

THE LIGHTS IN THE TUNNEL

**AUTOMATION, ACCELERATING
TECHNOLOGY AND THE
ECONOMY OF THE FUTURE**

Martin Ford

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CONTENTS

Introduction	1
Chapter 1: The Tunnel	7
The Mass Market	10
Visualizing the Mass Market	11
Automation Comes to the Tunnel	17
A Reality Check	21
Summarizing	24
Chapter 2: Acceleration	27
The Rich Get Richer	28
World Computational Capability	39
Grid and Cloud Computing	41
Meltdown	43
Diminishing Returns	47
Offshoring and Drive-Through Banking	54
Short Lived Jobs	57
Traditional Jobs: The “Average” Lights in the Tunnel	58
A Tale of Two Jobs	63
“Software” Jobs and Artificial Intelligence	67
Automation, Offshoring and Small Business	74
“Hardware” Jobs and Robotics	75
“Interface” Jobs	80
The Next “Killer App”	81
Military Robotics	85
Robotics and Offshoring	86
Nanotechnology and its Impact on Employment	87
The Future of College Education	90
Econometrics: Looking Backward	93
The Luddite Fallacy	95

A More Ambitious View of Future	
Technological Progress: The Singularity	100
A War on Technology	103
Chapter 3: Danger	107
The Predictive Nature of Markets	107
The 2008-2009 Recession	110
Offshoring and Factory Migration	113
Reconsidering Conventional Views about the Future	115
The China Fallacy	117
The Future of Manufacturing	124
India and Offshoring	127
Economic and National Security Implications for the United States	128
Solutions	131
Labor and Capital Intensive Industries:	
The Tipping Point	131
The Average Worker and the Average Machine	135
Capital Intensive Industries are “Free Riders”	138
The Problem with Payroll Taxes	140
The “Workerless” Payroll Tax	142
“Progressive” Wage Deductions	144
Defeating the Lobbyists	146
A More Conventional View of the Future	149
The Risk of Inaction	152
Chapter 4: Transition	156
The Basis of the Free Market Economy: Incentives	158
Preserving the Market	159
Recapturing Wages	162
Positive Aspects of Jobs	168
The Power of Inequality	169
Where the Free Market Fails: Externalities	170

Contents / v

Creating a Virtual Job	172
Smoothing the Business Cycle and Reducing Economic Risk	179
The Market Economy of the Future	180
An International View	183
Transitioning to the New Model	185
Keynesian Grandchildren	189
Transition in the Tunnel	192
Chapter 5: The Green Light	194
Attacking Poverty	196
Fundamental Economic Constraints	201
Removing the Constraints	202
The Evolution toward Consumption	204
The Green Light	207
Appendix / Final Thoughts	209
Are the ideas presented in this book WRONG? (Opposing arguments with responses)	210
Two Questions Worth Thinking About	223
Where are we now? Four Possible Cases	224
The Next 10-20 years: Some Indicators to Watch for	227
Outsmarting Marx	237
The Technology Paradox	239
Machine Intelligence and the Turing Test	241
<i>About / Contacting the Author</i>	246
<i>Notes</i>	247

INTRODUCTION

Like most people, I have been giving a lot of thought to the economic situation as the most serious crisis since the Great Depression has continued to unfold. Since I develop software and run a high tech business, I also spend a great deal of time thinking about computer technology, and so I began to focus on how economics and technology intertwine. The current crisis has been perceived as primarily financial in origin, but is it possible that ever advancing technology is an unseen force that has contributed significantly to the severity of the downturn? More importantly, what economic impact will technological acceleration have as we anticipate recovery from the current crisis—and in the years and decades ahead? What will the economy of the future look like?

Among people who work in the field of computer technology, it is fairly routine to speculate about the likelihood that computers will someday approach, or possibly even exceed, human beings in general capability and intelligence. Speaking at an industry conference in 2007, Google co-founder Larry Page said, “We have some people at Google [who] are really trying to build artificial intel-

ligence and to do it on a large scale. It's not as far off as people think."¹ Ray Kurzweil, a well-known inventor, author and futurist, states quite categorically that he expects computers to become at least as intelligent as humans by the year 2029.² While other experts are far more conservative about the prospect for machines that can achieve genuine intelligence, there can be little doubt that computers and robots are going to become dramatically more capable and flexible in the coming years and decades.

What is the likely economic impact of machines or computers that begin to catch up with—and maybe even surpass—the average person's capability to do a typical job? Clearly, the employment market would be one of the first areas to feel that influence. Put yourself in the position of a business owner and think of all the problems that are associated with human employees: vacation, safety rules, sick time, payroll taxes, poor performance...maternity leave. If an affordable machine can do nearly any routine job as well as a human worker, then what business manager in his or her right mind would hire a worker?

Even if computers never become truly intelligent, surely machines are likely to become far more capable in terms of their ability to perform a relatively narrow range of tasks. The reality is that a substantial fraction of the routine, specialized jobs held by average people—including many people with college degrees—simply do not really require the full intellectual breadth of a human being. This is the reason that a lot of jobs are boring. If computers can already beat the best chess players in the

world, isn't it likely that they will also soon be able to perform many routine jobs? In fact, I think there are good reasons to expect that machines may begin to approach this more specialized level of "intelligence" within a decade or two.

Since many of the people who work in fields like artificial intelligence and robotics are talking about the future prospects for these technologies on a fairly regular basis, I assumed that a similar discussion must be going on among economists. Surely, the economists are thinking ahead. If machines suddenly get smarter and start doing many of our jobs, then the economists will have a plan in place. At least they will have thought about it; they'll have some good suggestions. Right?

Well, no. It turns out that while technologists are actively thinking about, and writing books about, intelligent machines, the idea that technology will ever truly replace a large fraction of the human workforce and lead to permanent, structural unemployment is, for the majority of economists, almost unthinkable. For mainstream economists, at least in the long run, technological advancement always leads to more prosperity and more jobs. This is seen almost as an economic law. Anyone who challenges this "law of economics" is called a "neo-Luddite." This is not a compliment. (We'll talk about Luddites and the associated "Luddite fallacy" in some detail in Chapter 2 of this book.)

While most economists dismiss the question completely, the technical people seem to be entirely caught up in the excitement of the technology itself and what it might potentially promise. There is some discussion of the

fact that artificial intelligence might have serious impacts on society, but much of this is focused on the threat of truly advanced or even sentient machines in some way “taking over.” There is little attention given to the more mundane and immediate threats to the job market and the overall economy. Perhaps the technologists just assume that once the technology comes along, the economic issues will somehow work themselves out.

Now that is an unsupportable assumption. It would probably be reasonable to assume that technical problems will sort themselves out. Technology usually seems to find a way. But economic policy and political issues? Think back to 1993. Bill Clinton had just been elected and had promised to reform the health care system. As we all know, that effort failed. The major issues back in 1993 were very similar to what we continue to face in 2009. As this is being written, Congress is once again taking up the issue of comprehensive health care reform. It has taken a full 16 years to get to this point, and still the outcome is by no means certain.

But what happened with technology? In 1993, hardly anyone had heard of the Internet: it was something that people in government and at universities used primarily for work-related email. Some people had primitive cell phones. Microsoft had just introduced Windows 3.1, which for the first time brought a usable graphical interface to IBM PC-compatible computers. The evidence is pretty clear: a race between technology and our ability to reform our political and economic systems is really no race at all. So if we can foresee that technology is likely to have

a highly disruptive impact on our economy in the coming years and decades, then we really need to start thinking about that well in advance.

The disintegration of the Soviet Union in 1991 demonstrated quite conclusively that there is no good alternative to the free market system. Other economic systems simply cannot compete. In fact, it's probably reasonable to say that the free market economy is one of mankind's greatest inventions—ranking right up there with the wheel. The wealth and progress that we enjoy in the industrialized world would not have come into being without the underlying logic of capitalism. Historically, technology and the market economy have worked together to make us all more wealthy. Will this always be true? Is it simply a matter of leaving the system we have in place?

The reality is that the free market economy, as we understand it today, simply cannot work without a viable labor market. Jobs are the primary mechanism through which income—and, therefore, purchasing power—is distributed to the people who consume everything the economy produces. If at some point, machines are likely to permanently take over a great deal of the work now performed by human beings, then that will be a threat to the very foundation of our economic system. This is not something that will just work itself out. This is something that we need to begin thinking about—and that is the primary subject of this book.

Once you identify and begin to think about the economic ramifications of advancing technology, it becomes clear that these trends are already well established and may even underlie the current crisis to a significant extent. If

you make some very logical, and even conservative, assumptions about where technology is likely to lead in the coming years, much of the conventional wisdom about what the future will look like becomes unsupportable. In particular, important trends such as globalization simply may not play out in the way we have been led to expect. If we do not recognize these issues and adapt to the changes they imply, it will be very difficult—perhaps impossible—to achieve a sustainable recovery that will lead to long-term prosperity in the years and decades to come.

As we will see, technology is not just advancing gradually: it is accelerating. As a result, the impact may come long before we expect it—and long before we are ready. And yet, this issue is simply not on the radar. If after reading this book, you are concerned about the issues raised here, then I hope you will consider speaking out. Perhaps if enough people start to discuss these issues, even the economists will take notice.

Chapter 1

THE TUNNEL

What if technology progresses to the point where a substantial fraction of the jobs now performed by people are instead performed autonomously by machines or computers? Is that likely, or even possible? And if it is, what are the implications for our economy?

In this book, we are going to explore what increasing technological advancement, and in particular job automation, could mean to the economies of developed countries like the United States and also to the world economy as a whole. To do this, we are going to start by creating an imaginary simulation (or mental video game) that should provide some very useful insight into what we can expect in the future.

As we all know, in recent years the practice of offshoring, or outsourcing jobs to countries like India where wages are lower, has attracted a great deal of controversy. Many people in a variety of jobs and professions in the U.S. and other developed countries are now very concerned that their jobs might eventually be moved overseas.

While offshoring seems to get most of the attention at the moment, we also know that automation—the complete replacement of human jobs by machines—continues to go on in a variety of industries.

There are certain conventional views that most of us accept regarding these practices. For example, we are told that although automation and offshoring may result in significant job losses in certain industries, types of jobs, or geographic regions, this is part of the normal functioning of the free market economy. As jobs are eliminated in one area, economic growth and innovation create new opportunities. As a result, new products and services are developed, new businesses arise and new jobs are created.

We also know that practices like the offshoring of jobs and the relocation of manufacturing to low wage countries like China are creating new opportunities for workers in those countries. As a result, a massive new middle class is being created. As those newly wealthy people enter the world market, they create dramatic new worldwide demand for consumer products and services. Businesses in countries throughout the world will thus enjoy access to new markets, and as a result, new jobs will be created everywhere. In short, the general belief is that the trends toward globalization and automation may create temporary displacements and pockets of unemployment, but ultimately, technological progress creates new jobs and makes all of us more wealthy.

In this chapter, we are going to start off by creating a mental simulation that rejects these conventional wisdoms. We are instead going to make the following assumption:

At some point in the future—it might be many years or decades from now—machines will be able to do the jobs of a large percentage of the “average” people in our population, and these people will not be able to find new jobs.

Many people might disagree with this assumption; they may feel strongly that in our economy, new jobs will always be created. Let’s leave that aside for the moment; we’ll discuss it in great detail in the next chapter. For now, let’s just go ahead and use this assumption. After all, it’s only a simulation.

Who are these “average” people whose jobs we are going to simulate away? We simply mean the bulk of the working people in our population. Let’s say at least 50 to 60 percent of the employed population. These are just typical people doing typical jobs. In the United States, about 28 percent³ of the adult population has a college degree. So many of these average people may have gone to college or even graduate school, but most have not. They are the people who drive trucks, fix cars, and work in department stores, supermarkets and all types of offices and factories. They probably are not neurosurgeons, and they most likely do not have a PhD from MIT. They work on the loading dock, sell insurance or real estate or laptop computers, work in customer service, or accounting, in a variety of small businesses or at the post office. They are what we all think of as regular people.

So our assumption is going to be that, at some point down the line, machines or computers will take over a great many of these people’s jobs. Not all of them, but a lot. Maybe 40 percent. Maybe half. The exact number doesn’t really matter.

We are also assuming that, although these people might try very hard, they simply will not be able to find another job. Perhaps another job is created somewhere else in the economy, but maybe that job requires very advanced or specific education, skills or training, so that we can't have any reasonable expectation that this "average" person can fill that job. Or then again, maybe no new job is created. Maybe the new job just gets automated right away.

Before we get started with our simulation, let's look at the idea of the world mass market.

The Mass Market

Each of us, if we are lucky enough to live in one of the advanced nations of the world, enjoys access to an immense variety of products and services. As you walk through one of the large consumer electronics retail stores, you are confronted with a seemingly limitless number of different products in a variety of price ranges. Similarly if you enter a large bookstore, you'll be presented with literally thousands of different books, music CDs and movie DVDs.

This tremendous selection of products, and also services, which we now take for granted, is unprecedented in human history. Never before has such a variety been available—and certainly not to the "typical" people who comprise the majority of the population. All these products owe their existence to the mass market. In today's world, a business that sells mp3 players, cell phones, laptop computers, personal financial services, or automobiles sees a potential market comprised of tens or, in some cases, even

hundreds of millions of potential buyers. It is this seemingly limitless ocean of good customer prospects that makes very high volume production and marketing possible.

When a business creates products or services at high volume, it realizes economies of scale, and that, of course, results in lower prices. In addition, however, high volume production also makes it possible for the business to adopt statistical quality control techniques and to improve overall consistency and precision in the production process. The result is not just cheaper products—but better and more reliable products.

Because of the mass market, we enjoy a seemingly infinite variety of choices, and we also have come to expect products and services of consistently high quality. For most of us, the benefits of the mass market have had such a deep impact, that in a very real sense, they have become integrated into our culture and now govern the expectations that we have for the quality of our daily lives.

Visualizing the Mass Market

So that we can better understand how the mass market works, let's now create our mental simulation or "video game" of the market. Once we can visualize a working simulation, we can return to our original question about the impact of automation and see what might happen.

Before we start, I should mention that in order to keep things simple, we are thinking in terms of a single worldwide mass market. In fact, we know that different regions and countries actually have distinct but highly connected markets. The markets are currently kept sepa-

rate by things like geographic distance, language barriers, incompatibilities (many U.S. cell phones won't work elsewhere for example), and cultural differences. However, we know that continuing forces such as globalization and the Internet have caused the markets to become much more closely linked than in the past. For this reason, we can safely use a simple one-market model for our simulation.

* * * * *

To visualize the mass market, think of a vast tunnel. The tunnel is dark, but streaming through the tunnel are countless points of white light. The lights float along at a somewhat leisurely pace like tiny moving stars. Each light represents a single person (or consumer) who participates in the world mass market.

The number of lights seems limitless, but in fact they represent only a small fraction of the world's population. The lights include the people of the United States, Canada, Western Europe, Japan, Australia, New Zealand, and other developed nations. Also among the lights are wealthy people from throughout the world and the fast-growing middle classes in developing countries like China, India, Russia and Brazil. All told, there are perhaps somewhere around a billion lights in the tunnel.

The brightness of each light represents the purchasing power (or discretionary income) of each person. In order to enter the tunnel and participate in the mass market, a person must meet a certain threshold of purchasing power.

If we could go outside the tunnel, we would find over five billion barely perceptible lights. These dimly lit lights

represent the world's poor: the approximately 80 percent of the population that lives on less than ten dollars per day.⁴ These lights are, of course, eager to enter the tunnel. However, they are prevented from entering until they can achieve the necessary threshold of brightness. Nonetheless, at the entrance to the tunnel, we can see that a continuous stream of lights suddenly begin to shine more brightly and are thus able to enter the mass market. As we have said, these are the growing middle classes of China, India and other nations. The number of lights in the tunnel is constantly growing.

As we watch the lights float past, we notice that the vast majority shine with a medium range of brightness. These are the average (or typical) people who make up the middle class populations of the world.

Looking closely, we can see that there are also a significant number of much dimmer lights. These are the marginal participants in the mass market—people who just meet the threshold for remaining in the tunnel. These people either hold the very lowest paying jobs, or in many cases, they subsist on government transfer payments, such as welfare or unemployment insurance. Many of the dim lights stay that way only for a short time. They may be unemployed for a while but then find a new job and quickly begin to shine more brightly. Many others, however, are caught in the cycle of poverty and remain dim indefinitely. These people must constantly fight to stay above the threshold of brightness that keeps them in the tunnel. Some will fail. Even in the United States, there are people, such as the homeless, who have been cast out from the tunnel.

Finally, we see that there are a fewer number of lights which shine much more brightly than the rest. These are wealthy people. Many of these people have advanced educations or specialized skills and, as a result, earn a high income. We can see that among these bright lights there is also a range of brightness. We notice that the brighter the lights, the fewer they are in number. At the extreme, we can very occasionally see an intensely bright light, shining like a miniature sun. These are the truly rich people of the world: people who through inheritance or entrepreneurship or other means have acquired vast amounts of wealth.

Still, as we watch the scene inside the tunnel, it is the overwhelming number of the average lights that truly captivates us. We can feel instinctively that it is these average lights that collectively represent the true power of the mass market.

Now let's change our perspective so that we are inside the tunnel with the lights. Looking around us, we see that the walls of the tunnel are alive with a continuous mosaic of color and motion. The tunnel walls are tiled with thousands upon thousands of flat panel displays. Each display runs a continuous advertisement for a product or service that is offered for sale in the mass market. These panels vary greatly in size and arrangement.

Some panels are huge and are arranged in clusters, each advertising a specific product. These are the large corporations that have become household names. Although the large companies stand out, we can see that huge areas of the tunnel walls are covered in a patchwork of many thousands of much smaller panels. These are the

products and services offered by small businesses that also cater to the mass market.*

As we continue to watch the lights, we can now see that they are attracted to the various panels. We watch as thousands of lights steam toward a large automaker's panels, softly make contact and then bounce back toward the center of the tunnel. As the lights touch the panel, we notice that they dim slightly while the panel itself pulses with new energy. New cars have been purchased, and a transfer of wealth has taken place.

We know that a natural cycle exists within the tunnel. Almost instantly, we can see that many thousands of lights scattered randomly throughout the tunnel shine a little more brightly. These are the employees of the automaker being refreshed with new light. Another transfer of wealth has taken place. The autoworkers in turn make purchases from other business, small and large, and the light continues to parade through the tunnel.

We also know that behind the walls of the tunnel there are more businesses and interconnections that we can't see. A large steel company receives payment from the automobile manufacturer and, in turn, its employees shine with new light.

If we could watch the action in the tunnel over a long period of time, we would find that the tunnel is not at all a static place. We would notice that some of the panels on

* We can also imagine that small, locally oriented businesses (such as restaurants) are included in our tunnel. While these businesses obviously don't cater directly to the global mass market, they are nonetheless integrated into the activity that occurs in the tunnel, and they are heavily impacted by the overall health and vitality of the mass market.

the walls gradually grow dimmer and attract fewer lights. In some cases, they may reverse their decline and become strong again. But in many other cases, they weaken and grow dark.

Even as this happens, however, elsewhere on the tunnel walls, we see that new panels are appearing and growing stronger. A few seem to grow rapidly in size before our eyes. This is the process of creative destruction. In the mass market, the collective purchasing decisions of the lights determine which businesses succeed and thrive, and which ones ultimately decline and fail. This is a natural and cyclical process. When an inefficient business fails, its capital, resources and employees will eventually be transferred to a new, stronger business. As a panel on the tunnel wall goes dark, the lights that represent that company's workers will also grow dim. But over time, they will find new jobs and their light will be restored.

We now have a pretty clear picture of how the mass market works. We see the lights streaming toward and contacting various panels, and then, elsewhere in the tunnel, other lights brightening as wealth is cycled between consumers, businesses and workers within the tunnel. Over time, we see panels die and other new panels spring up, as old businesses that can no longer compete in the market are replaced with new, more competitive start-ups, often in completely new and different industries.

We can also feel that, in general, the total amount of light in the tunnel is increasing. This is partly due to the new lights constantly streaming into the tunnel, but we also have the sense that as the light is cycled throughout

the tunnel, its intensity seems to very gradually increase of its own volition—as though the very process of moving the light around naturally makes it grow over time.

This then is the mass market: a natural cycle of increasing light and wealth governed by the logic of the marketplace. It is the primary engine of our free market economy.

Automation Comes to the Tunnel

Now that we have a working simulation of the mass market, let's go ahead and perform our experiment with job automation. To keep things simple, let's first focus on the issue of jobs being taken over completely by machines or computers and leave the question of offshoring for later.

* * * * *

Now we are back in our tunnel. Very gradually, we begin to eliminate the jobs held by many of the average lights. As this happens, the impacted lights grow dimmer and in many cases disappear completely.

The automation process affects jobs throughout the world. In developed countries, the people who lose their jobs will usually continue to receive income, at least for a time, from government programs such as unemployment insurance. However, as we have seen, these programs generally produce only very dim lights. In third world countries with little or no safety net, these unlucky people will likely be cast out from the tunnel, and their light will disappear entirely.

The impact of automation is still very difficult to discern among the multitude of lights in the tunnel. We notice, however, that some of the brightest lights in the tun-

nel are beginning to shine with even more intensity. As jobs are eliminated, many of the businesses in the tunnel become more profitable. Some of this wealth is then transferred to the owners and top executives of the businesses. As this process continues, we see the brighter lights continue to slowly gain strength as more of the average lights gradually dim or flicker out. The distribution of income is becoming more concentrated in the tunnel.

Now, finally, we begin to see a real difference in the tunnel. It becomes obvious that there are fewer lights and that the number is continuing to diminish. Just as this realization strikes us, we immediately feel that there is a new sense of urgency pervading the panels that line the walls of the tunnel. The panels begin to dance with more and more desperate motion and color as they attempt to attract the dwindling number of lights.

The businesses on the walls of the tunnel are now suddenly seeing significantly slower demand for their products and services. This is happening even though many of the brightest lights in the tunnel have continued to gain in strength.

Imagine that your job is to sell as many \$50 cell phones as you can in one hour. You are offered two doors: Behind door #1 sit Bill Gates and Warren Buffet, the two richest people in America. Behind door #2 are a thousand average people. You may well be tempted to choose the first door just so you'll get to meet Bill and Warren, but in terms of getting your job done, you would probably agree that door #2 is clearly the best choice. This is because the demand for the mass market products that

drive our economy depend much more on the number of potential customers than on the wealth of any particular customer. You are not going to be able to sell 40 cell phones to one person, no matter how wealthy they are.

We can now sense that many of the businesses in the tunnel are clearly in trouble. Even though they are continuing to save money as automation slowly eliminates some of their remaining workers, this is not enough to make up for the reduction in sales they are experiencing. Many of these companies are now at the point where they must take action to survive.

A great deal of each company's resources is invested in factories, machines and equipment and offices. These things, which an economist might refer to as capital, are very hard to quickly get rid of. For example, if you just bought a lot of new automated machines for your factory, then you are stuck with them. You can't just return them and get your money back if demand for your products suddenly starts to fall. For this reason, a business which sees rapidly falling demand usually has only one choice in order to survive: cut more jobs. We see this, of course, as part of the normal business cycle. Businesses routinely lay off workers in bad times and then rehire in good times.

In the tunnel, we now see that the businesses are beginning to cut more and more jobs. They are becoming more desperate and, in many cases, they must eliminate even key employees that they formerly felt were crucial to their operations. As this happens, we begin to see some of the brighter lights in the tunnel rapidly begin to dim.

The continuing decrease in demand falls especially heavily on the manufacturing businesses located in devel-

oping nations like China. These businesses rely on producing very high volume products, which they export to first world nations. They are now severely cutting jobs and the flow of new middle class people into the tunnel has all but stopped.

As a result of the job cuts, the lights are becoming even more sparse in the tunnel. Many of the businesses are now failing and whole regions of the tunnel walls are growing dark. Now we see that many of the very brightest lights in the tunnel finally feel the impact and also begin to lose their light. The owners of the businesses in the tunnel are seeing much of their wealth gradually drain away.

The tunnel has become a far darker and more stagnant place. We sense clearly that the hopes of even the remaining brighter lights are gradually evaporating into the new emptiness of the tunnel.

A Reality Check

Clearly, our simulation did not turn out well. Perhaps our initial assumption about jobs being automated was wrong. But, again, let's leave that for the next chapter. In the meantime, we might wonder if we have made a mistake somewhere in the simulation. Let's see if we can perform some type of "reality check" on our result. Perhaps we can look to history to see if there is anything in the past that might support what we saw happen in our simulation.

Let's leave our tunnel and travel back in time to the year 1860. In the southern part of the United States, we know will find the greatest injustice ever perpetrated in the history of our nation. Here, long before the new light of advanced technology first began to shine, men had discovered a far more primitive and perverse form of job automation.

The injustice and moral outrage associated with slavery rightly attracts nearly all of our attention. For this reason, most of us don't have occasion to think about the overall economic impact of slavery. At the time Abraham Lincoln was elected president, we know that while the Northern population's moral objection to slavery was a primary divisive issue, there were also significant differences and debate about issues relating to the differing economic systems of the North and the South.

The Northern economy was built on free labor and entrepreneurship and tended to spread opportunity more equally throughout the population. In contrast, the Southern states relied on slave labor, and wealth was primarily concentrated in the hands of white plantation owners who

increasingly effective as the years progressed—ultimately achieving a 95 percent reduction in Southern cotton exports—and was certainly an important factor in the outcome of the war. By the time the war ended in 1865, the Southern economy was in complete ruin. One can speculate that if the blockade could have been maintained without an actual shooting war taking place, the economic impact alone might have in time led to the end of slavery.*

Summarizing

Both our tunnel simulation and our examination of the Southern slave economy seem to support the idea that once full automation penetrates the job market to a substantial degree, an economy driven by mass-market production must ultimately go into decline. The reason for this is simply that, when we consider the market as a whole, the people who rely on jobs for their income are the same individuals who buy the products produced.

Another way of expressing this is to say that although machines may take over people's jobs, the machines—unless we are really going to jump into the stuff of science fiction—do not participate in the market as consumers.

* Is it really reasonable to draw a comparison between the economic effects of slavery and advanced machine automation? I would argue that the comparison almost certainly underestimates the economic impact of autonomous machines. Because of its inhumanity, slavery carries with it obvious costs. These include both the direct costs of enslaving unwilling human beings as well as lost productivity. The owners of machines would, of course, see none of these costs. In addition, machines, which can operate essentially continuously, obviously have the potential to be far more productive than even a willing human worker could be.

Recall from our example of selling cell phones to the two billionaires or to a thousand regular people, that making a few people richer will not make up for losing a large number of potential customers. That may work for yachts and Ferraris but not for the mass produced products and services that are the backbone of our economy.

At the very beginning of the automation process this effect was not at all clear. The first businesses to automate saw a significant reduction in their costs as they cut workers, while the impact on the demand for their products was negligible—or in fact, demand may have actually increased for a time, as they were able to lower their prices. As a result, their profits, and therefore the wealth of their top employees and shareholders increased. These were the brighter lights in the tunnel that initially became stronger.

However, as nearly all businesses in the tunnel continued to automate jobs, at some point the decrease in the number of potential customers began to outweigh the advantages gained from automation. Once this happened, businesses were forced to cut even more jobs, which eliminated even more consumers from the market and caused demand to fall still further. From this point on, the economy entered a continuing downward spiral.

Not a very happy ending. However, we still need to examine our initial assumption. Is it really possible that, at some point in the future, machines or computers could take over the jobs performed by a large percentage of average workers without new jobs within the capability of these people being created? Could that really happen?

We'll look at that question in the next chapter. We'll also look at something called the Luddite fallacy—which is

an established line of economic reasoning that strongly contradicts the result we saw in our simulation

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NOTES

Introduction

¹ Larry Page on AI at Google: Web: http://news.cnet.com/2100-11395_3-6160372.html video: http://news.cnet.com/1606-2_3-6160334.html?tag=mncol;txt

² Kurtzweil has a \$20,000 bet with Mitch Kapor that a computer will pass the “Turing Test” and thus exhibit human-like intelligence (see last section of the Appendix) by the year 2029. Web: <http://www.longbets.org/1>

Chapter 1: The Tunnel

³ US Census Bureau, 2004, web: <http://www.census.gov/Press-Release/www/releases/archives/education/004214.html>

⁴ Percentage of world’s population in poverty, see the graph based on World Bank data at <http://www.globalissues.org/article/26/poverty-facts-and-stats>. My focus here is not on extreme poverty, which is measured at 1-3 dollars per day, but on an income level that prevents people from being viable mass market consumers.

⁵ Doris Kearns Goodwin, *Team of Rivals: The Political Genius of Abraham Lincoln*, Simon and Schuster , 2005, p 77.

⁶ “How deeply the curse of slavery...”, Letter from William H. Seward to Albert H. Tracy, June 25, 1835. Albert H. Tracy Papers, New York State Library, Albany NY (as cited in *Team of Rivals*, p 77).

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