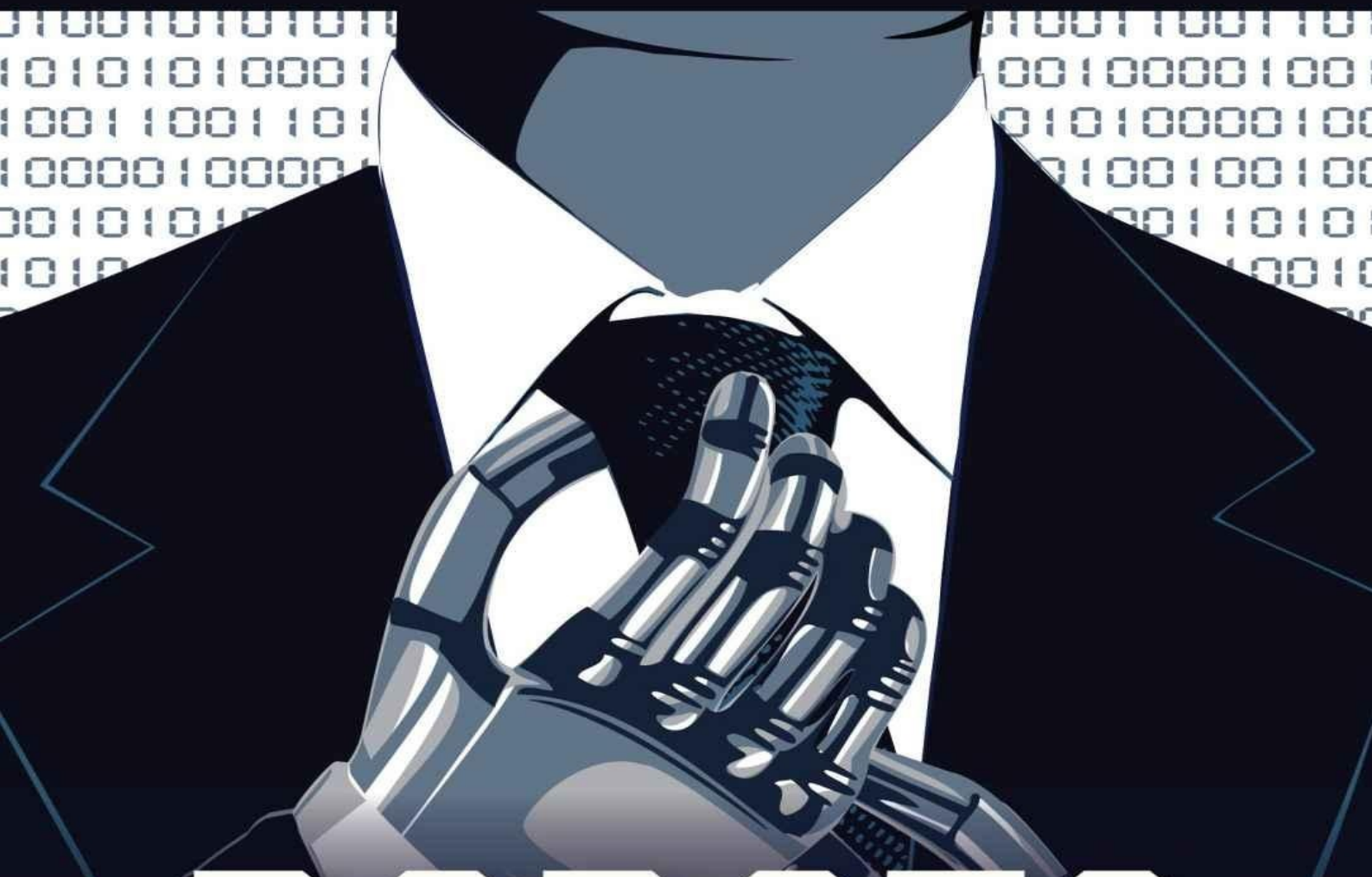
FEDERICO PISTONO



ROBOTS WILL STEAL YOUR JOB but that's OK

HOW TO SURVIVE THE ECONOMIC COLLAPSE AND BE HAPPY

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Foreword

When at the beginning of 2012 I have been contacted by Federico, asking for the opportunity exchange ideas, I was glad to comply. From an initial exchange of emails, we quickly proceeded to a online voice and video conversation, and a few days later we agreed to meet in person. He came visit for a day and stayed for the night with me and my family.

Meeting Federico is letting sunshine in your life. His enthusiasm, curiosity, and passion for h interests and sharing experiences with others make it impossible not to like him. We had a lot c common topics to talk about, and it was great to be able to quote books, references to each other an realize that the other read them too, or mention global movements, organizations and see that we we either both following them, or actively participating in them.

This is not only a brief description of the author of this book, and my experiences with him. think that it is also a glimpse of what more and more people will be able to do, with their time, wi their interests. Using technology, and online communications to find people with shared goals. Ver rapidly establish shared trust, communicate using flexible tools, and act together to advance joi objectives effectively. An exponential path to human connections!

Robots Will Steal Your Job, But That's OK is a smart, humorous, but thorough, and potentiall important approach to a fundamental question of our time. Knowing that Federico is working on i and that during the summer of 2012 he would have the chance to enrich his views with the experienc that he would have had at Singularity University, filled me with expectation. Because, as he describ it in informative, and actionable detail, the issues of this book are going to be felt and shared b billions of people. We are all going to live a future where we will have to redefine our roles, goal and purpose in life.

A lot of people are working of various technology solutions, and even if we don't have guarantee, statistically speaking we can rely on one or an other of those solutions to be found, and tho spreading quickly. That is why concentrating on people is important: we biological humans can't b easily debugged, our biases and fallacies are much harder to correct than the 2.0 release of any give gadget. And the process of designing a fruitful future full wonder, cannot but include the large possible number of people aware of the opportunities we have in front of us. This is why I am s excited that this book is now available, and that you chose to read it. If you like it, as I hope, mak sure to recommend it to your friends who will live, work, and love in the future with you.

– David Orba
CEO of dotSU
Advisor and Member of the Faculty
Singularity Universi
October 2012, New Yo

Understanding the complex relationship between automation and jobs requires empirical analys and a nuanced inquiry. Federico Pistono's book Robots Will Steal Your Job, But That's OK is unique and fearless contribution to the ongoing conversation on this topic. Pistono approaches th issues with a perspective that reflects his love of both people and technology. The approach

relentlessly constructive, optimistic, and controversial. Read it, then agree or disagree with variou
points, but join the dialog!

– Neil Jacobste
Co-chair AI and Robotics, Singularity Universi
October 2012, San Francisc

Dedication

To all the great people who are dedicating their lives in making the world a better place for everyone

To the emerging and growing zeitgeist of open science, open education, open culture, creativ commons, and the free software movement. You are the heroes of this generation, and give us hope f the future.

Preface

For years, I have been meaning to write a book, but I could never bring myself to finish on Whenever I became interested in a topic, it opened up a whole new and unexplored territory, whic then lead to another universe of things to discover and to understand. The more I searched, the mo there was to be found. Every time I believed I had a decent understanding of a topic, something ne would come up that challenged my previous assumptions. And so I was back to my studies again.

Maybe it is because I am a guy with a questioning nature. Too many things interest me, an sticking to a particular topic for long is an arduous task. Back in October 2011 I was travelling arou Europe, thinking about my future, preparing a speech for my next conference, when I finally decided was time for change. During a rainy day when I was in Sweden I realised that my goal of a 1,000-pag odyssey on how to fix society was unrealistic (and a bit egomaniacal). There were too many subject all too complex, and with too little time. I decided I would pick one thing, one that I believed to be the top of our priorities, and focus on that. Environmental sustainability and climate change came mind, but there are already many excellent books on this subjects (from people much more qualifie than myself), it would only be redundant. The future of technology and Artificial Intelligence wa another, but the same conclusion applied. Then I realised that one of the most pressing issues that w are going to face, both as individuals and as societies, was deeply overlooked. Technology displacing human labour.

Up until now, very few authors have addressed this issue. I was determined to fill this cultur gap. My audience would not be the ivory tower of academia, but the vibrant street of the crowds. Aft all, the people most affected by this will be common workers, and explanations of complex subjects simple, concise, and understandable terms that are accessible to everyone are rare. I promised myself would do that, but keeping an eye for change-makers as well, be they politicians, technophilantropist or CEOs.

One of the most difficult things for me was to decide what to include, and what to leave out. I ha to find the right balance. In that, I believe I may have not succeeded, although I have tried my best. my quest for clarity while staying under 200 pages, I may have failed in all of them. Some parts a probably too prolix (I probably rambled a lot), while I may have neglected some others. But such the nature of things. This is a complex topic, my first book cannot be perfect, and your feedback, bo positive and (especially) negative, will help me to improve it in the future.

What I hope this book will do for you is to make you think about your future, guide you understanding the world around you a little better, and help you navigate the endless sea of eve changing wonders. And while you are at it, it might make you smile a bit and become slightly happie

If I succeed in doing that, then the time and effort I put in writing this book was well spent.

Acknowledgements

When I launched this book project, I wanted to try something different from the typical routine book publishing. Call it a social experiment. Instead of going through the usual process of trying get an agent, to then maybe get an offer from a publishing company, to then get a 10% share of th sales at best (if all goes well), I decided to take a radically different route.

I figured that I write for the people who will read the book, not for the publishers. If peop believe in me and in the project, they will show their support. If the don't, so be it. Naturally, it is a b harder to go solo than it is to rely on someone else. You have to continuously prove your credibilit build a fan base, give interviews, write articles, manage your own promotion, and create a tru relationship with your audience.

I decided to go with the crowdfunding site IndieGoGo, and in just a few weeks 78 people decide to support my project, exceeding my initial funding goal by 130%. This gave me the chance to hire professional designer for the book cover, as well as a highly qualified proof-reader, my frien Katherine Nielsen.

On my site (http://robotswillstealyourjob.com/supporters) there is a list of tho forward thinking individuals who supported me during the campaign. Among them, a few stood out particularly generous, so I would like to especially thank Ben McLeish, Marco Bassetti, Danie Mancinelli, Mark Henson, Justin Gress, Eric Ezechieli, and Jonathan Jarvis.

Then to all my friends who gave invaluable advice, both in "real life"[1] and in the virtual worl and to my Facebook fans and twitter followers.

Thank you all.

You are awesome.

Introduction

You are about to become obsolete. You think you are special, unique, and that whatever it is that yo are doing is impossible to replace. You are wrong. As we speak, millions of algorithms created b computer scientists are frantically running on servers all over the world, with one sole purpose: c whatever humans can do, but better. These algorithms are intelligent computer programs, permeatin the substrate of our society. They make financial decisions, they predict the weather, they sugge which countries will wage war next. Soon, there will be little left for us to do: machines will take ove

Does that sound like some futuristic fantasy? Maybe so. This argument is proposed by a growin yet still fringe community of thinkers, scientists, and academics, who see the advancement technology as a disruptive force, which will soon transform our entire socio-economic syster forever. According to them, the displacement of labour by machines and computer intelligence wi increase dramatically over the next few decades. Such changes will be so drastic and quick that th market will not be able to abide in creating new opportunities for workers who have lost their job making unemployment not just part of a cycle, but structural in nature and chronically irreversible. will be the end of work as we know it.

Most economists discard such arguments. Many of them don't even address the issue in the fir place. And those who do address this issue claim that the market always finds a way. As machine replace old jobs, new jobs are created. Thanks to the ingenuity of the human mind and the need f growth, markets always find a way, especially in the ever-connected and globalised mass market w live in today.

In this book I will try to avoid picking either side based on belief, gut feeling, or hunch. Rather, will attempt to create an informed logical reasoning, based on the evidence that we have so far.

The book is divided into three parts. First, we will explore the topic of technologic unemployment, and its impact on work and society – I chose to focus on the US economy, but th same line of argument works for most the industrialised world. In the second part we will look into th nature of work itself, and the relationship between work and happiness. The last part is a bold attem to provide some practical suggestions on how to deal with the issues presented in the first two part Doing a thorough examination of each section would require a monumental work, possibly thousand of pages long, which far exceeds the purpose of this book. My intention is not to write a comple academic report, but rather to initiate a discussion, about what I think will soon be one of the bigge challenges that we have to face as a society, as well as individuals. Too often we treat things a separate subjects, not realising the interconnected nature of our reality. This mistake has made u weak and vulnerable. Over the last 70 years, we have set the stage of our own demise, we have becom increasingly discontent, the quality of our relationships has fallen, and we have lost track of wh really matters. Today, everything is amazing, and nobody is happy. It is time to take a step back an think about where we are going.

Let us begin the journey.

Part I
Automation and Unemployment

Chapter 1
Unemployment Today

We usually get a sense of how good (or how bad) things are by reading the news and by looking the world around us. We see how we live, we talk to our neighbours, we read newspapers, blog tweets, and watch TV. Very few people find the time to check for themselves the long and borin tables from the OECD Factbook, or the US Bureau of Labor Statistics. The business columns newspapers are often filled with financial jargon, which does not really encourage a cle understanding to those who are not familiar with the intricacies of the economic system. As a resu most people do not have a clue of what is really going on. A quick glance at the recent statistics abo job growth in the United States and in Europe should make us a bit concerned, to say the least.

In July 2011, the US Government released a report showing that 117,000 new jobs had bee created that month, and the New York Times featured a promising headline "US Posts Stronger Soli Growth in July".[2] But behind this veil of false hope, there lied a hidden and ugly truth. A growth 117,000 jobs was not even enough to make up for population growth (about 130,000 people eve month), let alone make a dent on the 12.3 million jobs lost during the 2008-2009 recession. Later the article, we discover a few more things. The official figure for the unemployment rate was 9.1% which is already staggeringly high, but it gets even more concerning when considering that additional 8.4 million people were working part time because they could not find a full-time job, a 1.1 million had become so discouraged that they have stopped looking for work altogether. If v include these people, the broader measure of unemployment was 16.1% in July 2011. Please take moment and let that sink in. The United States of America, possibly the wealthiest country in th world, had an unemployment rate at 16.1%, as recent as July 2011.

As if that was not enough, it turns out that only 58.1% of the population was working, the lowe level in nearly three decades.[3] Laura D'Andrea Tyson, Professor at the Haas School of Business at th University of California, Berkeley, calculated that even if we could somehow create 208,000 new jo per month, every month, for the foreseeable future, it would still take until 2023 to fill that gap.[4] As January 2012, thanks to massive efforts from both the private sector and the government, th unemployment rate fell to 8.3%.[5] A very mild consolation, considering that people employed part-tim for economic reasons, marginally attached to the labor force, discouraged workers, and long-ter unemployment, changed very little over the year. To make things even worse, the labour forc participation rate is 63.7%, its all time lowest since 1983, when women had not entered the work for in large numbers, and it is dropping consistently every year.[6]

MIT Economists Erik Brynjolfsson and Andrew McAfee make a lucid analysis of this problem their book Race Against The Machine: How the Digital Revolution is Accelerating Innovatio Driving Productivity, and Irreversibly Transforming Employment and the Economy[7], which deals wi the current unemployment crisis and tries to offer some solutions, particularly by reformi education, the system of economic incentives, and by promoting entrepreneurship. While I conc with their analysis, I think their solutions are limited to the way things have worked until now. The appear to be assuming that the system of economic incentives, what drives people, and human natu itself are almost immutable. According to Voltaire, "Work spares us from three evils: boredom, vice and need", and having a job has undoubtably been the driving force to combat them up until no

However, I challenge the assumption that this is the only way we can do that, and we shall explo why in the coming chapters.

Other authors have addressed the same issue. Jeremy Rifkin was one of the first to serious consider this problem. In 1995 he published The End of Work: The Decline of the Global Labor Forc and the Dawn of the Post-Market Era[8], where he predicted that worldwide unemployment wou increase as information technology eliminates tens of millions of jobs in the manufacturin agricultural, and service sectors. He traced the devastating impact of automation on blue-collar, reta and wholesale employees: “While a small elite of corporate managers and knowledge workers reap th benefits of the high-tech world economy, the American middle class continues to shrink and th workplace becomes ever more stressful”[9]. While he may have gotten some of the details wrong, th general outline is so spot-on that it seems almost prophetic. Over the past twenty years we hav witnessed the gradual disappearance of the American middle class, with rising costs and low income[1011], while the wealthiest Americans have accumulated more wealth than ever before in history

To get an idea of the disproportionate amount of wealth generated by the system, how uneven distributed it is, and exactly how it had gotten worse and worse since 1979, let us have a look at th following graphs[12].

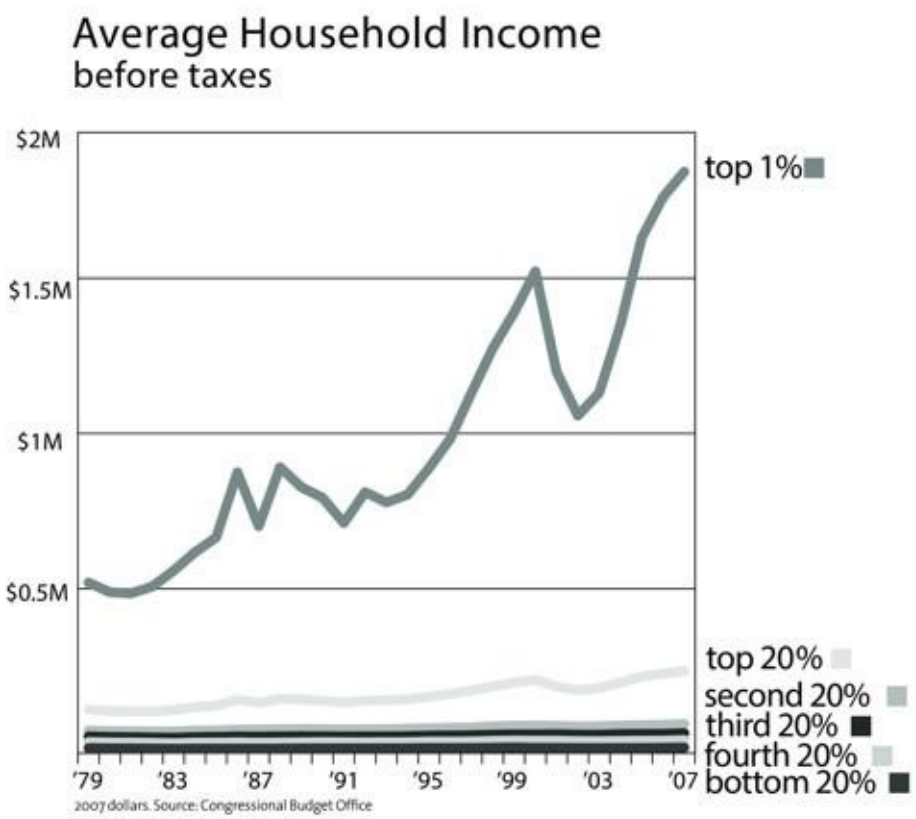

Figure 1.1: Average Household Income

As you can see from Figure 1.1, average household income had remained pretty much the sam for well over 80% of the population, while the top 1% experienced a tremendous increase, particular starting in 1994. Even more revealing is the change in share of income, calculated after taxes (Figu 1.2).

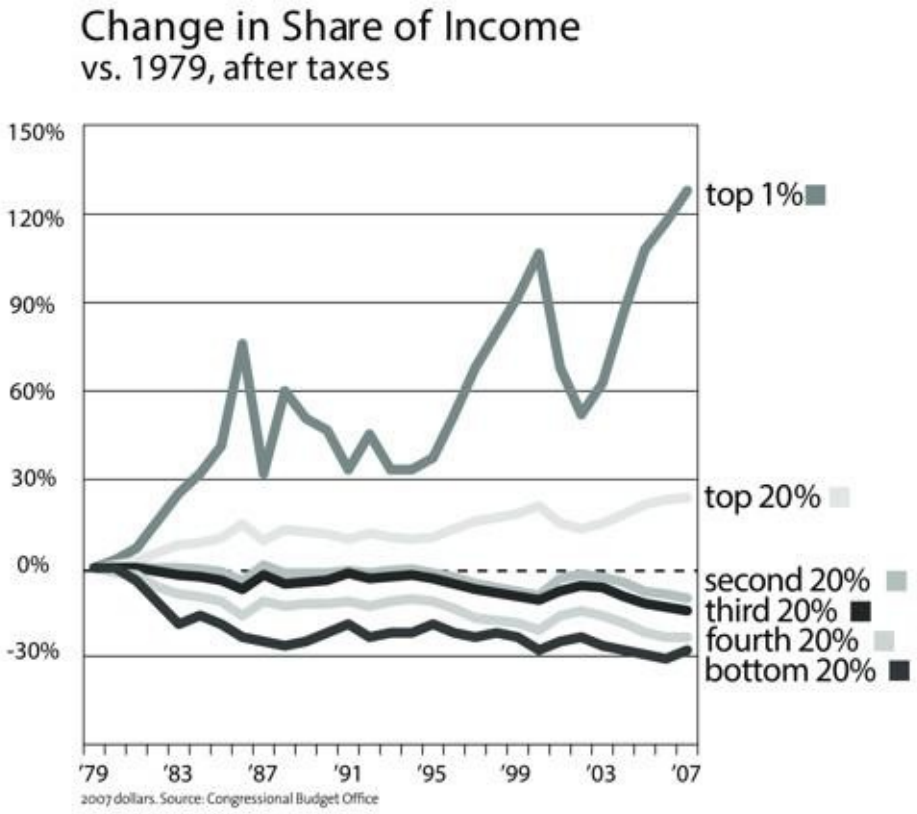

Figure 1.2: Change in share of income 1979-2007, calculated after taxes.

The lower 80% have actually seen a substantial decrease of income, while the very top has hard been affected. what is even more worrying is the distortion in the public perception of th phenomenon, even after the worldwide Occupy Movement broke out.

A 2011 paper by Harvard Professor Michael Norton and Duke University Professor Dan Ariel called Building a Better America – One Wealth Quintile at a Time shows just how skewed ou perception is.[13]

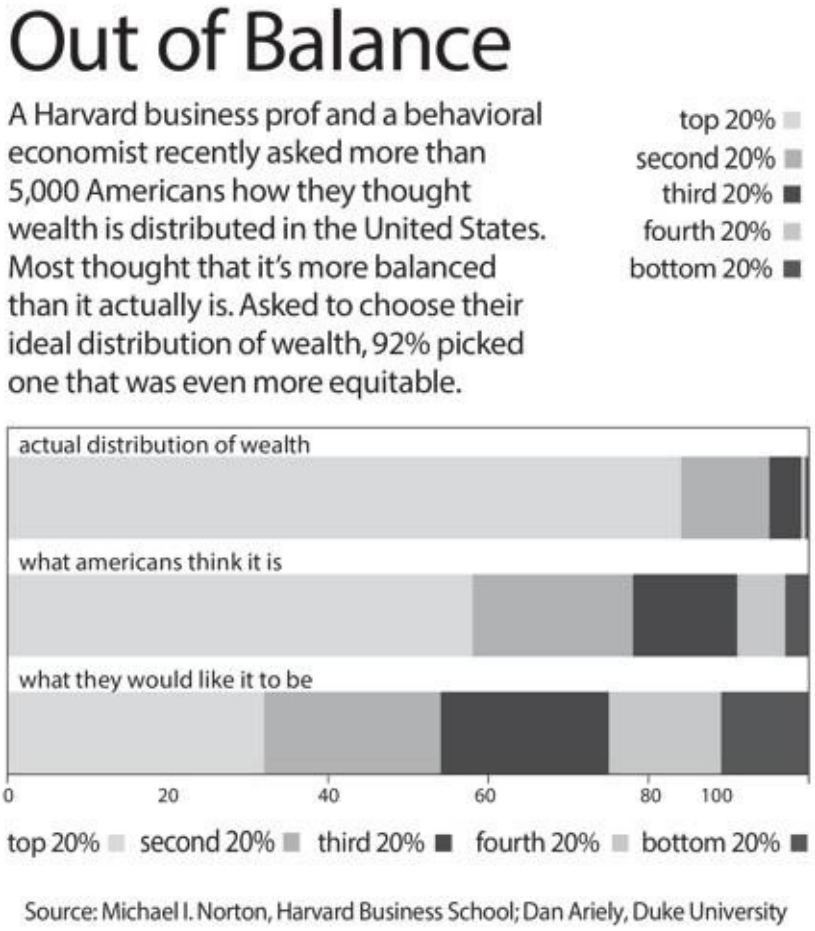

Figure 1.3: Building a Better America – One Wealth Quintile at a Time, Michael I. Norton, Dan Ariely. Journal Perspectives on Psychological Science.

History proved Rifkin right. The middle class is disappearing, the richest are getting richer, an we have no idea how bad the situation truly is. The question is, was Rifkin right about work an automation, too?

Martin Ford followed up on this, utilising his entrepreneurial and software engineerin perspective. His 2009 book The Lights in the Tunnel: Automation, Accelerating Technology and th Economy of the Future aims to show how automation will inevitably lead to structural unemploymen and millions of people, both skilled and unskilled workers, will soon find themselves out of th workforce, with little to no chance of getting back in. Ford has since written many articles on maj news websites, thereby bringing the issue of technological unemployment back into the public eye. H has also been a source of inspiration to me, when I decided to write this book. However, just as wi Brynjolfsson's book, I do not think his solutions are feasible; nor, in most cases, desirable.

I think all of these authors have identified a real problem, and they tried to propose solutions that problem using their knowledge, skills, analysis, and background. But as I read those books, I fe like there was something missing. Something was not accounted for. I felt as if they were trying find solutions in a context where solutions were nowhere to be found.

Before I continue, let us be clear on something. All of the authors I just mentioned are high qualified and intelligent professionals, with much more academic and working experience tha myself. That is not in question. But they were not born into a culture where things change

dramatically in just a few years. They had to adapt to the idea of rapid change, they were not born in generation that created this massive accelerating change. I was lucky enough to be part of th generation. I have seen the free and Open Source movement rise and become one of the greatest forc on the planet. The dreams I had when I was a child, that of small groups of dedicated and intellige people could change the world, have come true. It was exhilarating to witness these events, which a becoming even more ubiquitous, as their rampant increase scares the establishment and excites th revolutionaries.

Perhaps I am wrong, and all of this comes from my arrogant, blissful ignorance of youth. In fac that is most likely to be the case. But perhaps there is something. Something true, which transcen me as an individual, and just speaks through me. It is the collective intelligence of all the people have talked to, all the books I have read, the experiences I had in the ever connected cybernet organism known as the Internet. I do not pretend to be the voice of my generation, or that of the enti Web for that matter. But it is undeniable that these intelligences have shaped me, influenced me, an directed me over the years. And now I am simply remixing what I received. This is social evolutio copy, transform, and combine.[14]

However, there is also another possibility. It is entirely conceivable that we are all wrong, myse and those authors. Mainstream economists and analysts could be right. It may be that we do n understand some basic economic concepts, and that our analyses are nothing more than a fallac which could be easily solved by getting our economics right and by studying the past a little bit mor After all, we have seen unemployment fluctuate up and down for hundreds of years, only to go back familiar levels, without any substantial change in the structure of the economy. As new technologi come along, we cyclically move from one sector to another, creating new jobs, and everything worl just fine. Economists have a name for this phenomenon, which takes us back a long time. So, before dwell any further, let me tell you a story.

Chapter 2
The Luddite Fallacy

We are in England, at the end of the 18th century. A boy named Ned Ludd is a weaver from th village of Anstey, just outside Leicester. He does not know it yet, but he is about to make history.

It is a hard and laborious day of 1779, Ludd is apprenticed to learn frame-work knitting. But he averse to confinement or work, and refuses to exert himself. His master is displeased, and complai to a magistrate, who orders a whipping. In response, Ludd grabs a hammer and demolishes the hat frame. This act will be told by generations to come, and Ludd became history. Or so the story goes.

As with every myth, there are many variations of the story. Some accounts say that Ludd was to by his father, a framework-knitter, to ‘square his needles’. Ludd took a hammer and ‘beat them into heap’. Other stories can also be found, and nobody really knows which one is true, if any[15].

Whether or not any of it really happened is irrelevant. What matters is that news of the incide spread, and were distorted, like every good folk story. Whenever frames were sabotaged, people wou jokingly say "Ned Ludd did it". His actions inspired the folkloric character of Captain Ludd, al known as King Ludd or General Ludd, who became the alleged leader and founder of a moveme called, not surprisingly, ‘The Luddites’.

The Luddites can be traced back to Nottingham, England, around 1811. It was composed most of hosiery and lace workers, English textile artisans who protested – often by destroying mechanis looms – against the changes produced by the Industrial Revolution. These guys smashed knitti machines that embodied new labour-saving technology as a protest against unemployment. Simp put, machines were stealing their jobs, and they did not like where that was going.

People began to speculate whether this was the beginning of an irreversible process, or if thin would go back to normal. At the time automation was represented by no more than a steam-engi machine, something that could have hardly been seen as a realistic replacement for human labour general. However, some suggested that the problem of machine automation could exacerbate in a fe years, putting the very companies that produced goods at risk. Industrialist Henry Ford understood th quite profoundly. In fact, he paid his workers twice the going rate, so that they could afford to buy t cars that they themselves were producing.[16]

This makes sense. You need people to have enough money to buy the products you creat otherwise the cycle of production-consumption is interrupted. If automation replaces humans fast than they can find new occupations, you have a problem. As a result, people may get upset, and start jeopardise machines, in order to ensure their workers not lose their job. To this day, we still call thes people"The Luddites".

Neoclassical economists have dismissed such proposition as nonsense. They claim that th argument is a fallacy. Economist Alex Tabarrok famously said in 2003:

> If the Luddite fallacy were true we would all be out of work because productivity has be increasing for two centuries.[17]

And if you look around you, it would seem that the Luddite argument is indeed a fallacy. E studying the historical record, one should be pretty optimistic about the future of the econom Automation and mechanisation have consistently been introduced, and that led to an increase productivity. More work could be made, with less labour. More products were coming out of ou factories. More wealth was generated. But the total requirement for labour did not decrease. As th economy grew, so did our standard of living. And our perception of what is necessary for comfortable life changes accordingly. A hundred years ago, even the richest man in the world coul not even dream of owning a small electronic device that could connect him with whomever he like anywhere in the world. Today, not owning a cell phone is inconceivable to most people. Even in th poorest countries, people have access to cell phones. A boy in a village in rural Africa with a ce phone (you would be surprised of how many of them do) has access to more information than th president of the United States did 20 years ago. Some have gone so far as to argue that the poorest today are richer than the richest kings of the past. I would not agree with that, because many times it cheaper to obtain these technological marvels than it is to find food. You get the idea.

Over the past two centuries we have continued to rely on machines to increase our productivit but we have not been displaced by them. On the contrary, we created new jobs, new sectors, and ne opportunities. Machines allowed us to become more creative, more productive. As we moved from th agricultural to the manufacturing sector, and then to the services, we began to expand our dominatio of the planet.

So, if the idea that automation creates unemployment is a fallacy, then there is nothing to wor about. The staggering rate of unemployment that we are experiencing today in 2012 (8.2% in the U 24.1% in Spain, 21.7% in Greece, 14.5% in Ireland[18]) is just one of the many cycles of the econom Or it may be due to bad policies. Or bad politicians. Or the financial bubble of subprime mortgag that burst a couple of years ago. Maybe it is a combination of all of them. If that is the case, then v just need to elect better politicians, demand better reforms, and reduce the influence of the financi sector on the economy. In other words, it could be just a matter of time before things go back normal. Get back on your feet, work hard, and everything will be fixed. I would like to believe that really would. But the reality may be very different.

While these resolutions are certainly good ideas, and they are necessary for creating a bett society in which to live, they might not be sufficient. In fact, it might be that no matter how hard v try, how good the new wave of politicians will be, how resourceful our businesses are, or ho ingenious we can be, we will never escape from this crisis. We do not know if that is the case. But it a possibility, one that we should carefully consider and explore.

Kurt Vonnegut has claimed to have said so much at a private girls school, when he gave commencement address:[19]

Things are going to get unimaginably worse, and they are never, ever, going to get better again.

I know it is not exactly what you wanted to hear. The rising unemployment levels of the pa years could be just the tip of a huge iceberg, and we all could be riding a 21st century econom Titanic. I would like to believe that this is merely unjustified pessimism. But beliefs are heavi influenced by emotions, and the truth does not care what we believe. It just is.

So, how should we approach this conundrum? Will you be the eternal optimist, having faith in th

power of the market to adjust itself every time there is a new challenge? Or will you be th incorrigible pessimist, who believes we are doomed, and there is no hope left? Which side will yo take?

You see, I do not think it is a matter of picking sides. Or beliefs. Or gut feeling. I would like t take an objective position, as much as possible. I believe in good data, and good logic to interpret th data. I think we should cast aside our ideologies, our personal hunches, and we should use our reaso to try and predict the future from an informed perspective. If we want to do that, we are going to hav to explore a few things first. These are not exceedingly difficult ideas. In fact, once explained properly, they are quite simple. But they are also remarkably useful and amazing tools that help u understand the world around us better. Believe it or not, these tools are so basic that they could b easily taught in elementary schools, yet I met many college graduates who failed to apply them at th most fundamental level. Obviously, it is not because these people are not smart enough to understan them, but because they have never been taught to think about the future using these tools.

I will try to explain these ideas to the best of my abilities. If I succeed, you will be able to gras these concepts quite easily, and with them you will see the world from a whole different perspectiv You will have all the necessary tools to approach this challenging task, and make up your own min about which side of the debate you should take. From there, we will take off, think about the futur and see how to live better accordingly.

Let us get started.

Chapter 3
Exponential Growth

One of the most important, yet misunderstood concepts in our lives, is the nature of the exponenti function. You may have heard of this term before. Maybe it was mentioned in some newspaper artic in the technology section, briefly cited and hardly explained at all. Or perhaps under the nam "compound interest" when you took out a loan from your bank. Of course, they usually tend to glo over its real significance, and rarely does someone explain what it really means. Yet, it pervades ever facet of our lives, the economy, and the decisions we must take for the future. Understanding th power of the exponential function is key in proceeding further with the analysis presented in this boo

Albert Bartlett, Professor emeritus of Physics at University of Colorado-Boulder, during a ver famous lecture he gave, stated that “the greatest shortcoming of the human race is our inability understand the exponential function.”[20] This is no light statement. Professor Bartlett has lectured ov 1,600 times since 1969 on Arithmetic, Population, and Energy, trying to warn as many people a possible about the dangers in failing to understand this concept of utmost importance.

Before the end of this chapter, I want you to have a deep understanding of the exponenti function. I want you to grasp the intuition behind it. It does not matter whether you have a degree philosophy, in economics, if you are a college dropout, if you are uneducated, unemployed, if you a a Professor at university, or the CEO of a multinational corporation; chances are you do not ful understand what exponential growth really means. Yet, it is imperative that you do.

I gave many lectures during my life, to all kinds of audiences, and even among the most educate ones, people fell short when confronted with very simple examples of exponential growt Interestingly enough, when properly explained, it became obvious to everyone, even to the layperso This gives me hope, because it is crucial that everybody realises what it means, and what th consequences are of applying steady growth for a number of years.

Enough with my ramblings, are you ready? Good. Let us dig in and see what it is all about.

The exponential function is used to describe the size of anything growing steadily over time. F example, suppose you have to buy a house, and the bank gives you a loan at 7% interest. What means is that every year the amount of money you have to give back grows by 7%. The first year th quantity grows by a tiny amount (107% of the principle), but on the second year it grows relative the last amount, not to the original principle. So, 7% of 107%. The following year it grows even mor and so it goes. Can you guess what will the amount be in 20 years? Not too easy, unless you hav taken statistics in college. It is not my intention to explore the mathematics of the exponenti function (although it is really interesting and I suggest that some of you do). I want you to understa it in very clear and effective terms, so I will give you a simple formula that you can use any tim anywhere, and all you need is first-grade math. If you want to know how long will it take to doub any quantity that grows at a fixed rate, take the number 70 and divide it by the rate of growth[21]. This called the doubling time:

$$\text{Doubling time} = \frac{70}{\text{rate of constant growth}}$$

~~Let us go back to our example. Growth was 7% per year. It did not sound too impressive~~ befor did it? Now, take 70, divide it by 7, it gives us 10. That means that circa every 10 years the amount money we owe to the bank will double.

That looked easy enough, did not it? Well, that is because it is. It is a simple calculation, one th a 10-year old can do without breaking a sweat, and yet most politicians, policy-makers, urba planners, and economists worldwide fail to understand it. To be fair, any economist must have taken statistics course at university, and the rule of 70 (or one of its variations[22]) is widely known amor academics, so they know about it. But while the calculation may be easy to do, the implications doubling over time are far less obvious and very misunderstood.

So far we have seen what it takes to double the principle. Now, let us explore the effect of th doubling over time. Suppose we borrowed $100,000 from the bank at 7% interest. As we have see before, in just 10 years we will owe $200,000, or double the principle. But how about in 20 years? will not be $300,000, but instead $400,000, which is two times the previous amount of $200,0 (which was itself twice the principle). How about in 30 years? You got it, $800,000! Ten more years, is already $1.6 million. A few more years and you will owe more than you could ever make in you entire life. Luckily, most loans do not exceed the 30-year mark. But what would happen for oth things, things that are not mortgage loans, and that may grow far more than 30 years? Buckle yo seatbelt because we are just getting started.

3.1 Explosive Power

The idea of exponential growth is not new at all. In fact, it goes back thousands of years. Legend has that when the creator of the game of chess, some say it was an ancient Indian mathematician[23], showe his invention to the ruler of the country, the king was so pleased that he gave the inventor the right name his prize for the invention. The man, who was very wise, asked the king this: that for the fir square of the chess board, he would receive one grain of wheat, two for the second one, four on th third one, and so forth, doubling the amount each time. The king, who had no idea of the power of th exponential function, quickly accepted the inventor's offer, even getting offended by his perceive notion that the inventor was asking for such a low prize, and ordered the treasurer to count and han over the wheat to the inventor. Few days pass by, the inventor receives only a handful of grains, an the king is somewhat baffled. After a week, the inventor started brining home big bags of wheat. few days after that…you see where this is going, right? We start with 1, the next day we double, so w have 2 grains. The next day is 4 grains. Then 8, 16, 32, 64, 128, 256, 512... in just 10 days, we we from 1 to 1,024 grains. 10 doublings give you a 1,000-fold increase from the original amount. Here where things start to take off. 10 more doublings and you have 1 million grains. 10 more: 1 billio grains. Then 1 trillion... we can stop right there. We already passed the limit of our brain. Table 3.1 a graphical representation to describe the process[24]:

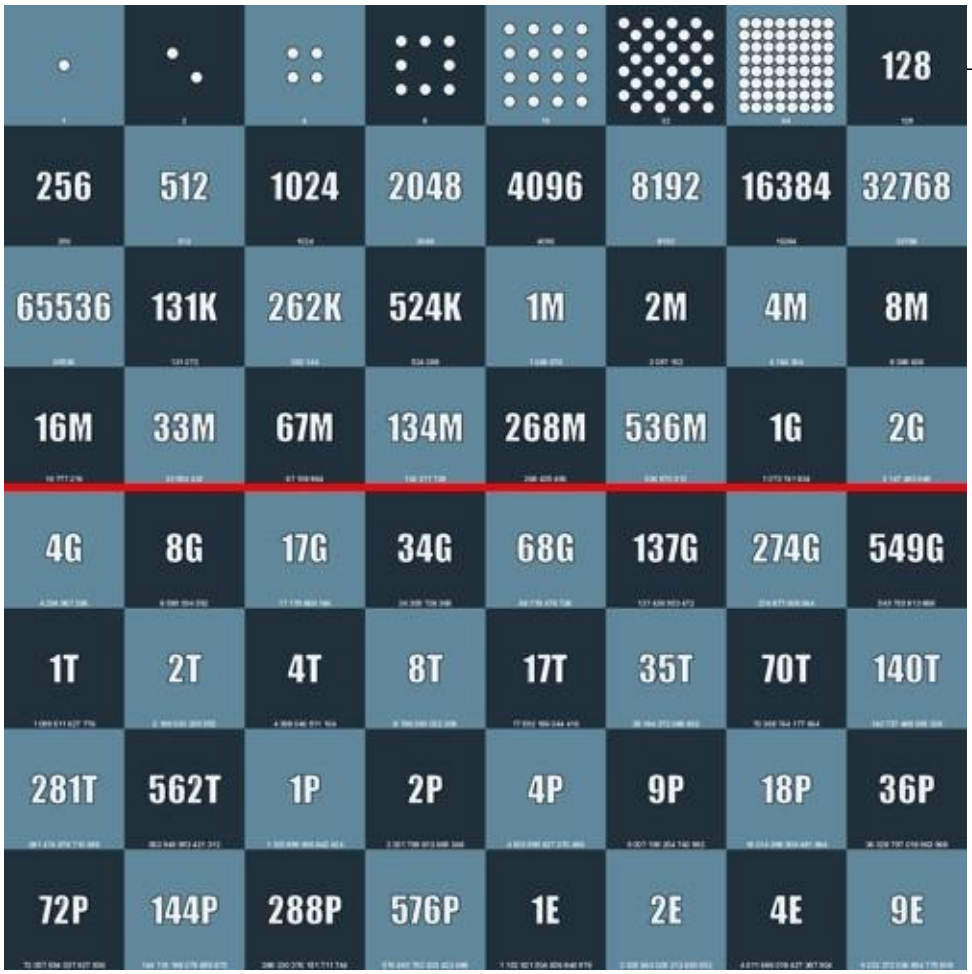

Figure 3.1: Top left, it begins with 1 grain. It goes on to the right with 2, 4, 8, 16... then number grow too big, we start to use the binary notation: K=kilo (1 thousand), M = Mega (1 million), G Giga (1 billion), T = Tera (1 trillion), P = Peta (1 quadrillion), E = Exa (1 quintillion).

On the entire chessboard there would be

$$2^{64} - 1 = 18,446,744,073,709,551,615$$

grains of wheat weighing 461,168,602,000 metric tonnes. That must be a lot of wheat. But just ho much wheat are we talking about? More then the king could afford, I can tell you that. In fact, it wou be a heap of wheat larger than Mount Everest, earth's highest mountain, with a peak at 8,848 metr (29,029 ft) above sea level. This is around 1,000 times the global production of wheat in 20 (464,000,000 metric tonnes). That is a lot of wheat. It might very well be more than the enti production of wheat in the history of humanity, combined.

As impressive and incredible as it may sound, we have to remember that this is not just intriguing fairy tale that we like to tell. It is not merely an intellectual curiosity. It is a story that hel us understand the world around us, and make predictions about how we should go about building o future.

Over the past three years I have given a number of talks, and often I like to play a little gam with the audience, to test their comprehension of an exponential increase. Most people do not get right away, even among the most educated of audiences, so do not feel bad if it does not come to yo on the spot.

Imagine an empty glass of water (technically a glass is made of glass and is full of air, but pleas bear with the limitations of our language). Place some bacteria inside, and let them replicate, b giving them food. The replication process is such that the number of bacteria doubles every minut After 60 minutes, the glass is full, and since there is no more space left for food, the bacteria die. Th question is: what percentage of the glass did the bacteria fill after 55 minutes?

Figure 3.2: On the left, at minute zero, there are no bacteria in the glass. On the right, after a certain amount of doublings, the bacteria filled the whole thing. But what happens at minute 55 (in the centre)?

How much would you say? Take a pencil and use this empty page to scribble, sketch, and c some calculations. The answer is on the next page, but I strongly encourage you to have fun and try out for yourself first.

Scribble, sketch, and have fun!

I hope you did try to solve it yourself, because learning is so much more fulfilling when it interactive. If you did not, too bad for you. ☹

In truth, the bacteria have only filled 3.125% of the glass. But how can this be? Well it is simpl If they double every minute, and they fill the entire glass in 60 minutes, then they will have filled ha the glass the minute before 60 (or 50% after 59 minutes), half of that the minute before 59 (or 25 after 58 minutes), and so on. Table 3.1 summary of the last 10 minutes, starting from the end.

Time Elapsed	Amount Filled	
60 minutes	100	.000%
59 minutes	50	.000%
58 minutes	25	.000%
57 minutes	12.	500%
56 minutes	6.	250%
55 minutes	3.	125%
54 minutes	1.	563%

53 minutes	0.	781%
52 minutes	0.	391%
51 minutes	0.	195%

Table 3.1: Exponential growth of bacteria in a bottle over the last 10 minutes.

It all makes sense now, does not it? Suddenly it becomes clear, even obvious. Who could not g this? It is so simple, right? Apparently, it is not. The most common replies I get are between 50 ar 90%. Even college graduates typically get it wrong. And let us not talk about politicians.

We will come back to this in the Appendix, with some real-world examples. For now, I think it safe to say that we all understand what steady growth means. Let us see now how this applies to o main interest for this chapter: information technology.