of the Innovation Economy.

These laws provide a foundation for understanding the economy of the 21st century. The techonomics form restates these time-based observations in a manner that relates capability delivered related to its cost. It has been a time-honored approach in engineering to develop empirical relationships between key measurable parameters by conducting a series of experiments and determining a best equation to fit the observed results. Fluid flow (Bernoulli's equation), heat transfer (Stephan-Boltzmann constant), and material strength testing (Poison's ratio) are only a few of the frequently used examples. With techonomics, the "series of experiments" is the market response observed over time to technology-driven change, particularly as it relates to production and delivery costs. Techonomic metrics can be extended to other markets, but these first three laws have had the greatest affect on the broadest number of markets. They are offered as a fundamental guide to understanding current trends in the economy.

Moore's Law: Law of Computational Ubiquity

The complexity (of integrated electronic circuits) for minimum costs has increased at a rate of roughly a factor of two per year.[1]
—GORDON MOORE, CO-FOUNDER, INTEL

Gordon Moore, co-founder of Intel, observed in 1965 that the number of transistors per square inch on an integrated circuit had doubled about every year. Moore predicted that this trend would continue for some time into the future. Simply stated, Moore's Law anticipates that the density of electronic components in an integrated circuit will double every 12 months. In the four decades since, the timeframe for this density doubling has been measured consistently in the range of 18-24 months, and this trend appears to be continuing. Because the gain in density is geometric (it doubles) in a linear timeframe (18 months), the compounded results over time are remarkable and have impacted every facet of technological progress during the past 40 years. *Figure 1* shows the number of transistors in the latest microprocessor from Intel during a 30-year span. Obviously, Moore's Law has been a strong predictor of electronic density during this period.

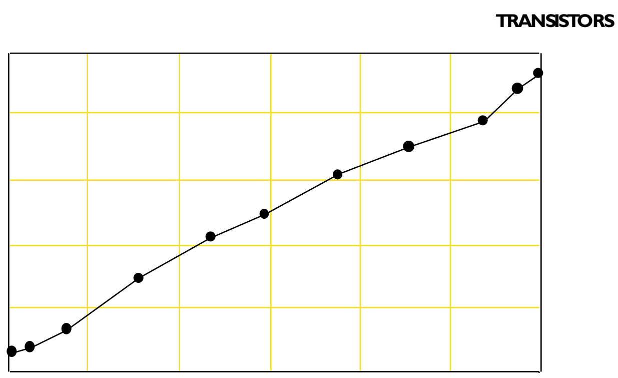

Figure 1 Evidence of Moore's Law over 30 years (SOURCE: INTEL WEBSITE).

Both speed and cost of an integrated circuit are tied to its packing density. Speed is governed by the speed of light (electricity) through the circuits—the closer the transistors, the faster the computational speed. The primary economic costs to an integrated circuit are the material wafer on which the circuit is printed and the capital costs associated with providing the facility to make the wafer. With an essentially fixed material cost involved in making the fixed-size wafer, the smaller the transistor size, the more transistor elements that can be made on the same wafer size. The result: more capability for the same price as the size of the transistors shrink. Casting Moore's Law in techonomic terms with the assumption that the total production cost of a silicon wafer has remained steady, the key metric to monitor the economic impact of technology progress predicted by Moore is the cost per transistor provided in the marketplace ($/transistor). Changes in this metric over time are shown in *Figure 2*.

The First Law of Techonomics is termed the Law of Computational Ubiquity because the exponentially dropping price of electronic computation supports its application to an ever increasing number of uses. Fundamentally, the first law implies that if a computational application is not economically feasible today, it is just a matter of time before it will be commonplace. For example, the computer that augmented control of the Lunar Excursion Module (LEM) that placed humans on the moon and returned them safely to the mothership in 1969 had less computational power than the PDA (personal digital assistant) that is widely available and affordable today.

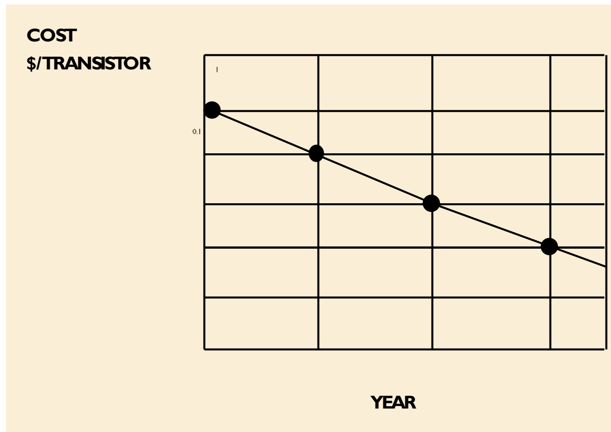

Figure 2 Fabrication cost per transistor (SOURCE: UNIVERSITY OF CALIFORNIA, BERKELEY, EE141 CLASS NOTES).

During the last 30 years, the implications of Moore's Law have permeated almost every consumer product imaginable. Smart traffic lights, home lighting controls, automobile windshield wipers, automated telephone systems, digital watches—a myriad of products now think for themselves. This massive distribution of imbedded computation has been made possible, not just by the technological advance, but by the economic viability of the technology—the *techonomics*. Today, it is not unusual for an automobile to contain more than 50 embedded microprocessors. The typical American home contained no microprocessors in the decade of the 1960s. Today, the American house makes a home for more than 200 of them in everything from appliances to entertainment systems to lighted tennis shoes. A snapshot of the digital permeation of our life is found in the excellent photo essay collection *One Digital Day*[2], which uses pictures to capture how the microchip is changing our world near the turn of the 21st century.

Ray Kurzweil, in his book *The Age of Spiritual Machines*[3], assumes the continuation of Moore's Law into the next century and imagines what the implications will be to our lives. He projects that by the year 2020, a $1,000 personal computer will have the processing power and memory equivalent to the entire experience of an individual human—a machine that can remember every activity of your entire life and reason at your level. Even more thought-provoking, if Moore's Law holds through the year 2040, Kurzweil anticipates that a $1,000 PC will have the equivalent capacity of the knowledge and memory of the entire living human race! The implications are staggering—a far greater impact on society than even the harnessing of steam or electricity. Electricity and steam were levers for physical work, and computers are levers for mental work.

To conclude:

> **First Law of Techonomics:** Law of Computational Ubiquity—The cost for equivalent computing performance halves every 18 months.
> TECHONOMIC METRIC: **$/transistor**

Metcalfe's Law Extended: Law of the Global Information Network

> *The connections of a network increase in proportion to the square of the number of nodes.*
> —ROBERT METCALFE, FOUNDER, 3COM

Robert Metcalfe was the inventor of the Ethernet protocol, a successful method for joining computers into a network. He was also a founder of 3Com. He made the observation, now known as Metcalfe's Law, that as the number of users on a network increases, the number of potential interconnections increases exponentially. The equation and a visible representation of Metcalfe's Law are shown in *Figure 3*.

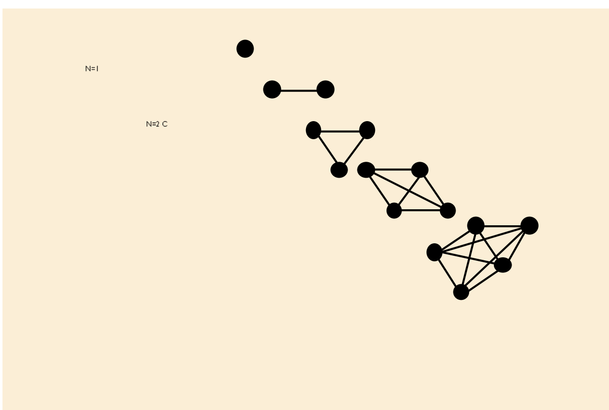

Figure 3 Visual representation and mathematical equation demonstrating Metcalfe's Law (N-Nodes, C-Connections).

Metcalfe's Law for a communications network points to a critical mass of users at the point when anyone can reach anyone directly and instantly. Compound Metcalfe's Law with the ability to access digitally stored on-line information in non-linear ways, and the potential impact of the Internet comes into focus. Not only can we reach anyone (the telephone network provided this), we can also instantly and non-linearly locate key information related to virtually any topic imaginable with a search engine and a few well-chosen key words. The techonomic metric trends the annual cost to access the network per page of information available ($/page). As of this writing, Google now searches 4.3 billion pages, and my high-speed Internet access costs about $400 per year. The second law metric ($/page) is about $0.0000001 per page. Compare that to 20 years ago when no pages were available to the masses ($/page was infinite) or the cost of your local Sunday paper at $1.00 per 100 pages ($0.01 per page), and you begin to grasp the implications of boundless information at minimal price.

With access costs decreasing and information availability exponentially increasing, the Internet is causing change to occur in every facet of 21st-century business. The transaction costs associated with outsourcing production, sales, distribution, and service of cooperative business activities are plummeting. The economic impact to the end user is that one can now reach or find almost anything, from almost anywhere, almost instantly. Combining Metcalfe's Law with Moore's Law, the proliferation of the global network has proceeded at a blinding pace as both computational and communication costs have simultaneously and exponentially fallen.

In a matter of less than 10 years the world has shrunk to a desktop—virtual access to the world's information at our fingertips. Technology has moved transactions from the tangible world (travel, postal mail, linear telephone calls) to the virtual world (Internet, search engines, ubiquitous computing, non-linear access). Nicholas Negroponte, in his book *Being Digital*, simply called this trend moving from "atoms to bits." Truly, if knowledge is power, today's web-savvy participants are substantially the most powerful people to ever walk the face of the earth.

> **Second Law of Techonomics:** Law of the Global Information Network—The cost of locating anything on the global network is diminishing exponentially as the number of users increases.
> TECHONOMIC METRIC: **$/annual access cost/page of network accessible information**

Coase Law Modified: Law of the Innovation Economy

> *Apart from the question of diminishing returns, the cost of organizing certain transactions within the firm may be greater than the costs of carrying out the exchange transactions in the open market.*
> —RONALD COASE, NATURE OF THE FIRM, 1937

Ronald Coase, a British economist, is known as the originator of a thought process called transaction cost analysis. He first disclosed the concept of transaction costs in his 1937 article entitled "The Nature of the Firm." In laymen's terms, transaction cost analysis is simply the *make or buy* decision—should a firm make a needed product internally or buy it from some external source? As individual consumers of goods, we perform these make or buy decisions many times daily. Do I grow my own food or go to the grocery? Do I cook dinner or eat out? Do I make my own clothes or buy them at the store? Do I mow the grass or hire it out? It's all about the value of our time, our skills, our desires, and our economic priorities. It's the same way with business, only the decisions for business are magnified by the financial discipline of the free market.

Coase studied several U.S. companies in the early 1930s. At Ford Motor Company's River Rouge Plant, he found a monolithic, self-contained factory that started with raw iron ore and produced automobiles. Ford was forced to "make" rather than "buy" many of its automobile components because the quantities Ford required were beyond the production capabilities of external suppliers. If you trace the automobile industry's progress through the years, a major shift in structural organization occurred in the 1970s as the Japanese used outsourcing to simultaneously improve quality and reduce costs. The entire industry has now followed suit in order to compete in the international marketplace.

Coase found that there are many elements that comprise transaction costs after a need is determined. A list of some, but not all, of these transaction elements includes:

- *Price:* How much will an item cost produced internally or bought externally?
- *Availability:* Is the item readily available, or is special design required?
- *Timeliness:* Can items be available in the quantities desired on schedule?
- *Location:* Is the item available at a location that is accessible?
- *Quality:* Is there a consistency and fitness of the product under consideration?
- *Trust:* What are the costs and ramifications if suppliers are dishonest?
- *Multiple sources:* Can I find additional sources if needed?
- *Switching costs:* How hard is it to change suppliers?

With the availability of nearly perfect information made possible by the global information network, many of the traditional transaction costs of outsourcing are significantly diminished. Specifically, location of multiple sources is now made easily, which causes switching costs to decrease and availability issues to diminish. External competition for traditionally internal transactions is both facilitated and accelerated. The pendulum shifts to the "buy" decision and away from the internal "make" decision as the quality and quantity of information expand for decision-makers.

The Law of the Innovation Economy anticipates a diminishing number of employees in an optimally sized corporation as all but the most essential functions are outsourced. The reduction in organizational size will be accompanied by an increasing number of efficient organizations—the age of the small business is upon us in the free market economy. Job growth statistics in the last decade bear this out. While *Fortune 500* composite employment has steadily dropped in the last decade, total employment has increased due to the jobs created by small businesses. Outsourcing, supported by the expanding global information network, results in more cost-effective production, more nimble operation, and a more flexible approach to the marketplace. Larry Downes and Chunka Mui[4] describe in detail the relationship between information efficiency and business organization resulting from reduced transaction costs, calling it the law of diminishing firms. If a firm maintains its revenues while reducing its employee base, this is an indication of increasing productivity of the firm. Innovative technology firms using efficient outsourcing networks are finding ways to increase the top (revenue) and bottom (profitability) lines while maintaining or decreasing the number of employees. Over time, this metric should increase at a rate in excess of inflation in a company that is becoming more efficient. Company mergers and expansion into unrelated efforts strongly affect this metric. The general trend of economic health of a private-sector organization can be monitored by the Third Law of Techonomics, as follows:

> **Third Law of Techonomics:** Law of the Innovation Economy—As the cost of transactions diminish, optimum organization size reduces, thereby increasing the revenues generated per employee.
> TECHONOMIC METRIC: **$revenue/employee**

EXTENDING TECHONOMIC ANALYSIS

> *Create a better and better product at a lower and lower cost to an ever increasing market.*
> —JOHN LINCOLN, LINCOLN ELECTRIC

Techonomics does not end with the first three "laws." It can be extended into a method for analysis of significant trends that are affecting business and society. Techonomic observations can be developed to track critical trends that drive your business or organization. Developing your own techonomic metrics is comparable to creating a virtual experiment. The goal is to create an empirical metric that provides insight into trends in the marketplace. The key steps are:

1. Select an item or market of interest.
2. Search for an economic cost component that is easy to observe over time (product cost, service cost, life cycle cost, …).
3. Seek a quality measure that changes as a result of technology progression (speed, size, capacity…).
4. Create a metric by combining the economic and technological components.
5. Track the metric as a function of time.

A simple example is in order to apply the techonomic approach. I have had an interest in digital cameras for the last 15 years and have seen the photography marketplace transformed. Stepwise, here is techonomics in action:

1. *Market of interest*—digital photography.
2. *Key cost element*—consumer-level digital cameras available at retail.
3. *Quality measure*—imager resolution as a function of pixels (picture elements).
4. *Techonomic metric*—camera cost $/pixels in imager.
5. Track the metric from 1990 to the present.

Digital cameras benefited from Moore's Law (more pixels in electronics for less cost) and from Metcalfe's Law (the global digital network provided a way to share the media). In 1990 there were few, if any, digital cameras for the consumer. In the mid-1990s, cameras with imagers borrowed from camcorders (640 x 480 pixels, 300,000 pixels) began to be introduced in the marketplace at a hefty price, ranging from $600-1,000. The marketplace responded by creating a demand for the product that justified development of imagers targeted at photography (higher image resolution, more color resolution, single-frame capture). By the late 1990s, a plethora of digital cameras entered the consumer marketplace offering resolution in the 2-megapixel range and priced between $600-800. Currently, 4-megapixel cameras can be obtained in the range of $400. The quality of the output of these cameras rivals film to consumers' eyes. Future advances will be in cost reduction provided by larger mass production and improved ease of use. The massive shift in the techonomic metric is now stabilizing as a competitive quality level has been reached. One also notices the recent establishment of service networks to cater to the digital photographer. This will increase the adoption rate of digital photography by the masses as the $/photograph for digital is now considerably less than the same measure for film.

A business advisor at Motorola once urged me to "Consider the potential applications of your technology when the cost is driven to 'nothingness' " (conversations with Nicholas Labun, 1993). At the time it was difficult for me to comprehend exactly what he meant. Because of the relentless progress of the first two laws of techonomics, I witnessed the transformation of our key product from a cost of goods of $3,500 to a worldwide deliverable experience with a cost measured in pennies—all in the span of three short years! The march to software rather than hardware implementation enabled by ever faster computers and the advent of the global network simultaneously reduced costs and extended application value. The vantage point of techonomics provides the user with the fixed fulcrum to observe and move the world.

Techonomic metrics consist of a measurable cost for the delivery of a key quality element of a product/service unit as observed over time. Exponential changes and discontinuities in the metrics can result from the introduction of new technologies into the marketplace. To sharpen your techonomic understanding of various markets, consider the following empirical techonomic metrics:

Flat Screen TV Displays

TECHONOMIC METRIC: **$/display pixel*inches^2**
[Unit cost/(number of pixels*screen area)]

Television standards and monitors have changed rapidly in the past ten years, after 25 years of stagnation. New media distribution (cable, satellite, broadband) and new formats (analog, high-definition, digital-compression) have brought about an increasing demand for programming. New display technologies based on improved digital processing, projection, flat screens, thin screens, LCD, plasma, and organics are revolutionizing the television viewing experience. With each new step in quality, the old methods lose favor and retain market position only by cost reduction. Tracking the display cost as it relates to the number of pixels and screen size is a way to optimize your purchasing power. The thin-screen TV market is still in the early adopter mode, and you can expect this metric to continue to fall until mass-market prices are met and technological innovations slow.

Consumer Internet Bandwidth

TECHONOMIC METRIC: **$per month/kbaud**
[Monthly cost/bandwidth delivered]

Consumer bandwidth and its penetration are key to the type of media that can be delivered across the Internet. Increasing bandwidth is required to deliver media from text to pictures to audio to video. Businesses delivering a media type where bandwidth cannot be supported or where penetration is too small are doomed to failure. It is a matter of proper timing of the market entry. Typical monthly fees for access at a specific rate determine the consumer bandwidth metric. A look over the past 15 years finds access cost relatively constant ($15-40 per month) while bandwidth speed has skyrocketed from 4,800 baud to several megabaud. In the last three years the metric has stabilized because the network is built. Competition between providers has intensified on a price basis, not a bandwidth performance basis.

Energy

TECHONOMIC METRIC: **$/kwhr**
[Cost/energy unit delivered]

The techonomic energy metric is easy to define but difficult to obtain. Simply stated, it is the cost of a unit of energy. The difficulty is to determine the total cost and usefulness of the energy form considering environmental costs, safety issues, availability, and regulations. Because energy can be obtained from multiple sources (coal, petroleum, natural gas, nuclear, biofuel, solar), industry often shifts from one source to another based on the law of supply and demand. More frequently these days, the law of supply and demand is superceded by the financial impact of regulations. The cost of regulation because of public fear caused the demise of the nuclear-power industry. We now live with the resulting consequences of air pollution from carbon-based energy production. As environmental regulations on coal-produced electricity increase, the demand for natural-gas-produced electricity has expanded. Free market forces driven by cost and availability are supplanted by regulation, monopoly, and intervention. One might conclude that the validity of techonomic analysis in a given market is inversely proportional to the degree of the economic impact ascribed to regulation, constraint of free trade, and governmental intervention.

Individual Healthcare
TECHONOMIC METRIC: **$/life**
[Average per capital annual cost * life expectancy]

As I explored techonomics in various markets, I found an unexpected trend in healthcare: techonomics in reverse—a market out of control. Much like an audio loudspeaker squeals when the microphone is placed in front of it (positive feedback), the healthcare industry is in a runaway condition, and techonomic metrics shed light as to why. No one would argue that technology in medicine is advancing. New drugs, new procedures, unraveling of the human genome, and new diagnostic tools are incrementally extending life expectancy. Average life expectancy for a U.S. female is nearly 80 years. Combine that with the average per capita expenditure of $5,000 per year in the U.S., and you have an average individual lifetime healthcare metric of $400,000 per life. Few individuals directly bear the brunt of these costs. During the past 40 years, out-of-pocket healthcare expenses have steadily dropped from more than 50 percent to under 20 percent.[5] Society and business are shouldering the load through insurance premiums. It is of little surprise that the burden of healthcare insurance is becoming unbearable for many businesses and individuals. The healthcare insurance benefit cost alone for a middle-aged worker and family of four far exceeds the minimum wage!

In healthcare we see the compound effects of improved technological practices increasing life expectancy and its attendant costs combined with reduced personal financial responsibility for control of expenses. If this trend is left unchecked, it will not only cause the collapse of healthcare provision as we know it, it will also lead to the demise of ability of the business sector to subsidize healthcare insurance. The next governmental attempt to control this fragile system will be the encouragement of medical savings accounts (MSA), which will be successful only if the economic responsibility for end-of-life medical treatment and expense is also placed with the individual.

Secondary Education
TECHONOMIC METRIC: **$/grad**
[Annual educational expenditures per student/ graduation rate]

The current primary and secondary educational systems in the U.S. exist in a contrived marketplace. Participation is mandatory, and provision of services is, for the most part, from a monopoly—the public school system. Implementation of technological advancements has been slow within this sector as competition for funds requires trade-offs among facilities, transportation, salaries, administration, athletics, and books, as well as current technology. The short product cycle life of key technological products also requires continuous investment to stay current. The lack of competition within the sector eliminates the incentive to incorporate best practices to remain viable. As a result, the educational metric of cost to produce a secondary school graduate is increasing at a compounded rate—the combination of higher annual-per-student expenditures and reduced graduation rates. The easiest way to introduce competition into the sector is through an educational voucher program to provide parents an opportunity to select options for their children. While extremely controversial, techonomics points to the reason why a voucher program would have a profound and ultimately positive impact on the educational system.

UNEXPECTED TECHONOMIC OUTCOMES

The techonomic thought process was developed during several years to aid in discerning the timing of technology-driven business opportunities. Many of the underlying concepts are discussed at length in *Unleashing the Killer App*[4] and *Crossing the Chasm*[6]. Deriving empirical metrics from experimental observations is a tested method in engineering and science, but a thought process for developing technology-driven cost metrics observed over time for the business marketplace is the foundation of the emerging philosophy of techonomics. In tracking many different markets with simple, observable metrics over time, one can obtain valuable insights for anticipating future trends.

In conclusion, one unexpected techonomic finding has arisen related to regulated/monopolistic markets in contrast to free markets. The techonomic metrics in controlled markets do not show the same kind of technology-driven cost reduction of free markets. In fact, in some highly controlled markets, techonomic metrics actually show poorer economic results as technology progresses. A techonomic study of the healthcare, education, and power utility sectors reveals the negative impact of constraining the marketplace. One area suffers from lack of individual financial accountability, and two suffer from the excesses of monopoly (governmental and quasi-private). Techonomic metrics reveal that when contrived forces overpower the free market in a given market sector, the adaption of best-technology practices succumbs to the preservation of the *status quo*. In a sector with constantly rising labor costs, if efficiency gains offered by technology advancement are not embraced, market metrics become regressive. In hindsight, it should not be a surprise that the techonomic analytical process developed to capitalize on the opportunities of the free market should reveal the economic cost incurred when free market practices are constrained.

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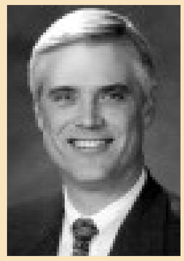

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