THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF ECONOMICS

ASIMOV'S CROSSROADS: A COMPREHENSIVE ANALYSIS OF MAN AND MACHINE AND THE ROBOTICS MOVEMENT'S IMPACT ON HUMAN WELFARE

PRAVEEN CHANDRAMOULI

Spring 2009

A thesis
submitted in partial fulfillment
of the requirements
for baccalaureate degrees
in Economics and Finance
with Honors in Economics

Reviewed and approved* by the following:

David Shapiro
Professor of Economics
Honors Adviser, Thesis Supervisor

Ed Coulson
Professor of Economics
Faculty Reader

*Signatures are on file in the Schreyer Honors College

Abstract

In this thesis, I examine the economic arguments for and against the hypothesis that technology is a unilaterally positive influence on human welfare. Using tools and theories from behavioral economics while referencing the latest scientific research in the fields of robotics and nanotechnology, I will examine the current relationship between man and technology. Next, the prevalent theories are applied to the current circumstances. Using concepts drawn from finance, microeconomics, and science, I will proceed in this argument. Ultimately, I will argue that there is an equilibrium, an optimal level of technology beyond which man is no longer aided, but deterred by a marginal increase in technological capacity.

Table of Contents

Introduction

Ever since the days of fire and simple machines, man has had a unique relationship with technology. It has vastly improved man's quality of life, from heating food to listening to music. Technology has given man command over his surroundings; his ability to discover and harness it has differentiated him from other creatures. Technological advances, while usually greeted with mixed reactions, have in the long run contributed greatly to the sophisticated and relatively easy lives we enjoy today (compared to our predecessors). There remains, however, a strong undercurrent of discord. People have lost their jobs, their sense of efficacy, and their sense of purpose. For a creature as driven by ego as modern man, these are not easy pills to swallow. This feeling of displacement drove a group of English textile workers in the early nineteenth century, led by Ned Ludd, to destroy the looms that threatened their work. Today, the Luddites are condemned as opponents of progress who acted destructively on their emotions.

Industrial and academic leaders in the technology field readily acknowledge that a new "revolution" is impending. Like the computer before it, this revolution will change the scope of the human experience in unimaginable ways, and allow for far greater ease in many of the tasks we perform. Nanotechnology and robotics are at the heart of this coming paradigm shift, and my thesis seeks to analyze their impact on human welfare and psyche. Specifically, I will explore possible frictions between technological evolution and the widespread societal acceptance thereof.

Most economic models of consumer choice start with a few basic assumptions, which latently function as an inquisition into the nature of man. One is that man acts to maximize time-adjusted utility: we invest money now in order to defer consumption to a later date, and we work more now in hopes of working less later. This subconscious set of economic

calculations composes what is known as the rationality assumption. The core of this is that man ultimately desires two things, consumption and leisure.

The former is defined as the use of various goods and services to maximize utility (happiness), and the latter is the ability to do whatever one wishes without interference from obligations. Based on this idea, I will discuss the supposed duality of human action: consumption and leisure. According to classical economic dogma, man pursues these two ends and these two alone. The problem with this theory arises when circumstances are taken to the extreme, as they might be in a potential future where technology renders the majority of human work obsolete. Free to spend his time as he pleases, and with increased opportunity for consumption, will future man openly embrace his newfound status? On the one hand, life is made infinitely easier; for a frame of reference, one only need compare the modern human experience to that only fifty or one hundred years ago. On the other hand, man is transformed into a peripheral being whose relative importance in the function of the macroeconomy is reduced steadily over time. To explore this issue, I will draw from the work of Tibor Scitovsky, Moses Abramovitz, Thorstein Veblen, and John Maynard Keynes. This group of economists emphasized the need to evaluate economic development through qualitative means, as opposed to the primitive consumption/leisure model.

Technology has largely served to improve man's condition as set forth by this set of theories. Advances in science have allowed us to spend less time traveling to loved ones and more time in their company, and less time preparing food and more time eating it. But the question that my thesis will answer is: “(When) will we stop wanting technology to do our work for us?" Another important trait of man, which most classical models ignore, is his ego. Indeed, many of our actions are driven by personal impressions of self-purpose, self-efficacy, and pursuit of goals. A homemaker might enjoy having a robot capable of cleaning his house, but might not

enjoy a similar robot capable of reading to his child in his stead. Likewise, if technology evolved to the point of basically removing all tasks from the spectrum of human necessity, it is easy to imagine the development of resistance. In spite of what some economists say, the intuition remains that man is not content to allow his life to be lived for him. Surely, humans place some value in the *pursuit* of happiness and not only the fruits thereof.

My hypothesis is that, through logical reasoning and analysis of technological and societal movements, one can foresee a time when humans come in conflict with their own scientific advances. I plan on establishing that a dissenting minority has historically emerged in response to any widespread technological improvement. Additionally, I will use work by leading scholars in technology to show that the scientific community already possesses the foundations for a robotics revolution. With these two bases covered, I will draft a framework to analyze the scope of technologies that will be accepted readily and those that will not. Predominantly, I will postulate that the distinction will take place when technologies "interfere" with certain interpersonal relationships and when they sufficiently hinder the ego. This leads me to a conclusion that humans will mount a resistance to these *prohibitively enabling* technologies.

The point of this work is to use economic theory, history, and rhetoric to construct a logical, forward-looking theory for the natural tension between man and machine. Implicitly, this breaks down into a struggle between man and himself, since technology is a product of human capital. Ideally, I seek to show a contradiction in certain facets of the classical theory of the individual. Alternatively, I will offer a different model that takes into account the previously discussed variables such as ego and interpersonal relationships. The structure of the topic is such that it does not lend itself to hard data analysis, regressions, and quantitative research. Rather, I will draw on elements of psychology and sociology as they pertain to the economic framework, and use economic logic as the basis of my claims. The result should be a well-

reasoned, cross-disciplinary analysis of an academic topic I find to be both fascinating and pressingly important.

A Scope of the Technological Landscape

In the *Matrix* film series, the main character glumly lives his pointless life as a computer-hacking drug dealer, only to be "liberated" by a group of bandits. They show him that everything that surrounds him—the buildings, the sidewalks, the food—are all in fact computer-generated simulations. In truth, humans are "plugged in" to the matrix, a vast computer program designed to harvest human energies to power a robot-controlled world. In the reality of the *Matrix* series, the machines run the world. Man is, functionally, some vague cross between a vegetable and an insect pupa.

Isaac Asimov also contributed greatly to the lore of the robot, already a great fascination for humans, with his *I, Robot* series. Man's desire to produce something in his image (some thinly-veiled God complex) culminates in robots that are a common and integral part of our society. They follow certain rules, are generally benevolent in nature, and even have emotions (holding grudges and falling in love with protagonists). Asimov, highly critical of those who feared technology, sought to paint a world where man and machine could exist peacefully. In a sense, this paints a diametrically opposite view from that of the Wachowski brothers' *Matrix* trilogy, which instead envisions a dystopia where man is at the mercy of machines.

These are undoubtedly epic concepts for a thriller movie, but no one believes that they could actually come to pass. I mean, under no circumstance would we actually allow our own creations (machines) to take so much control of our lives. No way would we allow a small elite of individuals to control every important facet of society. Besides, technology is not even close to being near the level where it could fulfill human operations and make intelligent decisions. Right?

Not quite. Humans have long had a tenuous, love/hate relationship with their own creations—mills, looms, cotton gins, airplanes, computers, the Internet. Some people always

rise in opposition to such technologies, which they feel threaten their way of life or occupation. Generally though, these technologies have still managed to make major headway, mostly due to the great efficiency and cost gains to be reaped from their use. In exchange for this, though, society pays a price—we become dependent on these machines. What would we do without a sewing machine today? Or cars? Or, perish the thought, the Internet? The answer is that the man/machine relationship is a complex symbiosis, in which both parties need each other. And with the present state of robotics research, it is not difficult to imagine a future with the technological capabilities (if not the conspiracy theories) portrayed in fiction and film.

Bill Joy, the founder of Sun Microsystems and inventor of the Unix programming platform, brought this concern to the foreground of the technological community with his article "Why the Future Doesn't Need Us" (2004). Published in *Wired Magazine*, the article sparked much discussion of the proper place for technology in society. Joy cited the work of other academics to articulate his concern that the line between man and machine is blurring. Of course, this statement in and of itself is meaningless; what matters is the implication, which is the question of what happens to man in such a world?

To Joy and others, the problem is that the evolution of technology could feasibly subvert human life. Joy actively fears (to the chagrin of many of his peers) the results of artificial intelligence which is capable of making decisions. He points to serious concerns regarding self-replication (the problem known as "gray goo" that pollutes hard drives with data waste) and the unpredictability of non-human intelligence. Even scaling this back, there exist concerns at more basic levels. The economic impact of some of these technologies is what I seek to analyze. But before we get there, we have to show that such phenomena (robots, artificial intelligence, etc.) are not out of the realm of possibility.

In truth, our level of advancement is quite remarkable. Innovators such as Joy, Bill Gates, and Ray Kurzweil have all remarked that existing technology provides a good starting point for future expansions in the genetics, nanotechnology, and robotics (GNR) revolution. Gates compares this field to the one that he helped proliferate, modern mass computing. "Robotics companies have no standard operating software that could allow popular application programs to run in a variety of devices," Gates writes (2006). While the wizard behind Microsoft acknowledges that "envision[ing] a future in which robotic devices will become a nearly ubiquitous part of our day-to-day lives" is currently still the stuff of science fiction, he also points out that we are closer than people might think. He points to the wide availability of computer power, which is exponentially cheaper per megahertz than a few decades ago. Gates also shines light on the success of nascent technologies, which now allow robots to "vacuum a room or help to defuse a roadside bomb—tasks that would have been impossible for commercially produced machines just a few years ago" (Gates 2006). He basically postulates that the main barrier standing in the way of massive robotic development is a lack of centralized software, concurrent hardware compatibility, and a general lack of organization on the part of innovators. But with the next stroke of the keyboard, Gates also mentions that many solutions are available, both in the history of the computing movement and in already-existing techniques. He concludes by estimating a big robotics impact on the human experience, specifically for "soldiers…"people with disabilities"…"construction workers and medical professionals" (Gates 2006).

Current research seems to back up much of Gates' claims. Academia is making significant gains in the robotics area. Addressing the problem of motion planning[1], researchers at Carnegie Mellon University have proposed a new model that improves the perceptive capability of robots (Dillman et al. 2007) and an optimization algorithm to allow robots to

[1] The inability of current robots to sense and react to physical obstructions such as cars, chairs, or children

maneuver in a household setting (Berenson et al. 2007). In the area of artificial intelligence, more interesting research is being undertaken. Some of the work focuses on expanding the ability of robots to learn using observation—one group of researchers used perceptive mapping to "teach" a robot how to play air hockey (Atkeson et al. 2003). Artificial intelligence is also being developed in the area of driving, where "road network information and moving obstacle information" are being programmed into robots to allow them to maneuver through intersections with success (Seo and Urmson 2008). Indeed, robot navigation is an exploding field, as researchers seek to create a "navigation architecture" that would, through a series of algorithms and navigation loops, allow machines to "generate safe paths through terrain while achieving specific goals. The navigator uses sensor data to evaluate terrain and locomotion components to execute motor and robot trajectories" (Nesnas et al. 2003, 2). The body of research success is quite significant; it seems that the field of robotics is growing quickly. Once the problem of context-based action is overcome for good, through the use of vast quantities of if/then/else looping structures, there is very little obstructing the widespread use of robots, at least from a software standpoint.

We must then turn to the ways that such research has had tangible impact in society, as opposed to the generally academic, forward-looking nature of the aforementioned projects. Presently, robotics technology is used in advanced surgeries, oil drilling and refining, manufacturing, database management, and general industrial work. More recently, technologies have been developed to help the blind (Mau et al. 1008). Radar concepts have been used to refine a "personal assistant" idea that would drastically improve efficiency in computing, web-surfing, and general technological errands (Bennett and Cohen 2007). The key observation here, once again, is that robotics is not an academic pipe dream or a comic book fantasy—the results are real, tangible, and effective.

Economic Impact and Analysis, Part I

We have established at this point that the technology exists to radically advance the role that robotics and nanotechnology can play in everyday life. Now, it is worth spending a few pages discussing how, through an economic lens, it will impact individuals. A main query that must be addressed is the economic nature of man. This is vital to forming a theory of how future society will adapt to the advances in technology. There are arguments to be made for the idea that robots will unilaterally improve the human condition, as well as those that point to a different interpretation. Either way, they are based on models that seek to identify and infer the motivational forces that effect action.

Typically, the classical model of Adam Smith and David Ricardo is the new student's introduction to how technology affects economic behavior. In this model, as articulated by the law of comparative advantage, technological endowments dictate productivity and each party's specialties. Initially used in Ricardo's "***On the Principles of Political Economy and Taxation,"*** the idea has been expanded upon several times over. Specifically relating to international trade and exchanges between parties, technology has long been used to explain differences in competencies and production possibilities frontiers.

The Hecksher-Ohlin model of trade moves one step further in this discussion. By eliminating technology as a differentiating variable, H-O equilibrium emphasizes the importance of factors of production (predominantly labor and capital) in determining a country's exports and imports. This model serves to outline a long-run view, a future (perhaps impossible) world where everyone has access to mostly the same level of enabling technologies. H-O is important to any discussion of man and machine because it seriously examines the fate of nations once this technological utopia (dystopia?) is reached. That is to say, when technology is widely

accessed, every nation is simply the product of its factor endowment levels, with prices of labor and capital determined accordingly.

Traditional models of economic behavior paint rational man as an individual who acts in his self-interest. Pursuant to this idea, he reacts positively or negatively to stimuli that increase or decrease his utility, respectively. The concept is very binary—events are forces that are either "good" or "bad," in a sense. Rationality assumes for man an ability to quickly and logically calculate preferences through this kind of utility mechanism. This is an assumption that has been debated quite often, and while its principles remain sound as a generality, the body of academic evidence building against some of its components is growing.

The idea is further explored in labor economics. When discussing the individual's willingness to supply labor, economists examine the tradeoff between consumption and leisure. People, faced with finite time, choose a balance between time spent in leisure and time spent generating income for consumption. This is the foundation of classic labor theory, and is again subject to interpretation and criticism. On the one hand, it seems to ascribe too mundane a preference set to man—reality is far different from this binary decision. But it simultaneously paints the worker as being able to discern quite accurately how much leisure he would have to sacrifice to work one additional hour and then discount future consumption appropriately to arrive at the time-adjusted opportunity cost of work. We see the emergence of weaknesses in the theory.

One reason that we cling to incomplete models is that they are readily expressed mathematically. To clear out the “noise” of reality, with all its esoteric interactions, researchers assume away these impediments. Paul Krugman details some models which failed to attract widespread attention in spite of their usefulness mostly because of their non-reliance on mathematical techniques (1995, 67). He goes on to criticize traditional model-building because

"especially in its early stages, [it] involves the evolution of ignorance as well as knowledge; and someone with powerful intuition, with a deep sense of the complexities of reality, may well feel that from his point of view more it lost than gained" (1995, 79).

Additionally, many traditional models are embedded with subjective assumptions. This touches on the larger issue of whether or not economics is a value-neutral social science, but suffice it to mention here that some people find "the idea that economics could be an objective science rather ironic" (Perelman 2006, 26). Certainly, a level of classical liberal orthodoxy has informed a great deal of contemporary academia—self-interest, marginalism, and profit-maximization are all at the heart of the current theoretical framework.

The above-mentioned flaws, a function of both academic process and subjectivity in practitioners, play an important role in understanding why technological progress might, in reality, be received differently than our current models might predict. In perhaps-oversimplified depictions of behavior, the effects of a change in a particular factor might not mirror their realistic effects. That is to say, the vacuum-like environment of the economic model might not provide useful information when dealing with reality. Let us consider a traditional "theory of the firm" problem. If a firm's production function can be represented by $P = AL^xK^y$ where L and K represent labor and capital and A represents factor productivity, then an increase in relevant technology will increase productivity. This allows a firm to product more output for any given level of factor inputs. Conversely, the firm could also utilize fewer inputs to acquire a given level of production. Either way, the shift in technology has helped the producer in this model, all else equal. This can be extended to the consumer as well. Increases in technology result in higher-quality and lower-price goods, which expands the consumer's consumption possibilities set and allows him or her to operate at a higher-level "indifference curve" than before.

If the factors named above were the only relevant ones, then the models would accurately portray a picture of technological progress in which everyone benefits. But this is not the case. There are psychological factors to consider, as well as labor concerns and issues of concentration of power. The productivity and consumption gains need to be weighed against these concerns when judging the full scope of costs and benefits.

One issue is the optimal level of ease desired by people. Of course this varies from person to person, but if technological progress is (as classical models would suggest) positive without exception, then there would seemingly be no limit to how much we would like to see it advance. We should theoretically never find ourselves in a position of having "too much ease." But intuitively, doubts arise about this statement. We might certainly appreciate a faster dishwasher or a personal dry-cleaning machine, but we might be slightly less thrilled about a robot or machine that tucks in our children or plays with the dog. That is to say, there is a set of occurrences for which we prefer our own slow, inefficient, error-prone ways to the calculating efficiency offered by technology. The theory presented in this paper is that that sphere of events of which we become protective can be identified as "goods" that revolve around experience and interaction.

It is much more likely that a certain technology will attract opposition if it infringes on what is considered a particularly "human" space. In spite of Kurzweil's predictions of the future, we remain at odds with nascent technology—we view it as an extension of human intelligence, but still beneath it. "Spiritual" machines[2] do not exist yet, and if they ever do, they will certainly be met with resistance (Kurzweil 1999). If and when computers become powerful enough to duplicate human emotion and interactions, they will be viewed more as a threat than as an asset. And if computing software continues to grow with and alongside robotics hardware, the

[2] These are defined by Kurzweil as machines that possess consciousness, independent thought, and singularity.

combination will push the boundaries of our technological capabilities far beyond their current level.

To elaborate on the kinds of experience goods that we are likely to protect from the machinations of technology, let us consider the role of the personal computer. Its purpose and scope have undergone a massive evolution since its introduction in the 1970s. Originally, the personal computer was just a screen that flashed lights for outputs and was operated by toggle switches (QWERTY keyboards did not become popular among computers until the 1980s) (Watkins 2001). Now, computers are a vital identifying component of our world; we use them integrally for business, education, health, entertainment, and general information. It is safe to say that most of the developed world is addicted to computers.

But we would be foolish to think that computing technology has reached its limits. Even at its current state, experts can see vast changes in the horizon. Kurzweil predicts that in one decade's time, computers will have all the capabilities of the human brain. He also believes that computer-to-computer or human-to-computer interactions will define most of the business and education realms—this is by no means a stretch to imagine, since we are already witnessing its beginnings. By and large, these improvements have been lauded for the ease that they afford their users. However, how much further can it go before widespread objections arise? Kurzweil's idea of "virtual sex" machines might be an appropriate point of discussion. If personal computers become able to simulate physical sensations, and if simulated relationships become a proxy of sorts for human intimacy, there will undoubtedly be a loud opposition (Kurzweil 1999). Similar disagreements can be expected to rise over other possible evolutions such as cloning, chip-like implants that allow internal computing and Asimov's vision of robots as a near-human presence in our society.

This “optimal ease” problem can also be defined in terms of what economists call the “bliss point.” Even though microeconomics assumes behavior to follow certain patterns—one of them being “more is better—there are certain notable exceptions. One of these is the bliss point, which is defined as the highest attainable level of utility. Beyond this level on a simple leisure/consumption graph, the marginal value of an additional unit of either parameter is *negative*. While we generally assume that marginal utility approaches zero for these parameters, there are certainly some areas (in food consumption, in television watching) that this does not hold.

The bliss point can be modeled on a three-dimensional graph with the z-axis representing utility and the xy-plane representing consumption and leisure choices, as in a typical microeconomics diagram depicting tradeoffs and indifference curves. As consumption and leisure levels approach the bliss point from below, utility builds and each additional unit delivers a positive value. The bliss point is where the partial derivative with respect to the z-axis is equal to zero. After this, the derivative becomes negative, which corresponds to a negative marginal utility.

In technology, this represents the “optimal ease” level. Beyond this bliss point at which our technological capabilities perfectly match our desired facilities, an additional development could negatively impact overall satisfaction. While it is true that passing this bliss point would require irrational behavior, this is by no means impossible. And with the way our society readily embraces the next gadget or computer, it is reasonable to postulate that our default reaction is to adopt a technology first and worry about possible ramifications later. Such a line of thinking opens the door for society to pass the proverbial bliss point.

Even aside from the issue of an optimal ease level, there are other problems that need to be considered. Historically, no one has opposed technological advances more than those

whose livelihoods and occupations are displaced by those changes. Those factions are the ones who are most likely to perceive technology as a threat and therefore oppose it. In the backlash against the Industrial Revolution, it was loom-workers and cottage industry that rebelled against the new machines. Opposition to free trade is headed by workers' unions who would stand to suffer lower wages and lower employment. Similarly, we can expect robotics innovations to be opposed by those employed in a variety of occupations. Domestic services will be affected by robots that can clean. Filing/clerking might be rendered obsolete by superior organizational systems and computerized records. Already, the medical profession is in a state of upheaval over robotic surgery and improving diagnostic hardware. And, to be coy but frank, it needs to be mentioned that the world's oldest profession could take issue with the evolution of "virtual sex" facilities.

Classical economists have been able to support technological proliferation in spite of these objections because of the fact that the aggregate economy benefited in the form of lower prices and more goods. These gains could then be used to provide relief to displaced workers. Whether or not these theories were actually put into action is disputable, but regardless, it becomes more difficult to use this justification once the relative proportion of displaced workers grows. The Luddites' cause was primarily unsuccessful because not enough people empathized with their plight. The English citizenry experienced more of the benefits of the Industrial Revolution than the costs, and these outweighed the unemployment and subjugation of a few weavers. Similarly, big labor has had to deal with the apathetic average consumer, whose grocery bill, computer prices, and cars come cheaper with free trade. But this balance of concern changes drastically once a technology affects more and more people. While it is difficult to calculate with any level of precision the total costs and benefits of any economic

force, it is safe to say that growing levels of unemployment which come about as a direct result of any one development lead to economic, social, and political unrest.

Inevitably, this is another main concern for policymakers, scientists, and the population at large. If we become even more dependent on the technologies that enable our everyday lives, and those technologies themselves attain singularity (the ability to evolve and replicate independent of human maintenance), then this comes with the direct consequence of more control and power being transferred into the hands of those who control such technologies. The United States, with an economy that rewards innovators through patents and the lucrative rents they bring, is a particularly relevant study in this matter. As it is, we have seen vast disparities in income and standard of living over the past half-century—these are, of course, also due to macroeconomic phenomena and policy, but the role of technology is also a contributing factor. With labor becoming less and less important, it has lost leverage at the bargaining table. Coupled with anti-union, pro-corporate policies, this has had the effect of precipitating "the implementation of the business agenda over the objections of the general public" (Chomsky 1999, 55).

A significant portion of the economic community backs the skills-based explanation of this phenomenon. The logic goes something like this: "rising inequality is mainly caused by a rising demand for skilled labor, which in turn is driven largely by technological change" (Krugman 2007, 131). While Krugman himself finds this to be only a partial explanation (he favors a theory that emphasizes the normative shift in public institutions toward corporatism), the roots are solid. Edward Lazear, former chairman of the Council of Economic Advisers and a supporter of the skills hypothesis, is quoted by Krugman: "What account for this divergence of earnings?...with the growing importance of computers, the types of skills that are required are…a much higher level of technical skills than the kinds of jobs that workers did in 1900 or

1970" (Krugman 2007, 131). Apart from this skills-based hypothesis, there is Krugman's theory of corporatism, which notes the shift in governments from pro-equality, strong-welfare policies to a course that emphasizes business interests even at the expense of inequality. He emphasizes the devolution of union activity in the United States, which has left labor more vulnerable to changes in wages and employment levels. What happens, then, when even more technological change occurs? How much more of the population will become excluded because of their relative unimportance? Whatever the answer, it seems reasonable to conclude that such trends cannot go on into perpetuity. Unless supplemented by a course of legislation or private initiative designed to expand access to human capital investment and provide a cushion for those who are excluded from an increasingly polarized economy, massive technological advances could portend further increases in inequality and further disparities in standard of living.

Economic Impact and Analysis, Part II

In spite of these various objections, one might argue that society at large will still embrace the proliferation of enabling technologies. After all, the computer has taken hold with little (if any) major resistance from labor groups and/or disgruntled consumers harboring Luddite sentiments. Partially, this is because the technology boom actually increased employment in administrative occupations (bls.gov) between 1990 and 2000. The business boom created by the so-called "technology bubble" brought with it a historically sunny employment outlook, even in areas that might have felt threatened. In a sense, this was a referendum of sorts on the ideas of the Triple Revolution (Agger et al.), which held that growth in computing and manufacturing would displace massive quantities of labor. Obviously, those theories were not upheld in this particular "revolution." So, it becomes slightly more difficult, especially from the viewpoint of most economic models, to imagine a widespread resistance to forthcoming technological change.

We have already introduced objections to the assumptions of classical theories of economic behavior which stipulate that individuals act as rational agents. This disparity seems odd, since economists supposedly try to model real-life behavior through a set of assumptions and postulates which allow them to isolate causes and effects. Ideally, anyway, this would be the case. But what we see is a marked difference between "*Homo sapiens*" and "*Homo economicus.*"

This is the distinction offered by Richard Thaler, who asserts that forthcoming models will return to a psychological, more esoteric portrayal of man as opposed to the mathematical machine assumed by most economists for the past sixty years (Thaler 2000). He briefly mentions that older models (such as those used by Keynes and Fisher) took more of a psychological approach than a mathematical one, both out of convenience and usefulness. An

increase in computing power allowed academics to impose more rigid restrictions on their studies, which came with mixed results. In present times, Thaler says, economists' portrayal of man has strayed too far from reality—a development that he predicts (hopes?) will right itself. He outlines several common problems with today's models of behavior. This way, the rational expectationalists of Friedman and Merton lose some of their quick-thinking, calculating abilities (aside: it seems fairly evident to this thesis' author that neoclassicals seem to give the common man too much credit intellectually and not enough psychologically) and replace them with context-based, ego-adjusted versions. Thaler admits, as did Krugman earlier, that there is good reason that such models have not already taken off in mainstream economics, and it is because of their mathematical ambiguity, which stems from the difficulty (if not impossibility) of quantifying higher-order behavior determinants. Once our simpler, more methodical models lose their relevance, the academic community should adapt accordingly.

While there has been an increase in scholarship arguing against the rationality assumption today, this is not to say that such disagreements have only been around recently. Indeed, behavioral economists have long decried the faults of a model that fails to incorporate dynamic, unpredictable outcomes in human action. This is crucial to understanding why there is reasonable doubt with respect to widespread acceptance of rapid increases in general technologies.

Tibor Scitovsky attacked this topic in his essay "Are Men Rational or Economists Wrong?" (1974). Scitovsky argues that supporters of the rationality assumption overlook some serious flaws that have been well-documented. He discusses money illusion, or human behavior that is driven by money and not the goods/services/comforts that money purchases. Particularly noteworthy are Scitovsky's comments about wealth accumulation:

> *Today, to make money just for the heck of it and greatly in excess of one's spending habits has become not only respectable but respected, and society has fully adjusted its notions of normal psychology and rational man to accommodate such behavior. It is something of a paradox that, of all people, the economist along should have failed to make room in his world for the likes of Anselm Rothschild and John D. Rockefeller.*
>
> (1974, pg. 226)

Scitovsky goes on to criticize Franco Modigliani's model of spending/saving (based on a life-cycle version of the rationality assumption) for its inaccuracy and flawed logic. "Modigliani's life-cycle hypothesis makes no allowance for people's inability to predict their day of death," which causes them to save more than expected (Scitovsky 1974, 226).

In addition to money illusion, Scitovsky talks about time illusion, in which people expend time in the form of leisure even though they would be "better off," in the view of the old rationality profile, using that time for other purposes. Scitovsky refers to survey data from the post-World War II boom, an era of rising productivity and wages. In theory, rising wages means that the opportunity cost of time rises (since that time could be spent earning a higher income), which should manifest itself in a reduction of non-productive activities. However, the opposite proved to be true—people spent more time in front of televisions and in malls as time went on (Scitovsky 1974, 228). He also looks at television viewing patterns over this same time frame and concludes that "all this is hard to fit into a theory of rational time allocation, which would have people…[crowd] more goods or more action into each hour of consumption time" (Scitovsky 1974, 231).

Lastly, and most relevant for the purposes of analyzing technological change as a socioeconomic phenomenon, Scitovsky investigates effort illusion. He opens the section with a point that has been made repeatedly in this paper: "To economize human skill and physical

effort is the principal aim of all technical and economic progress." Even if this modest assumption is accepted, we must still ask ourselves if "ease…remains desirable indefinitely and…whether the critical point of optimal reduction has not been reached and passed already." Then we have to consider the fundamental point of contention laid out in this thesis: whether "every organism has innate energies and capacities, the exercise of which seems to give it satisfaction" (Scitovsky 1974, 233). Current models do not provide for the possibility that maybe, just maybe, individuals enjoy work. Most contemporary theories would have us believe that man only works now to avoid work later, and that any mechanism that expedites this toil is welcome and immediately embraced. However, both data and surveys show otherwise. Even though economic models don't allow for an "enjoyment premium," so to speak, it is reasonable to think that in this respect, *homo economicus* still has a ways to go before catching up to *homo sapiens.*

Scitovsky's work certainly goes a long way toward addressing some of the major concerns with the rationality assumption. But he is by no means alone in this criticism. Thorstein Veblen's work, which was largely produced at the same time the neoclassical school of thought was developing (oddly enough), was devoted to the idea that social forces greatly informed economic behavior, and that models that painted the individual as some Kantian utilitarian in a bubble were misinformed. For example, he asserts in his *Theory of the Leisure Class* that "men of the upper classes are not only exempt, but by prescriptive custom they are debarred, from all industrial occupations" and that "manual labor…is the exclusive occupation of the inferior class"(Veblen 1899, 2). That is to say, individual abilities and desires are only a portion of what determines labor allocation and occupational organization. Additionally, there is a deep social component, one that dictates "acceptable" outcomes for each individual based on certain norms and pressures. And this makes sense intuitively—no

prince is going to be allowed to be a miner or a stevedore, even if these activities are what he prefers as an individual. Indeed, there is much to be said for social forces as a driver of economic behavior.

Veblen expands on this idea in the following chapters of his book. The idea is that class issues and divisions have a significant causal effect on economic behavior. He argues that "in any community where goods are held in severalty it is necessary, in order to his own peace of mind, that an individual should possess as large a portion of goods as others with whom he is accustomed to class himself" (Veblen 1899, 18). This too carries some psychological cogency—we've all heard of "keeping up with the Joneses" and lobbying for better Christmas presents than our classmates. Unlike his neoclassical counterparts, Veblen's interpretation is more accommodating; he stresses that these social forces are only a part of the explanation, but an important part. "The desire for added comfort and security from want," also known as the typical neoclassical explanation of action, is still credible and present in Veblen's model of behavior (Veblen 1899, 19).

But the portion of Veblen's work that proves most useful as far as predicting the effects of technological change is his discussion of conspicuous consumption and leisure. He rightly states that having wealth is necessary but not sufficient to climbing the ladder of social status. Additionally, "the wealth or power must be put in evidence" since "abstention from labor is…a requisite of decency" (Veblen 1899, 21-23). That is to say, people feel an impulse towards conspicuous displays of their wealth through leisure and consumption, even past the extent to which that wealth actually improves their utility. Here too, most readers can understand the logic—to extend the metaphors, keeping up with the Joneses only matters if *they see* that you're keeping up. The relation to technology here is twofold: first, Veblen's work serves as another reminder that the rationality assumption is an invalid predictor of human behavior;

second, it underscores the vicious "social climbing" environment in which most individuals find themselves. Driven by an impulse to one-up their peers and ascend in class, they are likely to embrace forces (services, technologies, capital goods) that achieve this end, regardless of long-term implications or actual intrinsic benefit.

For a long time, Veblen's work failed to gain traction, as the neoclassical school became predominant. However, a book published a full century after *Theory of the Leisure Class* brought it back into the proverbial spotlight. Paul Ormerod's *Butterfly Economics* pieces together much of the previous discussion of this section and puts forth a more holistic approach to evaluating economic behavior. Ormerod's "butterfly" is a concept that stresses interpersonal relationships. People have dynamic preferences, which according to the author are affected by their interactions with others. That is, new information gained alters internal supplies and demands for certain goods (labor, toys, computers, etc.). Ormerod discusses at length how individuals are motivated by the actions of others to pursue a certain course of their own action. He uses this to criticize the efficient markets hypothesis, that bastion of rationality, which holds that assets trade at their fundamental value and that all relevant information is already priced in. Through the lens of the butterfly, he points out that "prices fluctuate more than do fundamentals" and that this represents an "empirical falsification of orthodox theory" (Ormerod 1999, 16). Ormerod expands on this criticism by pointing out historical occurrences where non-fundamental, irrational movement caused financial markets to fall, tulip prices to skyrocket, and currencies to collapse.

The solution to this grave loophole in classical orthodoxy is, according to *Butterfly Economics*, to fashion an analytical framework that separates decision-making between two forces: the agent can "change behavior independently in reaction to news; or the agent can be persuaded to switch by the behavior of others" (Ormerod 1999, 19). This is a key development

in realistically portraying the psyche of the individual as it translates into economic behavior. Ormerod states as much, saying that this evolution "represents a very important intellectual advance for the social sciences, and offers a more powerful explanation of a wide range of phenomena than does conventional thinking" (Ormerod 199, 27). While Ormerod devotes too much of his book to extrapolating ant behavior as a relevant social model, his statements are both sensible and logical. The orthodox framework of economic analysis is simply insufficient as it stands.

So we are left with some important implications to be drawn from these various perspectives and the insight they have to offer as it pertains to technology. First, that it is inadequate to assume that any economic phenomenon will be accepted simply on the grounds that it makes life easier or that it permits us to do more. We do not operate in a bubble of utility-calculating purity, but rather in a messy, chaotic world where any number of forces are shaping every one of our actions (consciously or subconsciously). Second, that we are driven by psychological forces to compare ourselves constantly with those around us. We act not only for ourselves but also to display certain characteristics (weakness, strength, opulence, etc.) to the external world.

Given these statements, it is reasonable to say that we have to take a closer look at technology before pronouncing it to be unilaterally positive. Sure, it would greatly improve capacities for production and consumption and leisure, but there is more to life than these shortsighted goals. Scitovsky restates this as "there are many people who get satisfaction out of their work," especially given that "the marginal satisfaction of work is very different for different professions and groups of people" (Scitovsky 1973, 11). What if new technology fundamentally alters the labor market to eliminate autonomy or self-efficacy from the worker? This seems unlikely but certainly feasible in a future that involves more mass production and

standardization than ever before. What if requirements for labor are greatly reduced in the face of more efficient robotic replacements? One can certainly envision this scenario and the economic/political implications of a society that centralizes power in the hands of the few who control the technologies that power such a society. Just as Washington warned against enduring foreign entanglements and Eisenhower spoke words of caution regarding the military-industrial complex, we must now be aware of the new forces that offer the lure of bright, tangible benefits but whose negative aspects are less visible but no less significant.

Comments

The point of this line of thinking is to explore the possibility of developing a level of technological advancement that is above and beyond some sort of "social optimum" or "equilibrium." That is, the scientific community—as it has done in the past to some benefit and some detriment—might continue to work on technology irrespective of public demand. As they often do, scientists and academia could be more concerned with exploring new ideas and creating new toys than with any societal need. Such a phenomenon could have the effect of availing technologies to public and corporate leaders that in fact exceed the amount of desired capability.

Why then wouldn't such technologies (those that do not satisfy any needs) simply disappear from the marketplace? To answer this question, it might benefit us to look at the problem through the viewpoint of various relevant factions. For example, corporate leaders would likely openly embrace technologies that reduce their labor complement, reducing costs in the long run at least. Of course, these benefits would be passed on to consumers in the form of lower costs. But at the same time, labor is hurt through lower wages and lower employment. If such technologies take widespread effect, their impact would be uncertain, but it is reasonable to postulate that this impact will not be as unilaterally positive as in the past. A growing number of factions stand to be harmed in some way as robotics and nanotechnology advances grow more and more all-encompassing. Whereas the vast majority of individuals have been insulated from the negative impacts of past developments, it seems more likely that future advances will come with adverse consequences (in at least some facets of peoples' lives) for a relatively larger share of the population. Whether or not these more widespread consequences will overrule the positive effects of technological developments remains to be seen, but the possibility is certainly there.

Even aside from the obvious inequality and centralization of power concerns, which are valid in and of themselves, there is the question of dependence that must also be addressed. How far will we allow ourselves to go in the name of expedience? Certainly, individuals take a measure of pride in performing tasks (of all difficulty levels) for themselves, but we also have a proclivity to be mesmerized by the stupor of gadgets that offer ease. And again, we have to bring up the issue of "optimal" ease. At which point will we decide that an additional unit of ease is not worth the dependency we place on technology?

The theory presented here is that this line gets drawn around the scope of interpersonal interactions. We value those daily transactions that yield some positive social outcome. Think about it as a more complicated version of *The Sims* video game. In this computer game, when characters interact, they develop relationship points, which increase their overall happiness. In a sense, the same is true of real life. This is why we are eager to adopt methods that reduce barriers to such interactions. But while we prefer calculators to do our arithmetic or Google to do our research, the same would not necessarily be true of transactions that increase our "relationship points"—we might prefer doing those ourselves. On a broader level, it is a matter of ego: activities that play to individual pride or self-worth are more likely to be closely guarded. A mother who places high value on cooking a meal for her family might not embrace a cooking robot that renders her skills obsolete. That same robot might be a godsend to a foods manufacturer that mass-produces frozen dinners.

So, ego and interpersonal relationships represent two important boundaries that can define this "optimal" level of ease. Additionally, there is the idea of work as social progress. There is the very basic question of "why do people work?" While that question has many answers, two important responses are "to finance their desired activities" and "to support the lifestyles of themselves and loved ones." Indeed, work represents the key strategy through

which individuals can improve their social and class standing, in addition to economic standing. In a far-reaching future where human work requirements are reduced, this element could disappear for a large swath of the population. In the face of such developments, people would certainly want to maintain the possibility of social mobility through work, an outcome that would be endangered by prohibitively-enabling technologies in all labor sectors except higher-order technological programming. In a world where technology provides unparalleled ease for every person, individual accomplishments and skills mean relatively little, in the sense that they cannot be translated into tangible benefits for the holders thereof. In this admittedly-exaggerated dystopia of lazy, unproductive individuals that possess neither skills nor the market structure to use those skills, so many elements of our current assessment of self-worth are negated. This is not to say that those could not be replaced by other attitudes, but it would surely involve some friction or difficulty.

It is possible that society could enjoy widespread technological gains without having them infiltrate every corner of industry and home life. However, this tends not to be the case. As in the case of the Internet, television, transportation, and communication, important milestones become viewed as less of a privilege and more of a right as their influence grows. The rhetoric of class warfare and inequality resurfaces time and again as calls to guarantee these services (through infrastructure spending, broadband provision, and open-source software) grow. In a way, this is the ultimate nanny state—with people depending on machines to provide unparalleled levels of ease and comfort. Humans cease to be the central driving force of innovation and production. Standing at such a point, would it really be that difficult to imagine the world of *The Matrix* or Asimov?

There is no doubt that technology has been, by and large, a useful and positive tool for human progress. But it is just that—a tool by which society's conditions may improve. In a way,

this role could be threatened in years to come if technology becomes more than a means to an end. If, in developing new technologies, we lose sight of this crucial relation, we risk moving to a society whose direction is dictated not by markets and tastes, but rather by a devolved prisoner's dilemma that leads to widespread sloth, purposelessness, and folly.

Conclusion / Suggestions for Further Works

By now, it should be clear to the reader that the study of technology and its inevitable, inestimable effects on the human condition is an important undertaking. Before we carry forward with the massive technological changes of years to come, we must pause to think about the very real ramifications they can have on our lives. Indeed, one key message of this paper is that we might arrive at a time when the marginal social cost of a new advance might exceed its corresponding benefit. The fundamental question of technology—"What is its proper role in our lives?"—must be addressed. Do we believe that technology exists to serve human needs, or is its development and use exogenous to any demand? If we agree that technology's purpose is as an enabler of human endeavors, then logically, any advance that causes more damage than benefit is undesirable. The vagueness of such a calculation aside, it is important to concede that nothing deserves unilateral acceptance simply because it makes life easier in some respects. We must consider all impacts—economic, psychological, social—that affect the success and necessity of new technologies.

The purpose of this paper is to articulate a theory of the evolving relationship between man and machine, but also to generally stimulate a line of thought for future consideration. The ideas presented herein have typically been restricted to the minds of scientific geniuses (Joy, Gates), futurists (Kurzweil), and conspiracy theorists (the Wachowskis, Huxley, Asimov). While the future envisioned here might be far off, it is a worthy area of study for the economic community, both as an academic exercise and from a policy perspective. Further studies could be approached quantitatively through a forecasting light, or qualitatively through opposing theories on this relationship.

In a way, the only certainty in this academic space is uncertainty. No one *knows* what is going to happen, and to suggest otherwise would be both pretentious and naïve. However, this

should not preclude interesting and relevant research. If readers take nothing else away from this paper, I hope they grasp the supreme importance of technology in determining our way of life. The development of this relationship over time, and the many ways in which it impacts human welfare, is critically important for economists, policymakers, and laypersons to understand.

There is much room for study here. Certainly, one area would be in analyzing the employment impact of a new robotic development or computing tool, or its corresponding impact on the labor market (wages, other related sectors). Another likely more difficult study would be an attempt to quantify the "premium" placed on performing work for oneself. If there is merit to the Scitovskian idea that man values the "exercise of his own facilities," then there should be an amount by which this is preferred. Of course, this is highly individual in most cases, and therefore difficult to generalize. Other exigency studies would include a thorough analysis of how far we are from achieving serious advances in robotics and nanotechnology, essentially a more rigorous version of the "Scope of the Technological Landscape" section of this paper. Understanding the breadth and immediacy of technological developments will go a long way to determining the actual impacts that these changes could have.

We live in a time that is much different from those of our forebears, and likely much different from that of our descendants. From our earliest lessons in economics, we are told that technology plays a key role in these widespread societal changes. All of the models discussed in this paper, and all relevant theories on the subject, include the use of technology as a central element in determining welfare, employment, wages, the availability of goods and services, and comparative advantage. If we are to harness its power and use it to advance human welfare, we must also be prudent regarding its use and proliferation.

Works Cited

Abramovitz, Moses. "Economic Growth and Its Discontents." Economics and Human Welfare (1979).

Agger, Donald et al. "The Triple Revolution." The Ad Hoc Committee on the Triple Revolution. June 1964.

Asimov, Isaac. I, Robot. New York: Gnome P, 1950.

Atkeson, Christopher G., Darrin C. Bentivegna, and Gordon Cheng. Humanoid Robot Learning and Game Playing Using PC-Based Vision. Robotics Institute. 14 Mar. 2003. Carnegie Mellon University. 1 Feb. 2009 <http://www.cns.atr.jp/~dbent/Docs/dbent_iros02.pdf>.

Bennett, S. Rachel, and Paul Cohen. Evaluation of an Integrated Multi-Task Machine. Robotics Institute. Jan. 2007. Carnegie Mellon University. 16 Apr. 2009 <http://www.ri.cmu.edu/pub_files/pub4/steinfeld_aaron_2007_1/steinfeld_aaron_2007_1.pdf>.

Berenson, Dmitry, Howie Choset, and James Kuffner. An Optimization Approach to Planning for Mobile Manipulation. Robotics Institute. 23 May 2008. Carnegie Mellon University. 23 Mar. 2009 <http://www.ri.cmu.edu/pub_files/pub4/berenson_dmitry_2008_1/berenson_dmitry_2008_1.pdf>.

Bruni, Luigino. Handbook on the Economics of Happiness. London: Edward Elgar, 2005.

Chomsky, Noam. "Profit over People: Neoliberalism and Global Order." Seven Stories Press. 1999. New York, NY.

Cohn, Jeffrey F., Takeo Kanade, and Yingli Tian. Comprehensive Database for Facial Expression Analysis. Robotics Institute. Jan. 2000. Carnegie Mellon University. 16 Apr. 2009

<http://www.ri.cmu.edu/pub_files/pub2/kanade_takeo_2000_1/kanade_takeo_2000_1.pdf>.

Deaton, Angus. Economics and Consumer Behavior. Londom: Cambridge UP, 1980.

Dillman, Rudiger, and James Kuffner. Planning for Robust Execution of Humanoid Motions using. Robotics Institute. 2 Nov. 2007. Carnegie Mellon University. 18 Mar. 2009 <http://www.ri.cmu.edu/pub_files/pub4/michel_philipp_2007_2/michel_philipp_2007_2.pdf>.

Gates, Bill. "A Robot in Every Home." Scientific American. April 2006.

Hodgins, Jessica K., and Nancy S. Pollard. Optimizing Human Motion for the Control of a Humanoid Robot. Robotics Institute. 28 Jan. 2003. Carnegie Mellon University. 1 Feb. 2009 <http://www.ri.cmu.edu/pub_files/pub4/safonova_alla_2003_1/safonova_alla_2003_1.pdf>.

Joy, Bill. "Why the Future Doesn't Need Us." Wired Magazine Aug. 2004.

Keynes, John M. Essays In Persuasion. London: Cambridge UP, 1931.

Keynes, John M. The General Theory of Employment, Interest, and Money. London: Palgrave Macmillan, 1936.

Krugman, Paul. Development, Geography, and Economic Theory. Boston: MIT P, 1995.

Krugman, Paul. "The Conscience of a Liberal." W.W. Norton & Company. 2007. New York, NY.

Kuhn, Thomas. The Structure of Scientific Revolutions. University of Chicago P, 1962.

Kurzweil, Ray. The Age of Spiritual Machines. New York: Viking Adult, 1999.

Mau, Sandra, Nik Melchior, Maxim Makatchev, and Aaron Steinfield. BlindAid: An Electronic Travel Aid for the Blind. Robotics Institute. May 2008. Carnegie Mellon University. 22 Mar. 2009

<http://www.ri.cmu.edu/pub_files/pub4/mau_sandra_2008_1/mau_sandra_2008_1.pdf>.

Moravec, Hans. Robot: Mere Machine to Transcendent Mind. New York: Oxford UP, 2000.

Nesnas, Issa, Chris Urmson, and Reid Simmons. A Generic Framework for Robotic Navigation. Robotics Institute. 13 Jan. 2003. Carnegie Mellon University. 1 Feb. 2009 <http://www.ri.cmu.edu/pub_files/pub3/urmson_christopher_2003_1/urmson_christopher_2003_1.pdf>.

Oladi, Reza, and Hamid Beladi. "Non-traded Goods, Technical Progress and Wages." SpringerLink. 15 June 2007. 10 Apr. 2009 <http://www.springerlink.com/content/5r6k3mx3m1q66143/fulltext.pdf>.

Ormerod, Paul. Butterfly Economics: a new general theory of social and economic behavior. Basic Books, 2001. New York, NY.

Perelman, Michael. Railroading Economics. Monthly Review Press. 1 June, 2006. New York, NY.

Polanyi, Karl. The Great Transformation: The Political and Economic Origins of Our Time. 2nd ed. New York: Beacon P, 2001.

Scitovsky, Tibor. "Are Men Rational or Economists Wrong?" Nations and Households in Economic Growth (1974).

Scitovsky, Tibor. "The Place of Economic Welfare in Human Welfare." Quarterly Journal of Economics (1973).

Seo, Young-Woo, and Chris Urmson. A Perception Mechanism for Supporting Autonomous Intersection. Robotics Institute. 17 Sept. 2008. Carnegie Mellon University. 1 Feb. 2009 <http://www.ri.cmu.edu/pub_files/2008/9/iros-08-ywseo.pdf>.

Simon, Herbert A. "A Behavioral Model of Rational Choice." Quarterly Journal of Economics (1955). Www.econ.yale.edu. 15 Jan. 1999. Yale Department of Economics. 10 Apr. 2009 <http://cowles.econ.yale.edu/P/cp/p00b/p0098.pdf>.

Thaler, Richard H. "From *Homo economicus* to *Homo sapiens*." Journal of Economic Perspectives. November 2000.

Veblen, Thorstein. The Theory of the Leisure Class. Chicago: University of Chicago P, 1899.

Watkins, Thayer. "Early History of the Personal Computer." Www.sjsu.edu. San Jose State University. 1 Apr. 2009 <http://www.sjsu.edu/faculty/watkins/pc.htm>.

Praveen Chandramouli

417 Simmons Hall, University Park, PA 16802 610-905-9698 praveenchandramouli@gmail.com

EDUCATION:

The Pennsylvania State University — Schreyer Honors College — University Park, PA
Smeal College of Business | The College of the Liberal Arts — Class of December 2009
Bachelor of Science in Finance, Bachelor of Science in Economics
Honors in Economics
Thesis: Asimov's Crossroads: A Comprehensive Analysis of Man and Machine
Advisor: Dr. David Shapiro
GPA: 3.91 / 4.00

HONORS / AWARDS:

The Schreyer Honors College Scholarship
Student Leader Scholarship
Investment Technology Group Research Award
Charles G. Koch Foundation Research Award
PNC Bank Memorial Scholarship
Howard Eastman Math Award
Dean's List (all semesters)
Truman Scholarship Finalist

RELEVANT EXPERIENCE:

D.E. Shaw & Co., L.P. – Intern — May 2009 - August 2009
- Developed a framework to identify and mitigate company exposure to financial counterparties
- Managed liquidity requirements and cash movements for funds valued in excess of $500 million

General Electric Co. – Financial Management Program Intern — June 2008 – August 2008
- Led financial evaluations of the company's Healthcare division, specifically the GoldSeal imaging business
- Performed fundamental and statistical analysis on the company's portfolio of assets
- Coordinated cross-functional product assessments to improve productivity and accountability

Penn State University Economics Department — Researcher — January 2008 – December 2008
- Won research scholarships to work with a faculty member on a macroeconomics policy project
- Analyzed the effects of racial and socioeconomic discrimination in the subprime lending market
- Proposed solutions to eliminating major marketplace barriers and authored a paper on these findings

Carbon Trap Technologies – Business Consultant — August 2007 – December 2007
- Produced a comprehensive business plan for a startup venture looking to enter the carbon sequestration industry
- Collaborated with the Industrial Engineering Department to develop and price a pilot plant for the company
- Engaged in teamwork-based projects to generate a thorough report and prospectus for investor presentations
- Contributed to the company receiving renewable state and federal grants of over $100,000

LEADERSHIP / ACTIVITIES:

Penn State Investment Association – Healthcare Sector Analyst
- Analyzing securities in the healthcare sector using methods such as discounted cash flows, competitive comparables, and Excel modeling techniques.
- Evaluating healthcare equities in the current and prospective portfolio of the $5 million Nittany Lion Fund, which has beaten the S&P 500 by over 2% since its inception in 2005

University Park Allocation Committee — Elected Member
- Elected to manage and distribute the Student Activity Fee, a collective student-paid fund in excess of $3 million
- Allocated Student Activity Fee funds to various student group requestors
- Directly funded many campus programs and travel opportunities for students

South Halls Residence Association — Diversity Chair
- Represented South Halls at several campus-wide forums regarding diversity and other relevant topics

Intramural Basketball and Football

SKILLS / INTERESTS:

Fluent in Tamil, intermediate skills in French.
2nd Degree Black Belt in Tae Kwon Do
Microsoft Office Suite, Quickbooks Pro
Favorite Finance Book: *When Genius Failed*