The World After Capital

Work in Progress

This book is a work in progress. I have just finished a fairly major revision of the entire text. It now reads more cohesively and contains all the arguments I want to make. References are, however, currently broken (missing links, missing references, etc.) and the Appendix still needs a lot of work.

The process of writing in this way is an example of what I call the “Knowledge Loop” in the book. The Knowledge Loop consists of learning, creating and sharing. My writing is based on what I have learned. By sharing early, others can learn from my ideas and I, in turn, can learn from their feedback.

I know how powerful this approach is from my experience with blogging for over a decade. I have learned a great deal from reader comments. The same has been true here. You can see some of the amazing initial feedback. Thanks to everyone who has taken the time. If you want to send me a comment please email me at albert@worldaftercapital.org.

I am using gitbook to write *The World After Capital* and you can track the changes I am making on github. If you are knowledgable in using github you can also make a pull request as a way of contributing. I retain final “commit rights” for changes and as such take responsibility for any and all errors.

There is also a separate FAQ which I will be updating periodically. If you prefer reading on paper or on an eReader, you can download a copy in PDF.

Preface

As a venture capitalist, I am often asked 'What's the next big thing?' People tend to ask this when they are looking for a trend in technology, expecting me to talk to them about robotics or virtual reality. But I think that's a boring interpretation of the question, as these trends come and go as part of hype cycles that represent the waxing and waning of media interest in a particular technology. Instead I answer, 'Oh, nothing much – just the end of the Industrial Age.' And that momentous change is the subject of this book.

The World After Capital is unabashedly about some truly big subjects. In order to tackle why the Industrial Age is ending and what is going to come next, I will examine such things as the nature of technology and what it means to be human. It might seem a wildly ambitious thesis, but we are facing a transition as profound as that which took humanity from the Agrarian Age to the Industrial Age, so nothing less will do.

The current transition has been made possible by the advent of digital technology, so it is essential that we understand the nature of this technology and how it differs from what preceded it. It is also essential that we examine the philosophical foundations for what we want to accomplish – after all, we have the opportunity to decide what will follow the Industrial Age. In *The World After Capital* I will argue that the next age will be the Knowledge Age, and that in order to get there we must focus on the allocation of attention rather than capital.

Markets fail at allocating attention because prices cannot exist for directing our attention to problems and opportunities crucial for the survival and thriving of humanity. The climate crisis, for instance, is both more severe and more imminent than most people realize, and it is a direct result of our failure to pay attention. How quickly we address this crisis will to a large part determine the shape of the current transition. If we do not make drastic changes quickly, getting to the next age will be even more painful than the transition to the Industrial Age, which started in the eighteenth century, involved numerous violent revolutions and didn't conclude until the end of the Second World War.

The transition from the Industrial Age is already underway and has caused massive disruption and uncertainty. Many people are fearful of change and react by supporting populist politicians who promote the simplistic message that we should return to the past. This is happening all over the world; we saw it with the vote in the 2016 UK referendum to leave the European Union and with the election of Donald Trump as President of the United States in the same year. I started writing *The World After Capital* before both of those events, but they underline the importance of a future-oriented narrative that shows a path forward for humanity. Going back is not a viable option, and never has been. We did not continue foraging for food after the invention of agriculture, and nor did we remain farmers after the invention of industry (farming is still important, of course, but it is carried out by a tiny percentage of the population).

Each of these transitions required us to find new sources of purpose; as we leave the Industrial Age behind, our purpose can no longer be derived from having a job or from an ever-growing consumption of material goods. Instead, we need to find a purpose that will be compatible with the Knowledge Age. I feel incredibly fortunate to have found my purpose in investing in startups, as well as in examining why this transition is happening now and suggesting how we might go about it.

In a strange and wonderful way, much of what I have done in my life so far has brought me to this point. As a teenager in my native Germany in the early 1980s, I fell in love with computers. I started writing software for companies and then studied economics and computer science as an undergraduate at Harvard, writing my senior thesis on the impact of computerized trading on stock prices. After graduating I worked as a consultant and experienced the impact of information systems on the automotive, airline and electric utility industries. As a doctoral student at MIT, I wrote my dissertation on the impact of information technology on the organization of companies. As an entrepreneur, I co-founded an early Internet healthcare company. And as a venture investor, I have had the good fortune to back companies that provide transformative digital technologies and services, including Etsy, MongoDB and Twilio.

You might be wondering why I would choose to write this book as a VC – after all, surely it's a distraction from finding and managing investments in startups? However, working with startups gives me a window into the future; I get to see trends and developments before they become widely understood, and this puts me in a good position to write about what is going to happen. At the same time, writing about the future that I would like to see will help me find companies that can help bring that future about. I am writing *The World After Capital* because what I see compels me to do so, but I am also confident that writing it has made me a better investor.

Introduction

Humanity is the only species on Earth to have developed knowledge. I will make the term 'knowledge' increasingly precise as we go along, but for now will say that we are the only species that is able to read and write books. And this knowledge has enabled us to create increasingly powerful technology. Technological advance has the effect of broadening the 'space of the possible'; for instance, with the invention of the airplane, human flight became a reality.

When the 'space of the possible' is broadened, it brings with it both good and bad capabilities. This duality of technology has been with us from fire, the very first human technology. With the discovery of fire, it became possible to warm ourselves and cook, but also to burn down forests and enemy villages. Today, the Internet broadens free access to learning, but it can also spread hate and lies on a global scale.

And yet there is something special about our time: we are experiencing a technological non-linearity, in which the 'space of the possible' expands dramatically, thus rendering predictions based on extrapolation useless. The current non-linearity arises from the extraordinary power of digital technology, which far exceeds anything that was possible with industrial machinery, due to two unique characteristics. Digital technology delivers 'universality of computation' (it can compute anything) at 'zero marginal cost' (extra copies can be produced for free).

To understand what is happening, we therefore need to zoom out in time. Humanity has previously encountered two similar non-linearities. The first occurred roughly ten thousand years ago with the invention of agriculture, which ended the Forager Age and brought us into the Agrarian Age. The second started with the Enlightenment about four hundred years ago, which helped to usher in the Industrial Age.

Consider foragers one hundred thousand years ago, trying to predict what society would look like after the invention of agriculture. Even something that seems as trivially obvious as living in buildings would be hard to imagine from the viewpoint of migratory tribes. Similarly, much of what we have today – from modern medicine to computer technology – would resemble magic to those living as recently as the mid-twentieth century. It is not simply the existence of smartphones but also the availability and affordability of such technology that would have been hard to foresee.

The World After Capital has two goals. The first is to establish that we are currently experiencing a third period of non-linearity. The key argument is that each time the 'space of the possible' expands dramatically, the defining constraint for humanity shifts, meaning the scarcity that most requires allocation in order to meet humanity's basic needs changes. Specifically, the invention of agriculture shifted scarcity from food to land, and industrialization shifted scarcity from land to capital (which throughout *The World After Capital* refers to physical capital, such as machines and buildings, unless otherwise noted). Digital technology is now shifting scarcity from capital to attention.

Capital is no longer scarce in some parts of the world and it is becoming rapidly less scarce everywhere. We should consider this to be the great success of capitalism. But markets, which were the crucial allocation mechanism for capital, will not solve the scarcity of attention. We are bad at allocating attention, both individually and collectively. For example, how much attention do you pay to your friends and family, or to the existential question of the meaning of your life? And how much attention are we paying as a society to the great challenges and opportunities of our time, such as the climate crisis and space travel? Markets are not able to help us better allocate attention because prices do not, and cannot, exist for many of the issues that we should be paying attention to. Consider paying attention to your purpose in life: there is no independent supply and demand; it is up to you alone to allocate enough attention to this question.

My second goal in writing *The World After Capital* is to propose an approach that will help us overcome the limits of market-based capitalism and facilitate a smooth transition from the Industrial Age (in which capital is scarce) to the Knowledge Age (in which attention is scarce). Getting this right will be critical for humanity, as the two previous transitions were marked by massive turmoil and upheaval. We are already seeing signs of increasing conflict within societies and among belief systems across the world, fueling a rise of populist and nationalist leaders, including Donald Trump in the US.

How should we approach this third transition? What actions should society take now, when the non-linearity we are facing prevents us from being able to make accurate predictions about the future? We need to enact policies that allow for gradual social and economic change; the alternative is that we artificially suppress these changes, only for them explode eventually. In particular, I will argue that we should smooth the transition to the Knowledge Age by expanding three powerful individual freedoms:

- Economic freedom: instituting a universal basic income.

- Informational freedom: improving information access and shifting control of computation away from large corporations.
- Psychological freedom: practicing and encouraging mindfulness.

Increasing these three freedoms will make attention less scarce. Economic freedom will unlock the time that we currently spend in jobs that can and should be automated. Informational freedom will broaden access to information and computation. And psychological freedom enables rationality in a world in which we are overloaded with information. Each of these freedoms is important in its own right, but they are also mutually reinforcing.

One crucial goal in reducing the scarcity of attention is to improve the functioning of the 'knowledge loop', which is the source of all knowledge and consists of learning, creating and sharing. Producing more knowledge is essential to human progress; the history of humanity is littered with failed civilizations that didn't produce enough knowledge to overcome the challenges facing them.

To achieve collective progress through increased individual freedoms, we must establish a set of values that include critical inquiry, democracy and responsibility. These values ensure that the benefits of the knowledge loop accrue broadly to humanity and extend to other species. They are central to a renewed humanism, which in turn has an objective basis in the existence and power of human knowledge. Reasserting humanism is especially critical at a time when we are coming close to creating 'transhumans' through genetic engineering and augmentation, as well as 'neohumans' through artificial intelligence.

The World After Capital argues that increased freedoms combined with strong humanist values are the way that we will transition from the Industrial Age to the Knowledge Age. Though I am profoundly optimistic about the ultimate potential for human progress, I am pessimistic about how we will get there. We seem intent on clinging to the Industrial Age at all cost, which increases the likelihood of violent change. My hope is that in writing this book I can in some small way help to move us forward peacefully.

Digital Technology

Billions of people all over the world carry smartphones with them, powerful computers that are connected to a global network (the Internet). We often spend many hours a day on these devices, whether playing games or carrying out work. And yet, despite the growing ubiquity of digital technology, people often find it difficult to understand what exactly makes it so powerful.

There are even some who have derided digital technology, pointing to services such as Twitter and arguing that they are inconsequential when compared to, say, the invention of vaccines. However, it is becoming increasingly difficult to ignore the disruptiveness of digital technology. For example, while many previously well-established businesses are struggling, including newspapers and retailers, digital technology companies such Facebook, Apple, Amazon, Netflix and Google are now among the world's most highly valued [3].

Digital technology turns out to possess two unique characteristics that explain why it dramatically expands the 'space of the possible' for humanity, going far beyond anything that was previously possible. These are 'zero marginal cost' and the 'universality of computation'.

Zero Marginal Cost

Once a piece of information exists on the Internet, it can be accessed from anywhere on the network for no additional cost. And as more and more people around the world are connected to the Internet, 'anywhere on the network' is increasingly coming to mean 'anywhere in the world'. The servers are already running, as are the network connections and the end-user devices. Making one extra digital copy of the information and delivering it across the network therefore costs nothing. In the language of economics, the 'marginal cost' of a digital copy is zero. That does not mean that people won't try to charge you for this information – in many cases they will. Zero marginal cost is a statement that relates to cost rather than prices.

Zero marginal cost is radically different to anything that has come before it in the analog world, and it makes some pretty amazing things possible. To illustrate this, imagine that you own a pizzeria. You pay rent for your store and your equipment, and you pay salaries for your staff and yourself. These are so-called 'fixed costs', and they don't change with the number of pizzas you bake. 'Variable costs', on the other hand, depend on the number of pizzas you make. For a pizzeria, these will include the cost of the water, flour, any other ingredients you use and the energy you need to heat your oven. If you make more pizzas, your variable costs go up and if you make fewer they go down.

So what is marginal cost? Well, let's say you are making one hundred pizzas every day; the marginal cost is the additional cost of making one more pizza. Assuming the oven is already hot and has space in it, it is the cost of the ingredients, which is likely relatively low. If the oven had already cooled, then the marginal cost of the additional pizza would include the energy cost required for reheating the oven and might be quite high.

From a business perspective, you would want to make that additional pizza as long as you could sell it for more than its marginal cost. If you had already covered your fixed costs from the previous pizzas, every cent above marginal cost for the additional pizza would be profit. Marginal cost also matters from a social perspective. As long as a customer is willing to pay more than the marginal cost for that pizza, everyone benefits – you get extra contribution towards your fixed cost or profit, and your customer gets to eat a pizza they wanted.

Let's consider what happens as marginal cost falls from a high level. Imagine that your key ingredient was an exceedingly expensive truffle which meant that the marginal cost of each of your pizzas is $1,000. You clearly wouldn't sell many pizzas, so you might decide to switch to cheaper ingredients and reduce your marginal cost to a point where a larger number of customers are willing to pay more than your marginal cost, so your sales increase. And as you bring down the marginal cost further through additional process and product improvements, you would start to sell even more pizzas.

Now imagine that through a magical new invention you could make additional pizzas at close to zero marginal cost (say one cent per additional pizza) and ship them instantaneously to anywhere in the world. You would then be able to sell an exceedingly large number of pizzas. If you charged just two cents per pizza, you would be making one cent of profit for every additional pizza you sold. At such low marginal cost you would probably have a monopoly on the global pizza market (more on that subject later). Anyone in the world who was hungry and could afford at least one cent would want one of your pizzas. The best price of your pizza from a societal point of view would be one cent (your marginal cost) – the hungry would be fed and you would cover your marginal cost.

This is exactly where we currently are with digital technology. We can feed the world with information, and that additional YouTube video view, additional access to Wikipedia or an additional traffic report from Waze has a marginal cost of zero. We should expect certain digital operations to become huge and to span the globe in near-monopolies, which is what we are seeing with companies such as Google and Facebook. But – and this is critical to the idea of the Knowledge Age – it also means that from a social perspective, the price of marginal usage should be zero.

Why prevent someone from accessing YouTube, Wikipedia or Waze, either by not allowing them access to the system or by charging a price they can't afford? If the marginal cost is zero, any given individual might receive a benefit greater than the marginal cost. Best of all, they might use what they learn to create something that may in turn deliver extraordinary enjoyment or a scientific breakthrough to the world.

We are not used to zero marginal cost; most of economics assumes non-zero marginal cost. You can think of zero marginal cost as an economic singularity similar to dividing by zero in math – as you approach it, strange things begin to happen. We are already observing digital near-monopolies and power-law distributions of income and wealth, where small variations result in hugely different outcomes. Furthermore, we are now rapidly approaching this zero marginal cost singularity in many other industries, including finance and education. The first characteristic of digital technology is that it expands the space of the possible. This can result in digital monopolies but also has the potential to grant all of humanity access to the world's knowledge.

Universality of Computation

Zero marginal cost is only one property of digital technology that dramatically expands the space of the possible; the second is in some ways even more amazing.

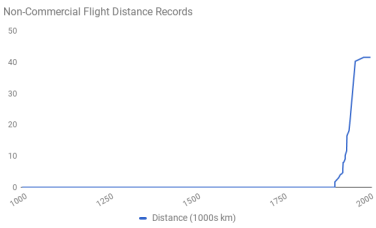
Computers are universal machines. I use this term in a rather precise sense; anything that can be computed in the universe can be computed by the kind of machine that we already have, given enough memory and time. We have known this since Alan Turing's groundbreaking work on computation. He invented an abstract computer that we now call a Turing machine [4], before coming up with a proof to show that this simple machine could compute anything [5].

By 'computation', I mean any process that takes information inputs, executes a series of processing steps and produces information outputs. That is – for better or worse – what a human brain does; it receives inputs via nerves, carries out some internal processing and produces outputs. In principle, a digital machine can do everything that a human brain does.

The 'in principle' limitation will turn out to be significant only if quantum effects matter for the functioning of the brain, meaning effects that require quantum phenomena such as entanglement. This is a hotly debated topic [172]. Quantum effects do not change what can be computed per se because even a Turing machine can theoretically simulate a quantum effect, but it would take an impractically long time – potentially millions of years – to do so [6]. If quantum effects are important in the brain, we may need further progress in quantum computing to replicate some of the brain's capabilities. However, I believe that quantum effects are unlikely to matter for the bulk of computations carried out by the human brain – that is, if they matter at all. We may, of course, one day discover something new about physical reality that will change our view of what is computable, but this so far hasn't happened.

For a long time, this universality property didn't matter much because computers were pretty dumb compared to humans. This was frustrating to computer scientists who had since Turing believed that it should be possible to build an intelligent machine, but for the longest time couldn't get it to work. Even something that humans find really simple, such as recognizing faces, had computers stumped. We now, however, have computers that can recognize faces, and their performance at doing so is improving rapidly.

An analogy here is the human discovery of heavier-than-air flight. We knew for a long time that it must be possible – after all, birds are heavier than air and they can fly – but it took until 1903, when the Wright brothers built the first successful airplane, for us to figure out how to do it [7]. Once they and several other people had figured it out, progress was rapid – we went from not knowing how to fly to crossing the Atlantic in passenger jet planes in fifty-five years (the British Overseas Airways Corporation's first transatlantic jet passenger flight was in 1958 [8]). If you plot this on a graph, you see a perfect example of a non-linearity. We didn't get gradually better at flying – we couldn't do it at all and then we could suddenly do it very well.



Digital technology is similar; a series of breakthroughs have taken us from having essentially no machine intelligence to a situation where machines can outperform humans on many different tasks, including reading handwriting and recognizing faces [9]. The rate of machines' progress in learning how to drive cars is another great example of the non-linearity of improvement. The Defense Advanced Research Projects Agency (DARPA) held its first so-called 'Grand Challenge' for self-driving cars in 2004. At the time they picked a 150-mile-long closed course in the Mojave Desert, and no car got further than seven miles (less than 5 per cent of the course) before getting stuck. By 2012, less than a decade later, Google's self-driving cars had driven over 300,000 miles on public roads, with traffic [11].

Some people may object that reading handwriting, recognizing faces or driving a car is not what we mean by 'intelligence', but this just points out that we don't have a good definition of it. After all, if you had a pet dog that could perform any of these tasks, let alone all three, you would call it an 'intelligent' dog.

Other people point out that humans also have creativity and that these machines won't be creative even if we grant them some form of intelligence. However, this amounts to arguing that creativity is something other than computation. The word implies 'something from nothing' and outputs without inputs, but that is not the nature of human creativity. After all, musicians create new music after hearing lots of music, engineers create new machines after seeing existing ones, and so on. There is now evidence that at least some types of creativity can be recreated simply through computation.

Google recently achieved a breakthrough in machine intelligence when their AlphaGo program beat the South Korean Go grandmaster Lee Sedol by four games to one [12]. Until that point, progress with game-playing software had been comparatively slow and the best programs were unable to beat strong club players, let alone grandmasters. The number of possible plays in Go is extremely large, far exceeding chess. This means that searching through possible moves and counter-moves from a current position, which is the approach historically used by chess computers, cannot be used in Go – instead, candidate moves need to be conjectured. Put differently, playing Go involves creativity.

The approach used for the AlphaGo program started out by training a neural network on games previously played by humans. Once the network was good enough, it was improved further by playing against itself. There has already been progress in the application of these and related techniques, which are often referred to as 'generative adversarial networks' (GANs) to the composition of music and the creation of designs. Even more surprisingly, it has been shown that machines can learn to be creative not just by studying prior human games or designs, but by creating their own, based on rules. A newer version of AlphaGo called AlphaZero starts out knowing the rules of a game and learns from playing games against itself [171]. This approach will allow machines to be creative in areas where there is limited or no prior human progress.

Universality at Zero Marginal Cost

As impressive as zero marginal cost and universality each are on their own, in combination they are truly magical. To take one example, we are making good progress in the development of a computer program that will be able to diagnose disease from a patient's symptoms in a series of steps, including ordering tests and interpreting their results [10]. Though we might have expected this based on the principle of universality, we are making tangible progress and should accomplish this in a matter of decades, if not sooner. Once we can do it, we will thanks to zero marginal cost be able to provide low-cost diagnosis to anyone in the world. We should let that sink in slowly in order to grasp its significance: free medical diagnosis for all humans will soon be in the 'space of the possible'.

The universality of computation at zero marginal cost is unlike anything we have had with prior technologies. Being able to make all the world's information and knowledge accessible to all of humanity was never before possible, and nor were intelligent machines. Now we have both. This represents as dramatic and non-linear an increase the 'space of the possible' for humanity as agriculture and industry did before, and each of those developments ushered in an entirely different age. We will be able to think better about what this implies for the current transition and the next age if we first put some foundations in place.

Part One: Laying a Foundation

In an early draft of this book, I discussed the impact of digital technology without first including any philosophical explanation for the situation we find ourselves in. The result was the literary equivalent of building a skyscraper without laying solid foundations: rapid progress followed by total collapse.

With digital technology so fundamentally expanding what we are able to do, we must establish some basic principles if we are to avoid misinterpreting current trends and phenomena. These principles will allow us to truly explore this new 'space of the possible' and the benefits that it might bring, instead of limiting and bending the technology to fit our existing economic and social systems.

What follows is an attempt to establish a firm foundation for how we might build a future, and one that is grounded in a clear set of values. I start with a brief definition of knowledge, a term I use extensively and in a way that is somewhat different from common usage. I will then explain the relationship between optimism and knowledge, as well as the importance of choices in shaping our future. This is followed by a discussion of why the existence of knowledge provides an objective basis for humanism, which sets it apart from other religious and philosophical narratives. Much of my thinking in this area has been influenced by the writing of David Deutsch, and in particular his book The Beginning of Infinity [13], which explores the history, philosophy and power of explanations.

I will then provide a definition of scarcity that is grounded in human needs rather than based on money and prices, using this definition to show how technology has shifted scarcity throughout history, leading to dramatic change in how we live. From there, the rest of the book lays out a plan of attack.

Knowledge

Knowledge, as I use the term, is the information that humanity has recorded in a medium and improved over time. There are two crucial parts to this definition. The first is ‘recorded in a medium’, which allows information to be shared across time and space. The second is ‘improved over time’, which separates knowledge from mere information.

A conversation that I had years ago but didn’t record cannot be knowledge – it isn’t accessible to anyone who wasn’t there when it happened, and even my own recollection of it will fade. However, if I write down an insight from that conversation and publish it on my blog, I have potentially contributed to human knowledge. The blog post is available to others across space and time, and some blog posts will turn out to be important contributions to human knowledge. As another example, the DNA in our cells isn’t knowledge by my definition, whereas a recorded genome sequence can be maintained, shared and analyzed. Gene sequences that turn out to be medically significant, such as the BRCA mutation that increases the risk of breast cancer, become part of human knowledge.

My definition of knowledge is intentionally broad and includes not just technical and scientific knowledge but art, music and literature. But it excludes anything that is either ephemeral or not subject to improvement. Modern computers produce tons of recorded information that are not subsequently analyzed. The reasons for this definition of knowledge will become clear as I use the term in the following sections and throughout the book.

Optimism

When I started my blog over a decade ago, I called myself a 'technology optimist'. I wrote:

> I am excited to be living [at] a time when we are making tremendous progress on understanding aging, fighting cancer, developing clean technologies and so much more. This is not to say that I automatically assume that technology by itself will solve all our problems […]. Instead, I believe that – over time – we as a society figure out how to use technology to […] improve our standard of living. I for one am […] glad I am not living in the Middle Ages.

This book is fundamentally optimistic, which is partly a reflection of my personality. I can't see how it would be possible to be a venture capitalist as a pessimist. You would find yourself focusing on the reasons why a particular startup would be unlikely to succeed and as a result would never make an investment.

I want to be clear about this apparent bias from the start. Optimism, however, is much more than a personal bias; it is essential for human knowledge. Acts of knowledge creation, such inventing a new technology or writing a new song, are profoundly optimistic. They assume that problems can be solved, that art will impact the audience (which is true even for a pessimistic song). Optimism is the attitude that progress is possible.

Progress has become a loaded term. After all, despite our technological achievements, aren't humans also responsible for the many diseases of civilization, for the extinction of countless species and potentially for our own demise through climate change? Without a doubt we have caused tremendous suffering throughout human history, and we are currently faced with huge problems including a global pandemic and the ongoing climate crisis. But what is the alternative to trying to tackle these?

The beauty of problems is that knowledge can help us overcome them. Consider the problem of warming ourselves in the cold. Humans invented ways of making fire, eventually documented them and have since dramatically improved the ways in which we can produce heat. We may take the existence of knowledge for granted, but no other species has it, which means whether they can solve a problem depends largely on luck and circumstance. So not only is optimism essential for knowledge, but the existence of knowledge is the basis for optimism.

There is an extreme position that suggests that we would have been better off if we had never developed knowledge [14. While this may sound absurd, much of religious eschatology (theology about the 'end times') and apocalyptic thinking is the counterpart to this position, asserting that a grand reckoning is inevitable. And while they are rare, there have been voices welcoming the COVID19 pandemic and the climate crisis as harbingers if not of apocalypse then at least of a great 'reset'. Though there is no guarantee that all future problems will be solvable through knowledge, one thing is certain: assuming that problems cannot be solved guarantees that they will not be. Pessimism is self-defeating, and apocalyptic beliefs can be self-fulfilling.

All of this is also true for digital technology, which has already brought with it a new set of problems. We will encounter many of them in this book, including the huge incentives for companies such as Facebook to capture as much attention as possible and the conflicts that arise from exposure to content that runs counter to one's cultural or religious beliefs. And yet digital technology also enables amazing progress, such as the potential for the diagnosis of disease at zero marginal cost. *The World After Capital* is optimistic that we can solve not only the problems of digital technology, but also that we can apply digital technology in a way that results in broad progress, including the knowledge creation needed to address the climate crisis.

Choices

Believing in the potential of progress does not mean being a Pollyanna, and it is important to remember that progress is not the inevitable result of technology. Contrary to the claims made by the technology writer Kevin Kelly in his book What Technology Wants, technology doesn't want a better world for humanity; it simply makes such a world possible.

Nor does economics 'want' anything; nothing in economic theory, for instance, says that a new technology cannot make people worse off. Economics gives us tools that we can use to analyze markets and design regulations to address their failures, but we still need to make choices relating to what we want markets and regulations to accomplish.

And contrary to what Karl Marx thought, history doesn't 'want' anything. There isn't a deterministic mechanism by which conflicts between labor and capital get resolved in favor of a classless society. Nor is there, as the political economist Francis Fukuyama would have it, an 'end of history', a final social, economic and political system. History it doesn't make its own choices; it is the result of human choices, and there will be new choices to make as long as we continue to make technological progress.

It always has been our responsibility to make choices about which of the worlds made possible by new technology we want to live in. Some of these choices need to be made collectively (in the form of regulation) and some of them need to be made individually (requiring self-regulation). And the choices we are faced with today are especially important because digital technology so dramatically increases the 'space of the possible' that it includes the potential for machines that possess knowledge and will eventually want to make their own choices.

Regulation

The people building or funding digital technology tend to be optimists and believe in progress (though there are a few opportunists thrown into the mix). Many of those optimists also believe in the need for regulation, while another group has a decidedly libertarian streak and would prefer governments not to be involved. For them, regulation stands against progress. The debates between these two groups are often acrimonious, which is unfortunate because the history of technology clearly demonstrates both the benefits of good and the dangers of bad regulation. So our energy is better spent on figuring out the right kind of regulation, as well as engaging in the processes required for enforcing and revising it.

The history of regulating automotive technology is instructive here. Much of the world currently gets around by driving cars. The car was an important technological innovation because it vastly enhanced individual mobility, but its widespread adoption would have been impossible without regulation. We needed to build roads and to agree on how they should be used, neither of which could have been accomplished based solely on individual choices. Roads are an example of natural monopolies: multiple disjointed road networks or different sets of rules would be hugely problematic – imagine what would happen if some people drove on the left side of the road and others drove on the right. Natural monopolies are examples of market failure that require regulation, and social norms are another form of regulation. The car would have been less widely adopted as a mode of individual transport without changes in social norms that made it acceptable for women to drive, for instance.

Not all regulation is good, of course; in fact, the earliest regulation of automotive vehicles was aimed at delaying their adoption by limiting their speed. In some cases they were required to be preceded by someone carrying a flag [16]. Similarly, not all regulation of digital technology will be beneficial. Much of it will initially aim to protect the status quo and to help established enterprises, including the new incumbents; the recent changes to net neutrality rules are a good example of this [17].

My proposals for regulation, which I will present later in the book, are aimed at encouraging innovation by giving individuals more economic freedom and better access to information. These regulations, which are choices we need to make collectively, represent a big departure from the status quo and from the programs of the established parties here in the United States and in most other countries. They aim to let us explore the space of the possible that digital technologies have created, so we can transition from the Industrial Age to the Knowledge Age.

Self-Regulation

Another set of choices has to do with how we react individually to the massive acceleration of information dissemination and knowledge creation that digital technology makes possible. These are not rules that society can impose because they relate to our inner mental states – they are changes we need to make for ourselves. For instance, there are a lot of people who feel offended by the content that they encounter on the Internet, from videos on YouTube to comments on Twitter. Other people become trapped in 'filter bubbles' that disseminate algorithmically curated information that only confirms their existing biases, while others spend all their time refreshing their Instagram or Facebook feeds. Even though some regulation can help, as well as more technology, overcoming these problems requires us to change how we react to information.

Changing our reactions is possible through self-regulation, by which I mean training that enhances our capacity to use our rationality. From Stoicism in ancient Greece to Eastern religions such as Hinduism and Buddhism, humans have a long tradition of practices designed to manage our immediate emotional responses. These mindfulness practices align with what we have learned more recently about the workings of the human brain. If we want to be able to take full advantage of digital technology, we need to figure out how to maintain our abilities of critical thinking and creativity.

What I have said so far about optimism and choices could be attacked as the privileged perspective of a white, male American venture capitalist. I might be deemed to be imposing my view on others. However, the next section will argue that an objective foundation for this perspective applies to all of humanity.

Humanism

What are the values that I am basing all this on, and where do they come from? In his book *Sapiens*, the historian Yuval Noah Harari claims that all value systems are based on equally valid narratives. He denies that there is an objective basis for humanism to support a privileged position for humanity as a species [18], but I will try to convince you that he is wrong. For not only is the power of knowledge a source of optimism; its very existence provides the basis for humanism. By humanism I mean a system of values that center on human agency and responsibility rather than on the divine or the supernatural, and that embraces the process of critical inquiry as the central enabler of progress.

Knowledge, as I have already defined it, is the externalized information that allows humans to share insights with each other. It includes both scientific and artistic knowledge. And we are the only species on Earth that generates this kind of knowledge, with the ability to share it over space and time. I am able to read a book today that someone else wrote a long time ago and in a completely different part of the world.

This matters a great deal because knowledge enables fundamentally different modes of problem solving and progress. Humans can combine knowledge created by other humans, allowing small changes to accrete into large bodies of work over time, which in turn provide the basis for scientific and artistic breakthroughs. Without knowledge, other species have only two methods of sharing things they have learned: communication and evolution. Communication is local and ephemeral, and evolution is extremely slow. As a result, animals and plants routinely encounter problems that they cannot solve resulting in disease, death and even extinction. Many of these problems today are caused by humans, but more on that shortly.

Knowledge has given humanity great power. We can fly in the sky, we can sail the seas, travel fast on land, build large and durable structures, and so on. The power of our knowledge is reshaping the Earth. It often does so in ways that solve one set of problems while creating an entirely new set, not just for humans but for other species. This is why it is crucial that we remember what we have learned from Spiderman: 'With great power comes great responsibility.' It is because of knowledge that humans are responsible for looking after dolphins rather than the other way round.

Progress and knowledge are inherently linked through critical inquiry; we are only able to make progress if we are capable of identifying some ideas as better than others. Critical inquiry is by no means linear, as new ideas are not always better than old ones. Sometimes we go off in wrong directions, but given enough time, a sorting takes place. For instance, we no longer believe in the geocentric view of our solar system, and only a tiny fraction of the art that has ever been created is still considered important. While this process may take decades or even centuries, it is blindingly fast compared to evolution.

My use of 'better' implies the existence of universal values. All of these flow from the recognition of the power of human knowledge and the responsibility which directly attaches to that power. And the central value is the process of critical inquiry itself. We must be vigilant in pointing out flaws in existing knowledge and proposing alternatives. After all, imagine how limited our music would be if we had banned all new compositions after Beethoven.

We should consequently seek regulation and self-regulation that supports critical inquiry. In business it often takes the form of market competition, which is why regulation that supports competitive markets is so important. Individually, critical inquiry requires us to be open to receiving feedback in the face of our deeply rooted confirmation bias. In politics and government, critical inquiry is enabled by the democratic process.

Freedom of speech is not a value in and of itself; rather, it is a crucial enabler of critical inquiry. But we can see how some limits on free speech might flow from the same value. If you can use speech to call for violence against individuals or minority groups, you can also use it to suppress critical inquiry.

Digital technology, including a global information network and the general-purpose computing that is bringing machine intelligence, are dramatically accelerating the rate at which humanity can accumulate and share knowledge. However, these same technologies also allow targeted manipulation and propaganda on a global scale, as well as constant distraction. In other words, digital technology massively increases the importance of critical inquiry, which is central to knowledge-based humanism.

Beyond critical inquiry, optimism and responsibility, other humanist values are also rooted in the existence of knowledge. One of these is solidarity. There are more than seven billion humans living on Earth, which exists in an otherwise inhospitable solar system. We need to support each other, irrespective of such differences as gender, race or nationality. The big problems that humanity faces, such as

infectious diseases and the climate crisis, require our combined effort and will impact all of us. Whatever our superficial differences may be, we are much more like each other – because of knowledge – than we are to any other species.

Once we have established solidarity, we can celebrate diversity as another humanist value. In current political debates we often pit individuality against the collective as if it is a dichotomy. However, no human exists by themselves – we are all part of societies and of humanity at large. By recognizing the importance of our common humanity, we create the basis on which we can unfold as individuals. Solidarity allows us to celebrate rather than fear the diversity of the human species.

Scarcity

Attention has replaced capital as humanity's defining constraint, in the third major shift in scarcity in our history. The first shift was from food to land at the start of the Agrarian Age, and the second was from land to capital at the start of the Industrial Age.

The word 'scarcity' has come to take on a meaning that is derived from economic theory. Many people now think of something as being scarce if its price is greater than zero. By this definition, land is still scarce – it costs a lot of money to buy a piece of land. And financial capital is still scarce because even with our current low interest rates, there is a price for borrowing money or raising equity.

However, there is a fundamental problem with this price-based definition of scarcity: anything can be made scarce by assigning ownership of it. Imagine for a moment that the world's atmosphere belonged to Global Air Ltd, and that company could charge anyone who breathes air a fee. Air would suddenly have become scarce, according to the price-based theory of scarcity. That might seem like an extreme example, yet some people have argued that assigning ownership to the atmosphere would solve the problem of air pollution, on the grounds that it would result in the air's owners having an economic incentive to maintain an unpolluted atmosphere.

I will now use a different meaning of scarcity, and one that is not based on price. Something is scarce when there is less of it than we need to meet our needs. If people are starving, food is scarce. One can think of this as technological (as opposed to economic) scarcity. The point here is that technological progress makes things less scarce. The eighteenth-century scholar Thomas Malthus was correct when he predicted that global population growth could be exponential [20]. His prediction that such growth would outpace growth in the food supply, resulting in ongoing shortages and mass starvation, turned out to be wrong because technological progress resulted in exponential increases in food production. In fact, recent advances in agricultural techniques have meant that the amount of land needed for food production is now declining, even as food production is continuing to grow rapidly.

But is it possible to make a distinction between needs and wants? If people are not starving but want more or different food, can food still be scarce? Modern economics equates the two, but we intuitively know that this is not the case. We need to drink water, but want to drink champagne. We need to provide our body with calories, but want to eat caviar. These examples are obviously extremes, but the point is that many different foods can be used to meet the need for calories. Desiring a particular food is a want, while getting enough calories is the need.

If something is no longer scarce, it isn't necessarily abundant – there is an intermediate stage, which I will call 'sufficiency'. For instance, there is sufficient land on the planet to meet everyone's needs, but building housing and growing food still requires significant physical resources and hence these things are not abundant. I can foresee a time when technological progress makes land and food abundant – imagine how much space we would have if we could figure out how to live on other planets. Digital information is already on a clear path to abundance – we can make copies of it and distribute them at zero marginal cost, thus meeting the information needs of everyone connected to the Internet.

With this needs-based definition of scarcity in place, we can now examine how technology has over time shifted scarcity for humanity.

History

I will now provide a highly abstract account of human history that focuses on how technology has shifted scarcity over time and how those shifts have brought dramatic changes in human societies.

Homo sapiens emerged roughly two hundred fifty thousand years ago. And for most of the time since then humans were foragers (also referred to as hunter-gatherers). During the Forager Age, the defining scarcity was food. Tribes either found enough food in their territory, migrated further or starved.

Then, roughly ten thousand years ago, humanity came up with a series of technologies such as the planting of seeds, irrigation and the domestication of animals that together we recognize today as agriculture. These technologies shifted the scarcity from food to land in what became the Agrarian Age. A society that had enough arable land (on which food can be grown), could meet its needs and flourish. It could, in fact, create a food surplus that allowed for the existence of groups such as artists and soldiers that were not directly involved in food production.

More recently, beginning about four hundred years ago with the Enlightenment, humanity invented a new series of technologies, including steam power, chemistry, machinery, mining and eventually electricity. Collectively we today refer to these as the Industrial Revolution and the age that followed as the Industrial Age. Once again, the scarcity shifted, this time away from food and towards capital, such as buildings, machinery and roads. Capital was scarce because we couldn't meet the needs of a growing human population, including the need for calories, without building agricultural machines, producing fertilizer and constructing housing.

In each of those two prior transitions, humanity radically changed how we live. In the transition from the Forager Age to the Agrarian Age we went from being nomadic to sedentary, from flat tribal societies to extremely hierarchical feudal societies, from promiscuity to monogamy and from animistic religions to theistic ones. In the transition from the Agrarian Age to the Industrial Age we went from living in the country to living in the city, from large extended families to nuclear families or no family at all, from commons to private property (including private intellectual property) and from great-chain-of-being theologies to the Protestant work ethic.

What accounts for these changes? In each transition the nature of the scarcity changed in a way that made measurement more difficult, which required more sophisticated ways of providing incentives.

In the Forager Age, when the scarcity was food, the measurement problem was almost trivial: everyone in a tribe sees how much food the hunters and gatherers bring back, and it is either enough to feed everyone or not. In so-called 'immediate return societies' (which had no storage) that is literally all there is to it. With storage the story gets slightly more complicated, but not by much. I believe that this explains many of the features of successful foraging tribal societies, including the flat hierarchy and the equality of sharing.

In the Agrarian Age, when the scarcity was land, the measurement problem got significantly harder: you can really only tell at harvest time (once per year in many regions of the world) how well-off a society will be. Again, I believe that this explains many of the features of successful agrarian societies, in particular the need for a lot of structure and strict rules. It is crucial to keep in mind that these societies were essentially pre-scientific, so they had to find what works by trial and error. When they found a rule that seemed to work, they wanted to stick with it and codify it (much of this happened via the theistic religions).

In the Industrial Age, when the scarcity was capital, the measurement problem became even harder. How do you decide where a factory should be built and what it should produce? It might take years of process and product innovation to put physical capital together that is truly productive. I believe that this explains much of the success of the market-based model, especially when contrasted with planned economies. Effectively, the solution to the incentive problem moved from static rules to a dynamic process that allows for many experiments to take place and only a few of them to succeed.

These changes in how humanity lives were responses to an increasingly difficult measurement problem, as technological progress shifted scarcity from food to land and then from land to capital. But the transitions don't occur deterministically; rather they are the result of human choice driving changes in regulation. For example, when it came to the scarcity of capital, humanity tried out radically different approaches between market-based and planned economies; as it turned out, competitive markets, combined with entrepreneurialism, were better at allocating and accumulating capital. Similarly, the Agrarian Age contained vastly different societies such as the Athenian Democracy, which was hugely advanced compared to much of society in the Middle Ages.

The other important point to note about the previous transitions is that they took quite some time and were incredibly violent. Agriculture emerged over the span of thousands of years, during which time agrarian societies slowly expanded, either subduing or killing foraging

tribes. The transition from the Agrarian Age to the Industrial Age played out over several hundred years and involved many bloody revolutions and ultimately two world wars. At the end of the Agrarian Age, the ruling elites had gained their power from controlling land and still believed it to be the critical scarcity; for them, industry was a means of building and equipping increasingly powerful armies with tanks and battleships. Even the Second World War was about land, as Hitler pursued 'Lebensraum' (literally 'room to live') for his Third Reich. It was only after the Second World War that we finally left the Agrarian Age behind for good.

We now, once again, find ourselves in a transition period, because digital technology is shifting the scarcity from capital to attention. What should be clear by now is that this transition will also require dramatic changes in how humanity lives, just as the two prior transitions did. It is also likely that the transition will play itself out over several generations, instead of being accomplished quickly.

Finally, there is historic similarity to the transition out of the Agrarian Age that explains why many governments have been focused on incremental changes. To understand, we should first note that capital today is frequently thought of as monetary wealth or financial capital, even though it is productive capital (machines, buildings and infrastructure) that really matters. Financial capital allows for the formation of physical capital, but it does not directly add to the production of goods and services. Companies only require financial capital because they have to pay for machines, supplies and labor before they receive payment for the product or service they provide.

Just as the ruling elites at the end of the Agrarian Age came from land, the ruling elites today come from capital. They often don't take up political roles themselves but rather have ways of influencing policy indirectly, exposing them to less personal risk. A good recent example is the role of the billionaire hedge fund manager Robert Mercer and his family in supporting groups that influenced the outcome of the US Presidential election in 2016, such as the right-wing news organization Breitbart [23].

Plan of Attack

My first major claim is that capital is no longer scarce, at least in the technological sense – we have sufficient productive capital to meet our needs through growing food, constructing buildings, producing clothes, and so on. To establish this, I will start by setting out a catalog of individual and collective needs. I will then examine current population trends to see what we can learn about the future growth in these needs, followed by an evaluation of our available capital to show that it is sufficient to meet those needs. That entire section of *The World After Capital* shows that physical capital is sufficient in aggregate. It does not address questions of wealth distribution which, will be discussed later.

My second claim is that attention is now scarce, meaning that our present allocation of attention is resulting in humanity's needs not being met. To establish this I will start by pinning down more precisely what attention is and presenting several examples of human needs that either are already no longer met, such as the need for meaning, or are at risk of not being met in the future, such as calories due to the climate crisis – all due to a lack of attention. After that I will consider how much human attention is currently caught up in Industrial Age activities and how more attention is being trapped through the dominant uses of digital technology, such as advertising-based social networks. I will also discuss why market-based capitalism cannot be used for the allocation of attention.

I will then make concrete suggestions for how to facilitate the transition to the next age, which I call the Knowledge Age. In keeping with the ideas about knowledge and humanism I presented earlier, my suggestions focus on increasing freedoms as the basis for more available attention and improved allocation of that attention.

Part Two: Capital Is Sufficient

To show that capital is sufficient, I must establish that there is enough of it to meet our needs. The only way to do that is by examining what those needs are and separating them clearly from our unlimited wants. We must then consider population trends, so we can see how many humans are likely to have those needs in the future. Only then can we attempt to see if our existing capital is sufficient to meet the needs.

Needs

The definition of scarcity introduced in Part One is based on the idea of needs, so to argue that we are currently experiencing a shift to attention being the new scarcity requires us to demonstrate that we have sufficient capital for them. But agreeing on what constitutes human needs is not a simple task. What follows should be seen as a step along the way. A list of needs is the type of externalized human knowledge that can be improved over time through the process of critical inquiry.

In an early draft of *The World After Capital*, I grouped needs into categories such as 'biological', 'physical' and 'social', but the boundaries between them seemed rather arbitrary. So instead I am distinguishing between individual and collective needs, where the former apply to a single person and the latter are the needs of humanity. Another challenge in putting together such a list is that it is easy to confuse a need with a strategy for meeting it. For instance, eating meat is a strategy for addressing our need for calories, but humans can, of course, acquire calories from many sources.

Individual Needs

These are the basic needs of the human body and mind, without which individual survival is impossible. A single individual has these needs even when they are completely isolated, such as if they are traveling alone in a spaceship. The first set of individual needs relates to keeping our bodies powered. These include:

Oxygen. On average, humans need about 550 liters of oxygen every day [24], depending on the size of our body and physical exertion. Our most common solution to this need is breathing air. Although that may sound obvious, we have developed other solutions through technology – for example, the blood of patients struggling to breathe can be oxygenated externally.

Water. We need to ingest between two to three liters of water per day to stay hydrated [25], depending on factors such as body size, exertion and temperature. In addition to drinking water we have other solutions for this, such as the water contained in foods that we eat.

Calories. To power our bodies, we require between 1,500 and 3,000 calories per day [26], a need we solve by consuming food. The best way to obtain calories, however, is surprisingly poorly understood – the mix between proteins, lipids and carbohydrates is subject to debate.

Nutrients. The body cannot synthesize all the materials it requires, including certain amino acids, vitamins and minerals – these must be obtained as part of our nutrition. This is another area that is surprisingly poorly understood, meaning that the mix of nutrients we need to acquire seems unsettled.

Discharge. We also need to get things out of our bodies by expelling processed food, radiating heat and exhaling carbon dioxide. Humans have made a great deal of progress around solving our needs around discharge, such as public sanitation.

The second set of individual needs relates to the operating environment for humans. From a cosmic perspective, humans have an incredibly narrow operating range. Even here on Earth we can live without technological assistance only in relatively few places. Here are some of our basic operating needs:

Temperature. Our bodies can self-regulate their temperature, but only within a limited range of environmental temperature and humidity. Humans can easily freeze to death or die of overheating (we cool our bodies through sweating, also known as 'evaporative cooling', which stops working when the air gets too hot and humid). We therefore often need to help our bodies with temperature regulation by controlling our environment. Common strategies to meet our temperature needs include clothing, shelter, heating and air conditioning.

Pressure. Anybody who has gone diving will be aware that our bodies do not handle increased pressure very well. The same goes for decreased pressure, which is one of the reasons why we find air travel exhausting (airplane cabins maintain pressure similar to being at the top of an eight-thousand-foot mountain).

Light. Most humans would be hard-pressed to achieve much in complete darkness. The solution to our need for light was for a long time the light from the sun, but much human ingenuity has gone into the creation of artificial light sources.

The third set of individual needs arises from how we deal with a complex and ever-changing environment. As we go through life, we all encounter challenges that we need to overcome, resulting in three fundamental individual needs:

Healing. Whenever we damage our body, it needs to heal. The human body comes equipped with extensive systems for self-healing, but beyond a certain range it needs external assistance. We have developed many solutions, which are often grouped under the term 'healthcare'.

Learning. When we are born, we are quite stupid – we have to learn basic skills, such as walking and how to use tools. When we encounter a new situation, we have to learn how to deal with it. We group many of the strategies for solving the need for learning under the heading 'education', but other solutions include self-study, experimenting to gain experience and parenting.

Meaning. As humans, we have a profound psychological need for meaning in our lives. One solution is to have a purpose, and religious beliefs have long been a source of purpose for humans. Another key strategy to solve this need comes from our interactions with other humans, including having other people acknowledge our contributions to a project or even merely recognize our existence.

This last set of needs may strike you as being at a much higher level than the earlier ones. The idea of sorting individual needs into a hierarchy, as Abraham Maslow did, is intuitively appealing, but such an idea is misleading – all these needs are vital. For example, Maslow put needs like calories at the bottom and needs like meaning at the top, implying that calories are more foundational than meaning. But we know from the work of Viktor Frankl and others that meaning is essential to human effort and that accessing calories requires effort. As a thought exercise, picture yourself alone in a spaceship and try to remove any of the above; you'll soon realize that they are all equally important.

Collective Needs

Our collective needs arise from living together in societies and sharing space and resources. Meeting them is what allows human societies to survive and advance.

Reproduction. Individuals can survive without sex, but reproduction is a need for societies as a whole. We have learned how to reproduce without sex; in the future, there may be different solutions for the continuation of a human society – whether here on Earth or elsewhere.

Allocation. Access to physical resources has to be allocated. Take a chair as an example. Only one person can comfortably sit in it at a time – when there are multiple people, we need a way of allocating the chair between them. If you are by yourself, you can sit on a chair whenever you want to – allocation is a collective need.

Motivation. This may seem like an individual need, but it exists as a collective one in the sense that societies must motivate their members to carry out tasks and follow rules. Even the most primitive societies have solutions for this problem, often in the form of rewards and punishments.

Coordination. Whenever more than a single human is involved in any activity, there is a need for coordination. Take a simple meeting among two people as an example. In order for the meeting to take place, they need to show up at the same place at the same time. We have developed many communication and governance mechanisms to address this need.

Knowledge. As I have argued in earlier sections on optimism and humanism, knowledge is the central collective human need – without it, a society will encounter problems that it cannot solve. History is full of examples of societies that lacked sufficient knowledge, such as the Easter Islanders or the Mayans. This is not about what any one individual has learned but rather about the body of knowledge that is accessible to society. Later in this book we will examine solutions for generating more knowledge, faster.

These collective needs may strike you as abstract, but this is the result of identifying needs rather than their solutions, which are much more concrete and readily recognizable. For instance, governments and laws are examples of solutions to collective needs such as allocation and coordination, as are markets and firms and, more recently, networks and platforms. In other words, many of the institutions of society exist because they help us solve a collective need.

Enablers

You might ask about energy – isn't it something we all need, both individually and collectively? For instance, we individually need energy to maintain the temperature of a house, and we collectively need energy to power our communications infrastructure. But as those two examples show, energy is not a direct human need but an enabler of specific solutions to our needs.

Here are four foundational enablers:

Energy. For a long time, humans relied on direct sunlight as the primary source of energy. Since then we have developed many ways of generating energy, including better ways of capturing sunlight. Producing more energy and having it available in concentrated and highly regulated form via electricity has enabled new solutions to human needs.

Resources. In early human history, all resources were found in nature; later, we started growing and extracting resources. Many modern solutions have been made possible by access to new kinds of resources. Mobile phones, for instance, provide new solutions to individual and collective needs – they are made possible by the existence of some esoteric raw materials, including so-called rare-earth elements.

Transformation. Energy and resources alone are not enough, though – to enable most solutions, we need to figure out how to use the former to transform the latter. This involves chemical and physical processes. Physical capital, in the shape of machines, has been a crucial enabler of many new solutions to human needs. For instance, a knitting machine can quickly transform yarn into clothing, one of our key solutions for maintaining the human operating environment.

Transportation. The final foundational enabler is the ability to move stuff, including people. This is another area in which we have made great progress, going from human-powered to animal-powered to machine-powered transportation.

As with the case of needs, I have deliberately chosen enablers that have a high degree of abstraction. Coal-fired power plants provide energy, as do solar panels – and nuclear fusion will do the same at some point in the future. These three examples have dramatically different characteristics, but they are all energy enablers.

While I expect further changes, I believe that my current version of needs and enablers satisfies my argument that there is sufficient productive capital in the world. To turn this into a more quantitative approach, though, we need to consider the size and growth of the human population.

Population

In 1798, Thomas Malthus predicted widespread famine, as population growth outstripped humanity's ability to grow food [27]. His prediction was half-right: Global population did explode at the start of the nineteenth century.

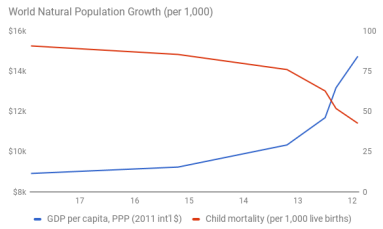
Since then, the human population has grown from about 1 billion to over 7 billion people [28]. However, the thing to note first is that Malthus's dire fears about the implications of this population growth have not been realized. There has been no global-scale starvation and most people do not live in abject poverty. In fact, the number of people living in extreme poverty around the world has declined, even though population growth has been about twice as fast as Malthus's predicted upper limit of 1 billion people added over 25 years [29].

What Malthus got wrong was the rate of technological progress. First, he was pessimistic about our ability to improve agricultural productivity. Since his writing, there have been huge advances in agriculture: the percentage of the global workforce employed in that sector has declined from more than 80 per cent to 33 per cent and is falling rapidly (in the US and other advanced economies, agriculture represents 2 per cent or less of employment). In the last 50 years alone, the land required to produce the same output of food around the world has declined by 68 per cent [31].

Second, Malthus could not foresee the scientific breakthroughs that enabled the industrial revolution. That revolution not only powered the increase in agricultural productivity but also gave us dramatic advances in our standard of living, including increased life expectancy, faster transportation and cheaper communication.

The fact that Malthus has been wrong so far is no guarantee that his predictions will not catch up with us, which would happen if population growth were to outstrip technological progress. We have seen this happen on occasion, such as in India [32] and other parts of the world that have experienced population growth in excess of technological progress, resulting in mass starvation.

However, as it turns out, population growth responds to technological progress. In particular, there is a strong and well-documented relationship between levels of infant mortality, living standard and birth rates. As better medical technology reduces infant mortality and better production technology increases standards of living, birth rates decline. Max Roser has produced some beautiful charts as part of his amazing 'Our World In Data' project that show how this combined effect of progress on birth rates occurs all around the world [33].



So despite the extraordinary growth in global population over the last 200 years, simply assuming that it will continue into the future would be a mistake; there are strong signs that the world's population is likely to peak. Some people claim that this debate is crucial because they don't think the world can sustain, say, 11 billion people. However, this argument misses a key point. The world cannot sustain 7 billion people – its current population – either, unless we continue to make technological progress. The ways we have managed to support 7 billion people so far have created all sorts of new problems, such as water and air pollution and, most pressingly, the climate crisis. We need continued technological progress to solve these problems.

Instead the key takeaway should be that needs will not continue to grow exponentially because population growth will slow down. All the signs suggest that the global population curve is starting to decelerate, whereas the rate of technical progress is continuing to accelerate [34] [35]. Knowing these things, we can be optimistic about progress in relation to population growth. Or put differently, Malthus will ultimately turn out to be wrong both about the rate of technological progress and the long-term rate of population growth. I have already described why digital technology is so disruptive. We will see in more detail later how it is contributing to an acceleration of knowledge creation, and thus progress.

Capital

As the title of this book states, one of my fundamental claims is that there is enough capital in the world to meet everyone's needs. That means meeting the individual needs of at least 7 billion people, as well as the collective needs of the societies they live in. If there is plenty of slack today, capital will no longer be the binding constraint for humanity going forward as population growth is decelerating while technological progress is accelerating.

It is tempting to look at this in terms of financial capital, but that would be succumbing to the misleading veil of money. Dollar bills don't feed people and gold bars can't be used as smartphones. The capital that matters is productive physical capital, such as machines and buildings.

Financial capital is not irrelevant, of course – it is required for the initial construction of physical capital and to meet the ongoing needs of the economy. If I want to build a factory or a school, I need to pay the construction workers and the suppliers of machines before I can start making money. And many businesses have ongoing expenses to pay each month before they can collect revenues from customers. When cash outflows precede cash inflows, a financing mechanism is required; to accumulate physical capital, we need to be able to accumulate financial capital.

In the history of financial capital there have been many important innovations, and the introduction of marketplace lending has been an important recent one. The allocation of financial capital to projects through markets has been enormously successful, and it is the success of the market-based approach that gives us a large enough physical capital base to meet our basic needs.

Many recent innovations in finance, however, rather than contributing to the creation and allocation of physical capital, have had the opposite effect and contributed to the excessive 'financialization' of the economy. This refers to a growth in financial activities that are decoupled from or even harm the formation of physical capital but help generate personal wealth. One example of excess financialization is companies borrowing money to buy back shares instead of investing in innovation. The derivatives and structured securities, such as collateralized debt obligations (CDOs), that powered the housing bubble are another example. This is not to say that there aren't potentially legitimate uses of these tools – it is just that they have grown beyond what is needed for physical capital formation and taken on a life of their own. This can be seen both in the increased size of the financial sector as part of the overall economy and in the wealth generated by making money from money instead of from productive capital.

What is the role of 'human capital' in all of this? I am putting the phrase in quotation marks as it is a fundamental misnomer. Humans provide labor and machines are capital. Handmade goods represent a tiny fraction of what we use to meet our needs, and hence the focus in this section is on machines and physical capital more broadly.

The better question to ask is: what is the role of knowledge? The answer is that advances in knowledge are essential for making capital more effective. Even more fundamentally, physical capital cannot exist in the first place without knowledge. Taking an MRI scanner as an example, you cannot build one without a lot of knowledge of physics and engineering. However, in a world where everyone's needs are taken care of, it might be possible to build the same machine without the need for financial capital, as you might not have to pay people in advance. And with enough knowledge, in the form of advanced robots, it will even be possible to build one without 'human capital', or labor.

In conclusion here, we should realize that financial capital serves no purpose in and of itself, other than the gratification of ego. Imagine a Spanish galleon full of gold was caught in a storm. Though the sailors aboard had ample access to financial capital, what they really needed to survive was either more knowledge or better physical capital. For example, if they had more knowledge of the weather they could have circumnavigated the storm. Or if they had a stronger boat, they could have simply rode out the storm. If anything, the gold is a hindrance to their survival – throwing it overboard might help the boat get away from the storm more quickly.

We will now examine whether physical capital is sufficient for meeting our needs.

Individual Needs

My claim is that capital is no longer the binding constraint for meeting our individual needs. This is especially true for the developed economies, but it is increasingly true globally. Let's start by considering the needs emanating from keeping our bodies powered (see the

Appendix for additional supporting information).

Oxygen: There is plenty of air for us to breathe; the key challenge is having clean and breathable air. China and India are both currently struggling with this, but they developed rapidly and are reliant on outdated energy sources. What is needed here are improvements to capital, such as switching to electric cars from internal combustion engine ones.

Water: There is plenty of it for everyone in the world to drink (the oceans are full of water). Though there are distribution and access problems, including right here in the United States (for example, the crisis of polluted drinking water in Flint, Michigan), physical capital is not a binding constraint. We are even able to build new desalination plants in record time.

Calories: We have made dramatic progress in farming; the amount of land required globally has begun to decline as a result of increased productivity. There have been significant recent breakthroughs in vertical farming, the practice of growing plants under controlled conditions, and in automated farming. For instance, one of the world's largest vertical farms operates in Jersey City, and the Japanese indoor farming company Spread is working on a fully automated facility that will be able to produce 30,000 heads of lettuce per day [155].

Nutrients: This is primarily a question of knowledge, as we still don't fully understand which nutrients the body really needs to ingests in what quantities. We obtain most of them from food, but depending on our diet we may need to add some supplements. The remaining amounts tend to be small and we can produce plenty of them already (in developed countries entire industries have sprung up trying to convince people to buy and consume food supplements that they do not need).

Discharge: This is primarily addressed through modern sewage technology. Here too, capital is no longer a binding constraint, though its uneven distribution around the world is a problem. However, the rate of migration from the Chinese countryside into the country's cities shows how quickly that situation can change.

Now let's consider the needs relating to the operating environment for humans.

Temperature: The Chinese construction boom of the early 2000s also illustrates how quickly we can build shelter, which together with heating and air conditioning is one crucial solution to our temperature needs. In the US, a construction boom was powered by artificially cheap mortgage credit. Though a lot of housing was built speculatively and remained empty, it powerfully demonstrated our construction capacity. Clothing is another strategy for meeting our temperature needs. The price of clothing has been falling in many parts of the world, including the United States. Capital is not a constraint here – indeed, we have the ability to clothe the world's population many times over.

Pressure: Thankfully, we have nothing to do here, as we have plenty of space for humans to live in the right pressure range. This is a great example of a need that we do not consider much at all but that would loom very large were land not inhabitable and we had to go underwater or into space.

Light: We have become very good at providing light. One study shows how the hours of light provided by 60 hours of labor in the United States exploded from around 10 in 1800 to over 100,000 by 1990. Since then, we have made further progress since with LED lighting. That progress has also come to other parts of the world, for instance in the form of off-grid, solar-powered lamps.

Finally we come to the more abstract individual needs.

Healing: We often read that healthcare consumes an increasingly large fraction of the economy, especially in the United States, but that does not imply that capital is scarce. In industrialized countries we have plenty of hospital space and doctor's offices. But didn't the COVID19 pandemic show that we didn't have enough ICU beds? No – countries that reacted to the virus in good time stayed well within their capacity. Overall capital is sufficient for healing. We have extensive diagnostic facilities and are able to produce large quantities of medicine. Our bodies are extremely complex; as a result, basic issues such as how diet relates to health are poorly understood.

Learning: Nor are we constrained by capital when it comes to learning. This is increasingly true not just in industrialized nations but also globally, due to the expansion of wireless networks and the increasing affordability of smartphones. We are not far away from being at a point where we have enough capital for anyone in the world to learn anything; the binding constraint is the availability of affordable content and the time it takes to learn and teach.

Meaning: The final individual need, that of meaning, is not and has never been constrained by capital. Capital plays no role in meeting our need for it.

Collective Needs

At first it might seem difficult to see how capital relates to our collective needs – how could it have anything to do with such abstract concepts as motivation and coordination? In discussing why capital today is sufficient, I will briefly point out how it was in the past scarce with regard to these needs.

Reproduction: Capital has always been sufficient for reproduction – otherwise, we would not be here today.

Allocation: During the Industrial Age the allocation of capital, such as where to build a factory and what it should produce, was the central allocation problem, and it was the scarcity of capital that made it difficult to meet this need. When there were few roads and other means of transportation, there were few places a factory could be built. Today, the allocation problem for capital is no longer constrained by capital. And because capital is no longer scarce, it is also no longer the dominant allocation problem. As we will see in the next section it has been replaced by the allocation of attention, for which capital is largely irrelevant.

Motivation: Again, it might at first seem as if capital never played a role here. But consider what it was like to work in an early factory, when the outputs were generally not affordable for the workers. Contrast this with much of the period following the Second World War, when we already had a fair bit of capital making possible the mass production of goods that workers could afford. Today motivation is no longer constrained by capital.

Coordination: One of the primary ways to meet the need for coordination is through communication, which was heavily constrained by capital for the longest time. Today, however, we can hold a real-time video conference with nearly anybody in the world. And some of the big coverage gaps, such as parts of Africa, are rapidly being filled in.

Knowledge: Finally, our collective need for knowledge was for a long time constrained by capital. Making books, for instance, was expensive and time-consuming, and copies could only be made by humans, which introduced errors. The spread of knowledge was limited by the need to create and supply physical copies, constraints that we have now left behind. There were also other ways in which capital was scarce as far as knowledge was concerned. For instance, we had insufficient scientific instruments for inspecting matter, such as microscopes. Today, by contrast, we are able to build massive undertakings to support science, such as the Large Hadron Collider.

Enablers

Our progress on the four foundational enablers – energy, resources, transformation and transportation – is another way to understand why capital is no longer scarce. There have been massive breakthroughs on all four during the Industrial Age.

Energy: The biggest breakthrough in energy was the development of electricity, which allowed us to apply energy precisely. Our remaining challenges relate to the production, storage and distribution of electricity; further improvements will let us solve needs in new ways, but we are not fundamentally energy-constrained. For instance, at current efficiency rates, covering a small percentage of the Earth's surface with solar panels would cover all our electricity needs.

Resources: The availability of resources was completely transformed during the Industrial Age through mining, which was enabled by innovation relating to transportation (railways) and energy (steam power). People who have concerns about sustainability sometimes point to the scarcity of resources as the primary constraint, but there are three sources that we can tap in the future: recycling, asteroid mining and eventually transmutation. For instance, a lot of electronics currently end up in landfill instead of being recycled. We achieved the first soft landing on an asteroid as far back as 2001.

Transformation: Our ability to transform materials also improved radically during the Industrial Age. For instance, chemistry enabled the synthetic production of rubber, which previously had to be harvested from trees. Machine tools enabled the rapid transformation of wood and metals. We later added transformation technologies such as injection molding and additive manufacturing technologies, which is often referred to as '3D printing'.

Transportation: Here we went from human-, animal- and wind-powered to machine-powered, dramatically changing our capabilities. We can fly across continents and oceans on commercial flights, reaching any major city in a single day. While some people have complained about a recent lack of progress, pointing to the lack of commercial supersonic options following the retirement of Concorde, there has

been extraordinary progress in flight safety. More recently, work has resumed on developing new options for commercial supersonic flight and we have also made tremendous progress with reusable rockets and autonomous vehicles (for instance, with drones and the robots that are used in warehouses).

The progress made on all these enablers has allowed us to produce more physical capital, to do so more rapidly and cheaply, and to transport it anywhere in the world. One illustration of how far we have come is the fact that smartphones only became available in 2000 but by 2017 there were over 2 billion smartphone users in the world.

I am not claiming that everyone's needs are being met today, and nor am I arguing that governments should be meeting people's needs through government-run programs such as food stamps or subsidized housing – quite the opposite. My point is that physical capital is no longer the constraint when it comes to meeting our individual and collective needs.

The great success of capitalism is that capital is no longer scarce. However, we now face a scarcity of attention, and capitalism will not solve it without changes in how we regulate our society and ourselves. Before we can examine the scarcity of attention, we must understand how digital technologies have the potential to change the role of labor.

Part Three: Attention Is Scarce

To show that attention is scarce, I must establish that there is not enough of it to meet our needs. I will start by defining attention, before presenting several examples of needs that either are already no longer met due to a lack of attention, such as the need for meaning, or are at risk of not being met in the near future. After that, I will consider how much human attention is currently caught up in Industrial Age activities and how an increasing amount of attention is being trapped through our current uses of digital technology, such as advertising-based social networks. I will also discuss why market-based capitalism cannot be used for the allocation of attention.

Attention

Attention is to time as velocity is to speed. If I tell you that I'm driving at a speed of 55 miles per hour, that does not tell you anything about where I am going, because you do not know my direction. Velocity is speed plus direction. Similarly, if I tell you that I spent two hours with my family yesterday (time), that does not tell you anything about what occupied our minds — we could have been having an engaging conversation or we could have been immersed in our phones. Attention is time plus intentionality.

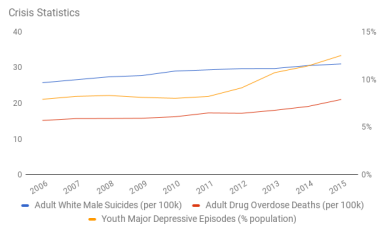
The amount of human attention in the world is finite. We have 24 hours in the day and need to spend some of it eating and sleeping. Most people in the world have their waking hours taken up by earning an income and consuming goods and services, leaving relatively little time for attention that they can freely allocate. A hard limit on available attention also exists for humanity as a whole – as I argued earlier, we are headed for peak population, at which point we will no longer be increasing available attention by adding more people.

Crucially, we are not able to go back in time and change our past attention. A student who walks into an exam unprepared cannot revisit the preceding weeks and study more. A world that enters a pandemic unprepared is not able to go back in time and do more research on coronaviruses.

Individual Attention Scarcity

First, let's consider attention at the individual level. The need for meaning is no longer being met due to a lack of attention by most people to the crucial questions of purpose and belief systems at a time of great transition. All over the world, people had become used to constructing meaning around their jobs and beliefs, but both these things are undermined by digital technologies. Many jobs have come under pressure from automation or outsourcing. Content is no longer contained by geographic boundaries and people are increasingly exposed to opinions and behaviors that diverge from their core beliefs. In combination, these challenges are leading to a crisis of identity and meaning. This crisis can take many different forms, including teenage depression, adult suicide – particularly among middle-aged white men – and fatal drug overdoses. Between 2006 and 2015, these problems increased by 60 percent, 20 percent and 40 percent respectively.

The situation is not dissimilar from when people left the countryside and moved to big cities during the transition to the Industrial Age, in the process giving up identities that had been constructed around land and professions. They were uprooted from their extended families and confronted with people from other regions who held different beliefs. Then too there was a marked increase in mental illness, drug abuse and suicide.



The Industrial Age had little use for an individual sense of meaning – somebody with a strong sense of personal purpose does not readily operate an industrial machine day in, day out. Early in the Industrial Age, religion still provided a source of meaning for a lot of people. As the Industrial Age progressed, work and consumption have increasingly become sources of meaning. Church attendance decreased while commercial advertising grew massively and became a significant alternative narrative about meaning, eventually culminating in the idea of 'retail therapy'.

Given the new transition, it is not surprising that we are currently seeing a rise in populist leaders with simplistic messages, such as Donald Trump in the United States and Viktor Orbán in Hungary. A recent study found that the average share of the vote for populist parties throughout Europe is more than double what it was in the 1960s [46]. People who lose meaning when their purpose and beliefs are challenged want to be told that things will be okay and that the answers are simple. 'Make America Great Again' is an example of one such message. Instead of building new meaning, which requires considerable attention, these backward movements promise an easy return to a glorious past. Similarly, we are once again seeing a growth in church attendance as well as in various spirituality movements, all of which promise to restore meaning.

This individual scarcity of attention is not confined to any one demographic. People who work multiple jobs to pay rent and feed their families are definitely impacted, but so are many people in high-paying jobs, who are often working more hours than ever. I often meet young people who want to work for a technology startup or to enter venture capital. Most of them are looking for advice about how to apply to a specific position. After discussing that for some time, I usually ask them a more open question: 'What do you want from your next position?' That often elicits more interesting answers – they might talk about learning a new skill or applying a skill that they have recently learned. Sometimes people answer with a desire to contribute to some cause. When I ask them 'What is your purpose?', shockingly few people have paid enough attention to this question to have an answer.

Collective Attention Scarcity

Humanity is also not devoting nearly enough attention towards our collective need for more knowledge to address the threats we are facing and seize the opportunities ahead of us. In terms of the threats we face, we are not working nearly hard enough on reducing the levels of carbon dioxide and other greenhouse gases in the atmosphere. Or on monitoring asteroids that could strike earth, and coming up with ways of deflecting them. Or on containing the current coronavirus outbreak (an early draft of *The World After Capital*, written before 2020, said 'containing the next avian flu' here).

Climate change, 'death from above' and pandemics are three examples of species-level threats that are facing humans. As I wrote earlier, we are only able to sustain the current global human population due to our technological progress. Each of these risk categories has the potential to fundamentally disrupt our ability to meet individual needs. For example, the climate crisis could result in a large-scale global crop failure, which would mean we could no longer meet everyone's needs for calories and nutrients. This is not a hypothetical concern; it has led to the downfall of prior human civilizations, such as the Rapa Nui on Easter Island or the Mayans, whose societies collapsed due to relatively small changes in their local climate. Now, however, we are facing a climate crisis on a truly global scale, and we should be using a significant amount of all human attention to fight this threat.

On the opportunity side, far too little human attention is spent on things such as environmental cleanup, educational resources and basic research. The list here is nearly endless, and includes unlocking quantum computing and advancing machine intelligence. The latter is particularly intriguing because it could help produce more knowledge faster, thus helping to reduce the scarcity of attention.

None of this means that everyone has to become a scientist or engineer – there are lots of other ways to allocate attention to address these threats and opportunities. For instance, learning about the climate crisis, sharing that knowledge with others and becoming politically active are all ways of allocating attention that directly or indirectly create more knowledge. So is creating art that inspires others, whether it is to directly take an action, or simply as a source of meaning. This is why when I talk about not creating enough knowledge, I am not limiting it to scientific knowledge but all knowledge, as defined earlier.

Attention scarcity is difficult to alleviate, and I therefore propose it as a possible explanation for the Fermi paradox. The scientist Enrico Fermi famously asked why we have not yet detected any signs of intelligent life elsewhere in our universe, despite knowing that there are plenty of planets that could harbor such life. Many different explanations have been advanced, including that we are the first and hence only intelligent species or that more advanced intelligent species stay 'dark' for fear of being attacked by even more advanced species (the premise of the sci-fi trilogy 'The Three-Body Problem' by Cixin Liu). Alternatively, perhaps all civilizations develop until they have sufficient capital but then suffer from attention scarcity, so they are quickly wiped out by a pandemic or a meteor strike. If civilizations that can build radios don't persist for very long, they will be hard if not impossible to detect.

Why is our scarce attention so poorly allocated that we are facing a potential extinction-level event in the form of the climate crisis? One reason is that we currently use the market mechanism to allocate attention. The next sections explain how it is sucking a lot of attention into a few systems such as Facebook, while also keeping much of it trapped in Industrial Age activities. Finally, we will consider why markets fundamentally cannot allocate attention, which points to the crucial limits of capitalism.

Misallocation

We have seen that attention is scarce, making the proper allocation of available attention the crucial challenge for humanity. As we will see later, digital technology can be used to help with this, but in the present, the primary effect of digital technology has been to misallocate attention.

The Internet is exponentially increasing the amount of available content; most of the content produced by humanity has been produced in the last few years [43]. As a result, it is easy to be overwhelmed; our limited attention is easily absorbed by the increasing amount of content. Humans are inadequately adapted to the information environment we live in. Checking email, Twitter, Instagram and watching yet another YouTube clip or Snapchat story provide 'information hits' that trigger the parts of our brain that evolved to be stimulated by novelty. For hundreds of thousands of years, when you saw a cat there was an actual cat; now, the Internet can produce an endless stream of cat pictures. In 2017, the average person spent roughly two hours on social media every day [45].

It is not just the explosion in the quantity of information – it is also that the dominant companies through which we access this information, such as Google, Facebook and Twitter, are generating most of their revenues by capturing and reselling our attention. That is the essence of advertising, which is their business model. Advertisers literally buy attention for their message – in order to grow, they invest in algorithms designed to present captivating content to their users, in order to capture more of their attention. News sites like Buzzfeed and the Huffington Post do the same.

Capturing attention is much more easily accomplished by appealing to the parts of our brain that find kittens cute and react with outrage to perceived offenses. Conversely, the companies responsible for these systems are not incentivized to recommend to you to close your computer, to put down your smartphone and spend more time with friends or to go outdoors and clean up the environment. The financial markets closely track metrics such as number of users and time spent, which are predictors of future growth in advertising revenue. Put differently, the markets that drive the predominant way we use digital technology to allocate attention reflect the interests of investors and advertisers, which are often orthogonal to individual and community interests. As we will see later, the problem runs even deeper, as it is impossible to construct proper markets for attention.

Trapped

While digital technology is being used to capture our attention, we should also consider what the bulk of attention is dedicated to today. Not surprisingly, since we are just beginning to transition out of it, the vast bulk of human attention is focused on Industrial Age activities, in particular labor and consumption. For example, in the US many people work forty or more hours per week, which amounts to 35 per cent of waking hours (assuming eight hours of sleep per night). People in the US now spend over 70 hours a week consuming (much of this in the form of media, including Facebook, YouTube, Netflix and similar services), which amounts to over 60 per cent of their time awake. To understand why so much of our attention is spoken for, I present the concept of the 'job loop'.

The Job Loop

Thinking dispassionately about labor is hard, because over the last couple of centuries we have become convinced that employment is essential for the functioning of the economy and for individual dignity. Let's start from the perspective of production. If you want to make products or deliver a service, you require a series of inputs, including buildings and machines (capital), raw materials or parts (supplies) and human workers (labor). For much of history, capital and labor have been complementary – as the owner of a company, you couldn't use your physical capital without having labor to operate it. That was true for manufacturing and even more so for services, which often use little capital and consist primarily of labor.

However, there is nothing in economics that says that all production processes should require labor; its necessity is an artifact of the production functions that were technologically available when economists developed the theory of production. If company owners are able to figure out how to do something cheaper or better by using less or no labor, that's what they will choose to do. When it was acquired by Facebook for $19 billion, WhatsApp had fewer than 50 employees.

Having no labor at all might make sense for a single company, but it does not for the economy as a whole, as it is currently constructed – who will buy the goods and services if people are unemployed and don't have any money? A famous exchange between Henry Ford II and Walter Reuther, head of the United Automobile Workers union, went as follows:

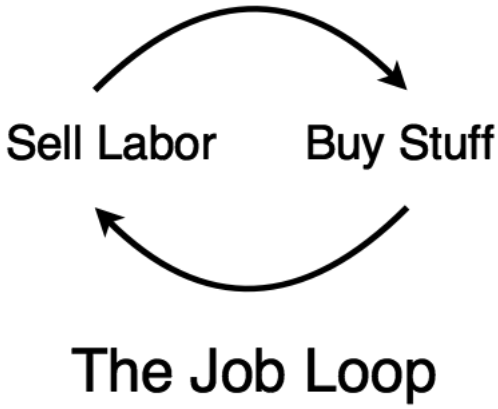
> Henry Ford II: Walter, how are you going to get those robots to pay your union dues? Walter Reuther: Henry, how are you going to get them to buy your cars? [38]

If we all had inherited wealth or sufficient income from capital, an economy without labor would not be a problem and we could enjoy the benefits of cheaper products and services courtesy of robots and automation.

For a long time, the possibility of a slump in consumer demand due to less labor seemed not just unlikely, but impossible. There was a virtuous loop at the heart of economic growth: the 'job loop'.

In today's economy, the majority of people sell their labor, producing goods and services and receiving wages in return. With their wages, they buy smartphones, books, tools, houses and cars. They also buy the professional assistance of attorneys, doctors, car mechanics, gardeners and hair stylists.

Most of the people who sell goods and services are in turn employed, meaning that they sell their labor, and they buy goods and services from other people with what they are paid. And round and round it goes.



The Job Loop

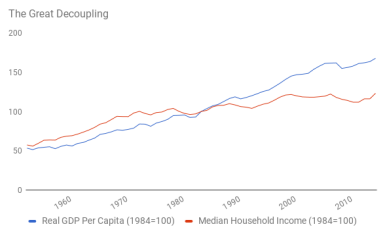
The job loop worked incredibly well in combination with competitive markets for goods and services and in a properly functioning financial system. Entrepreneurs either used debt or equity to start new businesses and employed people at wages that were often higher than older businesses, increasing their employees' purchasing power. It was a virtuous cycle that resulted in unprecedented prosperity and innovation.

Some might point out that many people these days are self-employed, but that is irrelevant if they are selling their time. For instance, a graphic designer who works as an independent contractor is still paid for the labor they put into a project. It is only if they design something that is paid for over and over without them spending further time on it, a graphics template for instance, that they have the opportunity to leave the job loop.

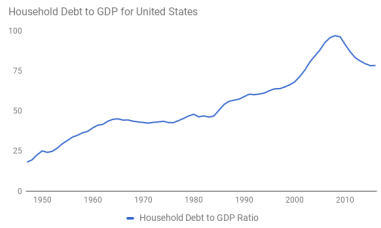
There are multiple problems with this virtuous cycle today. First, as we calculated at the outset of this section, it traps the vast majority of human attention. Second, when things contract, the effect of mutual reinforcement applies in the other direction. Take a small town, for example, in which local stores provide some of the employment. If a big superstore comes into town, total retail employment and wages will both fall. Fewer store employees have income, and those who do have less. If they start to spend less on haircuts and car repairs, the hair stylist and car mechanic earn less and can spend less themselves, and so on. This is directly related to the third problem, which is that the job loop is breaking down both on the labor and the consumption sides, but not in a way that is releasing attention.

The Great Decoupling

To understand what is happening to the job loop, we need to look at a change in the economy that has become known as 'the great decoupling'. For a long time, as the economy grew, the share of GDP going to labor grew at the same rate. However, starting in around 1980, GDP continued to grow while household income remained flat.



The growth of GDP was increasingly financed by consumers going into debt, until we reached the limit of how much debt households could support. The first event that really drove that point home was the collapse of the US housing bubble. There is some evidence that we are hitting another such point right now, as a result of the COVID19 crisis that has led to dramatic increases in unemployment.



The decoupling may be partly driven by demographics, but the primary driver appears to be technology. As technological innovation accelerates, there will be further pressure on the job loop. What should be particularly worrisome is that jobs in developing countries have a high exposure to automation [39]. As a result, these countries may either skip 'the golden age of the job loop' entirely or have a much diminished version.

So, while we want to free up the attention trapped in the job loop, we need to figure out how to do so gradually rather than through a rapid collapse. But is such a collapse even possible?

Lump of Labor or Magic Employment Fallacy?

With the job loop still dominant, people have to sell their labor to earn a living. Until recently, most economists believed that when human labor is replaced in one part of the economy, it finds work in another part. These economists refer to a fear of technological unemployment or under-employment as the 'lump of labor fallacy'.

The argument is that automating some part of the economy frees up labor to work on something else – entrepreneurs might use this newly available labor to deliver innovative new products and services, for example. There is no fixed 'lump' of labor; rather there are potentially an infinite number of things to work on. After all, this is what has happened historically – why should this time be different?

To understand how things could be different, we might consider the role horses have played in the American economy. As recently as 1915, 25 million horses worked in agriculture and transportation; by 1960, that number had declined to 3 million and then we stopped keeping track [40]. This decline happened because we figured out how to build tractors, cars and tanks – there were no uses left for which horses were superior to a mechanical substitute. The potential for the same thing to happen to humans was pointed out by the economist Wassily Leontief in his 1952 article 'Machines and Man' [41].

Humans obviously have a broader range of skills than horses, which is why we have so far always found new employment. So what has changed? Well, we have figured out how to have computers do lots of things that until recently we thought only humans could do, such as driving a car. Digital technology gives us universal computation at zero marginal cost. Suddenly, the idea that we might have fewer uses doesn't seem quite so inconceivable.

Those who claim that this is committing the 'lump of labor fallacy' argue that we haven't considered a new set of human activities that will employ people, but that line of thinking might also be flawed. Just because we have found new employment in the past, that doesn't mean we will in the future. I call this assumption the 'magic employment fallacy'.

We can be incredibly creative when it comes to thinking of new things to spend our time on, but the operative question for people selling their labor is whether they can get paid enough to afford solutions to their needs, such as food, shelter and clothing. The only thing that matters for this question is whether a machine or another human is capable of doing whatever we think of more cheaply.

This turns out to be the central problem with the 'magic employment fallacy'. Nothing in economic theory says what the 'market-clearing price' for labor – the wage level at which there is neither unemployment nor a labor shortage – ought to be. It might be well below what people need to cover their needs, which could present a near-term existential threat to many people.

We thus appear to face a dilemma. On the one hand, we want to free up human attention outside of the job loop. On the other hand we want to avoid a rapid collapse of the job loop. In order to understand how we can accomplish both, we need to consider the relationship between the cost of labor and innovation.

Expensive Labor and Innovation

Some people argue that unions made labor expensive, resulting in unaffordable products and services. However, increased labor costs in fact propelled us to become more efficient; entrepreneurs overcame the challenge of more expensive labor by building better machines that required fewer humans. In countries such as India, the abundance of cheap labor meant that for a long time there was little incentive to invest in a machine; it was cheaper to have people do the work by hand.

Globally, we face the risk of being stuck in a low-innovation trap, as a result of a fear that automation will make labor cheap. For example, we might end up with many more years of people driving trucks across the country, long after a machine could do the same job more safely [42]. What is the incentive to automate a job if you can get someone to do it for minimum wage?

Some people object to automation innovations on the grounds that work is an integral part of people's identity. If you have been a truck driver for many years, for instance, who will you be if you lose your job? At first, this might sound like a completely legitimate question. But it is worth recalling that the idea that purpose primarily has to do with one's profession, instead of belonging to a religion or to a community, is an Industrial Age phenomenon. So if we want to free up attention via automation, we need to come up with a new answer.

Limits of Capitalism

Capitalism has been so successful that even communist countries like China have embraced it. But it cannot solve the scarcity of attention without significant changes in regulation, as a result of three important limitations. First, prices will always be missing for things that we should be paying attention to. Second, capitalism has limited ways of dealing with the concentration in wealth and market power arising from digital technologies. Third, capitalism acts to preserve the interests of capital over knowledge. We need to make changes now, precisely because capitalism has been so successful – the problems that are left are the ones it cannot solve.

Missing Prices

Capitalism won't help us allocate attention because it relies on prices that are determined in markets. Prices are powerful because they efficiently aggregate information about consumer preferences and producer capabilities, but not everything can be priced. And increasingly, the things that cannot be priced are becoming more important than those that can – for example, the benefits of space exploration, the cost of the climate crisis or an individual's sense of purpose.

The lack of prices for many things is not just a question of a missing market that can be created through regulation. The first foundational issue is the zero marginal cost of copies and distribution in the digital realm. From a social perspective, we should make all the world's knowledge, including services such as medical diagnoses, available for free at the margin. As long as we rely on the price mechanism, we will under-produce digital resources. Just as the Industrial Age was full of negative externalities such as pollution, resulting in overproduction, the Knowledge Age is full of positive externalities, such as learning, which implies underproduction. If we rely on the market mechanism, we will not pay nearly enough attention to the creation of free educational resources.

The second foundational issue is uncertainty. Because prices aggregate information, they fail when no such information exists. When events are either incredibly rare or have never occurred, we have no information on their frequency or severity; the price mechanism cannot work when forecast error is infinite. For instance, large asteroid impacts on Earth occur millions of years apart, and as a result there is no price that can help us allocate attention to detecting them and building systems for deflecting them. As a result, we pay a trivial amount of attention to such problems relative to the potential damage they would cause.

The third foundational issue is new knowledge. The further removed such knowledge is from creating a product or service that can be sold, the less use the price mechanism is. Consider early aviation pioneers, for example. They pursued flight because they were fascinated by solving a challenge rather than because there was an obvious market for air travel. Or take the early days of quantum computing; actual machines were still decades away, so the price mechanism would not at that time have allocated attention to the discipline.

The fourth foundational issue is that in order for markets and prices to exist, there have to be multiple buyers (demand) and sellers (supply). There is no demand and supply for you to spend time with your children or to figure out your purpose in life – capitalism cannot help us allocate attention to anything that is deeply personal.

Power Laws

When it comes to the distribution of income and wealth, many different outcomes are possible and what is realized depends on the underlying production functions. Consider a manual production function that was common before industrialization. If you were a cobbler making shoes by hand, for instance, there was a limit to the number of shoes you could produce.

Then along came industrialization and economies of scale. If you made more cars, say, you could make them more cheaply. That is why, over time, there were relatively few car manufacturers around the world and the owners of the surviving ones had large fortunes. Still, these manufacturing businesses stayed fairly competitive with each other even as they grew large, which limited their market power and the amount of wealth that was created. Many service businesses have relatively small economies of scale, which has allowed a great many of them to exist and markets such as nail salons have remained competitive. The financial industry is one clear exception to this among services businesses – a few large banks, insurance companies and brokerage firms tend to dominate and that has accelerated in recent years, largely because financial services have already been heavily impacted by digital technology.

With digital technology we are seeing a shift to ever higher market power and wealth concentration. When you plot the outcomes, such as companies by revenue, the resulting curves reveal so-called 'power laws' – the biggest firm is a lot bigger than the next biggest firm, which in turn is a lot bigger than the third largest firm. This pattern is pervasive throughout digital technology and the industries in which it plays a major role. For instance, the most watched video on YouTube has been watched billions of times, while the vast majority of videos have been watched just a few times. Or in e-commerce, Amazon is an order of magnitude larger than its biggest competitor and several orders of magnitude larger than most e-commerce companies. The same goes for apps – the leading ones have hundreds of millions of users, but the vast majority have just a few.

Digital technologies are driving these power laws not only due zero marginal cost, as explained earlier, but also as a result of network effects. Network effects mean that a service gets better for all participants as it adds more participants — for example as Facebook grew, both the new users and the early users had more people they could connect with. This means that once a company grows to a certain size it becomes harder and harder for new entrants to compete as their initially smaller networks offer less benefit to participants. In the absence of some kind of regulation, the combination of zero marginal cost with network effects results in extremely lopsided outcomes. So far, we have seen one social network – Facebook – and one search company – Google – dominate all others. This shift to power laws is driving a huge increase of wealth and income inequality to levels that are even beyond the previous peak of the early 1900s. Inequality beyond a certain level is socially corrosive, as people start to live in a world that is disconnected from the problems faced by large parts of the population.

Beyond the social implications of such inequality, the largest digital companies also wield undue political and market power. When Amazon acquired a relatively small online pharmacy, signaling its intent to compete in that market, there was a dramatic drop in the market capitalization of pharmacy chains. Historically, market power produced inefficient allocations due to excessive rents as prices were kept artificially high; in digital markets, powerful companies have often pushed prices down or even made products free. While this appears positive at first, the harm to customers comes via reduced innovation, as companies and investors stop trying to bring better alternative products to market.

Joseph Schumpeter coined the term 'creative destruction' to describe the way in which markets create new products to replace old ones. Indeed, if you look at the dominant companies today, they are quite different from those of the Industrial Age. However, such innovation is now more difficult, if not impossible. During the Industrial Age, machines served a specific purpose, which meant that when a new product or manufacturing technology became available, the installed base of machines became essentially worthless. Today, general-purpose computers can easily implement a new product, add a feature to an existing one or adopt a new algorithm. Production functions with information as a key input have a property known as 'supermodularity': the more information you have, the higher the marginal benefit of additional information. This gives the incumbent companies tremendous sustained power – they gain more marginal value from a new product or service than a new technology does.

Self-Conservation

Toward the end of the Agrarian Age, when land was scarce, the political elites came from the landowning classes, and their influence wasn't substantially diminished until after the Second World War. Now, though we have reached the end of the period in which capital was scarce, the political elites largely represent the interests of capital. In some countries such as China, senior political leaders and their families own large parts of industry outright. In other countries such as the United States, politicians are influenced by the owners of capital because of the need to fundraise.

A study conducted at Princeton University has analyzed to what extent public support for a policy influences the likelihood of that policy being enacted [47] in the United States; for the bottom 90 per cent of the population, their preferences have no influence. Only the preferences of the wealthiest 10 per cent of the population matter. And even within the wealthiest 10 per cent, there is a huge concentration of influence among a small number of individuals. For instance, over a five-year period, the 200 most politically active companies spent nearly $6 billion on lobbying.

Individual and corporate lobbying results in policies that are favorable to owners of capital, such as low rates of capital gains tax. Low corporate tax rates, with loopholes that allow the accumulation of corporate cash in countries where taxes are low, are also favorable to owners of capital. So in 2020 we have some of the lowest effective tax rates for corporations and wealthy individuals and families in US history ('effective' means what is paid after exemptions and other ways to reduce or avoid tax payments).

In addition to preserving and creating benefits for owners of capital, they have also attacked the creation and sharing of knowledge. Corporations have lobbied heavily to lengthen terms of copyright and strengthen copyright protection. Scientific publishers have made access to knowledge so expensive that libraries and universities struggle to afford the subscriptions. [48]

A key limit of capitalism thus is that without meaningful change it will keep us trapped in the Industrial Age. As long as that is the case, we will continue to over-allocate attention to work and consumption and under-allocate it to areas such as the individual need for meaning and the collective need for the growth of knowledge. Parts Four and Five of *The World After Capital* will examine how we can get out of the Industrial Age, but first we will take a closer look at the power of knowledge and the promise of the digital knowledge loop.

Power of Knowledge

Have you watched television recently? Stored food in a refrigerator? Accessed the Internet? Played games on your smartphone? Driven in a car? These are all things that billions of people around the world do every day. And while they are produced by different companies using a wide range of technologies, none of them would be possible without the existence of knowledge.

Knowledge, as I have earlier defined it, is the information that humanity has recorded in a medium and improved over time. As a reminder, there are two crucial parts to this definition. The first is 'recorded in a medium', which allows information to be shared across time and space. The second is 'improved over time', which separates knowledge from information. The improvement is the result of the operation of the critical process, which allows for existing pieces of knowledge to be criticized and alternative pieces to be proposed.

I began this section with examples of everyday technologies that would not exist without knowledge. An even stronger illustration of the power of knowledge is that without it, many of us would not even be here today. As we saw in our discussion of population, Malthus was right about population growth but wrong about its consequences because he did not foresee the development of technological progress powered by improved knowledge.

Let's look at a specific example of how this process unfolded. Humans breathe air, but for a long time we did not know what it consisted of. Oxygen and nitrogen, the two primary components of air, were not identified as elements until the late eighteenth century. Separately, although manure had been used in agricultural practice for millennia, it was not properly studied until the early nineteenth century. That led us to understand that ammonia, which consists of nitrogen and hydrogen, is a powerful fertilizer. Progress eventually resulted in the Haber process, by which atmospheric nitrogen is converted into a form that can be available to plants. Invented in the early twentieth century, it became crucial to raising agricultural yields globally, thus averting the dire consequences Malthus had envisaged. For most humans today, about half the nitrogen in our bodies has been touched by the Haber process on its way into plants and animals that we subsequently ingest.

My simplified history of the discovery of nitrogen fixation doesn't capture the many false starts along the way. It seems strange to us now, but at one point a leading theory as to why some materials burn was that they contain 'phlogiston' which was thought to be released during combustion. Without the improvement of knowledge over time, we might have remained stuck at that theory, not found oxygen and nitrogen and failed to increase agricultural yields.

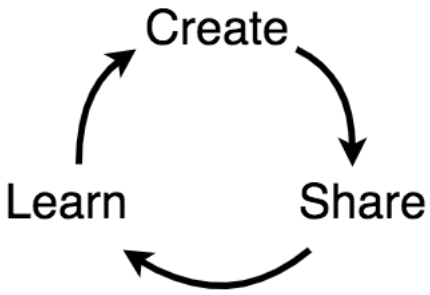
When thinking about the power of knowledge, we must remember that our lifetimes are trivial in the timescale of humanity, which in turn is trivial compared to that of the universe. When considering longer timeframes, we should regard all speculative propositions that don't contravene the laws of physics as possible – a line of thinking inspired by a theoretical foundation for science called constructor theory [53].

Consider for a moment what knowledge might allow us to do in the future. We might rid ourselves of fossil fuels, cure any disease, take care of every human's basic needs and travel to other planets in our solar system (organizations like SpaceX and NASA are already working toward this goal [51]). Eventually we might even travel to the stars. You might think interstellar travel is impossible, but it actually isn't. Extremely difficult? Yes. Requiring technology that doesn't yet exist? Yes. But impossible? No. It is definitely not imminent, but it will become possible with the further accretion of knowledge.

We are the only species on Earth that has created knowledge – not just science, but also art. Art allows us to express our hopes and fears, and culture has helped motivate the large-scale coordination and mobilization of human effort. We might think of the technical component of knowledge as underpinning the 'how' of our lives and the artistic component the 'why'. If you have ever doubted the power of art, just think of the many times throughout history when dictators and authoritarian regimes have banned or destroyed works of art.

The Knowledge Loop

Knowledge has already made possible something extraordinary: by means of the innovations of the Industrial Age we can, in principle, meet everyone's needs. But we need to generate additional knowledge to solve the problems we have introduced along the way, such as the climate crisis. New knowledge does not spring forth from a vacuum; instead it emerges from what I call 'the knowledge loop', in which someone learns something and creates something new, which is then shared and in turn is the basis for more learning.



The Knowledge Loop

The Knowledge Loop

The knowledge loop has been around since humans first developed written language, some five thousand years ago. Before that, humans were able to use spoken language, but that limits learning and sharing in terms of both time and space. Since the invention of written language, breakthroughs have accelerated and access to the knowledge loop has broadened. Those include moveable type (around one thousand years ago), the printing press (around five hundred years ago) and more recently the telegraph, radio and television. Now we are in the middle of another fundamental breakthrough: digital technology, which connects all of humanity to the knowledge loop at zero marginal cost and also allows machines to participate in it.

It is easy to underestimate the potential of digital technology to further accelerate and broaden access to the knowledge loop; to many people, it seems as if these innovations have so far under-delivered. As the investor Peter Thiel once complained, 'We wanted flying cars and all we got was 140 characters.' In fact, we have made great progress on flying cars since then, in no small part because digital technologies have already helped accelerate the knowledge loop.

The Promise and Peril of the Digital Knowledge Loop

The zero marginal cost and universality of digital technologies are already leading to learning, creating and sharing, giving rise to a digital knowledge loop. And as can be seen in the example of YouTube, it holds both amazing promise and great peril.

YouTube has experienced astounding growth since its launch in beta form in 2005. People around the world now upload over 100 hours of video content to the platform every minute. To illustrate just how much content that is, if you were to spend 100 years watching YouTube 24 hours a day, you would be unable to watch all the videos uploaded in a single week. YouTube contains amazing educational content on topics as diverse as gardening and theoretical math. Many of those videos show the promise of the digital knowledge loop, but the peril is also clear: YouTube also contains videos that peddle conspiracies, spread misinformation and even incite hate.

Both the promise and the peril are made possible by the same characteristics of the platform: all the videos are available for free to anyone in the world, and they become available globally the second they are published. Anybody can publish a video, and all you need to access them is an Internet connection and a smartphone. As a result, two to three billion people, almost half of the world's population, has access to YouTube and can participate in the digital knowledge loop.

These characteristics are found in other systems that similarly show the promise and peril of the digital knowledge loop. Wikipedia, the collectively produced online encyclopedia, is another good example. At its most promising, someone might read an entry and learn the method used by Pythagoras to approximate Pi, before creating an animation that illustrates this method and publishing it on Wikipedia, making it easier for other people to learn. Wikipedia entries result from collaboration and an ongoing revision process. You can also examine both the history of the page and the conversations about it, thanks to a piece of software known as a 'wiki' that keeps track of the historical edits [54]. When that process works, it raises the quality of entries over time. But when there is a coordinated effort at manipulation, Wikipedia can spread misinformation instantly and globally.

Wikipedia illustrates another important aspect of the digital knowledge loop: it allows individuals to participate in extremely small ways. If you wish, you can contribute to Wikipedia by fixing a single typo. If ten thousand people fixed one typo every day, that would be 3.65

million typos a year. If we assume that it takes two minutes to discover and fix a typo, it would take nearly fifty people working full-time for a year (2,500 hours) to fix this many typos.

The example of a Wikipedia spelling correction shows the power of small contributions that add up within the digital knowledge loop. Their peril can be seen in social networks such as Twitter and Facebook, where the small contributions are likes and retweets or reposts to one's friends or followers. While these tiny actions can amplify high-quality content, they can just as easily spread mistakes, rumors and propaganda. These information cascades can have significant consequences, ranging from jokes going viral to the outcomes of elections being affected. They have even led to major outbreaks of violence.

Some platforms make it possible for people to contribute passively to the digital knowledge loop. Waze is a GPS navigation app. It tracks users that seem to be in a car, and the speed at which they are moving. It then passes that information back to its servers, and algorithms figure out where traffic is moving smoothly and where drivers will encounter traffic jams. Waze then proposes alternative routes, taking the traffic into account. If you follow a different route proposed by Waze, you automatically contribute your speed on that detour, a further example of passive contribution. To see the peril of passive contribution, consider Google's autocomplete for search queries, which are derived from what people frequently search for. As a result, they often reflect existing biases, but they can also amplify them: often, instead of typing out their whole query, users select one of the autocompleted options presented to them.

The promise of the digital knowledge loop is broad access to a rapidly improving body of knowledge; the peril is that it will lead to a post-truth society that is constantly in conflict. Both of these possibilities are enabled by the same characteristics of digital technologies; once again, we can see that technology by itself does not determine the future.

Technology Is Not Enough

To achieve the promise of the digital knowledge loop and avoid its peril will require a massive societal transition on a par with the two prior ones we have gone through, from the Forager Age to the Agrarian Age and from the Agrarian Age to the Industrial Age. We now need to leave the Industrial Age behind and enter the next one, which I am calling the Knowledge Age. We have based our economies around the job loop, which traps a lot of our attention. We have based our laws governing access to information and computation, as if those were industrial products. We have adopted a range of beliefs that keep us tied to jobs and consumption and are utterly overwhelmed by the new information environment. All of that has to change.

The transition, however, will be difficult because the Industrial Age is a system of many interlocking parts, and systems have a lot of resistance to change. As we saw earlier, simply harnessing digital technology to the existing system results in a hugely uneven distribution of power, income and wealth. And even worse, it tilts the digital knowledge loop away from its promise and towards peril.

The human species is facing problems that we can only overcome if we use digital technology to alleviate rather than worsen attention scarcity. We must the reap promise and limit the perils of digital technology for the knowledge loop. In order to accomplish the transition into the Knowledge Age, we need to make dramatic changes in regulation and self-regulation, and this is what we will examine in Part Four.

Part Four: Enhancing Freedom

My first major aim in writing this book was to establish that we are currently experiencing a period of non-linearity, and my second aim is to propose how we might transition to the Knowledge Age. Our challenge is to overcome the limits of capitalism and move away from a society that is centered on the job loop towards one that embraces the knowledge loop. This section of *The World After Capital* will propose regulatory changes that would increase human freedom and unlock the promise of the digital knowledge loop. There are three components to this:

1. Economic freedom. We must ensure that everyone's needs are met without them being forced into the job loop. Once we have economic freedom, we can embrace automation and enable everyone to participate in and benefit from the digital knowledge loop.
2. Informational freedom. We must remove barriers from the digital knowledge loop that limit learning from existing knowledge, in order to accelerate the creation and sharing of new knowledge. At the same time, we must build systems into the digital knowledge loop that support critical inquiry.
3. Psychological freedom. We must free ourselves from scarcity thinking and its associated fears that impede our participation in the digital knowledge loop. Much of the perceived peril arises from a lack of psychological freedom.

With these increased individual freedoms will come the possibility of a peaceful transition from the Industrial Age to the Knowledge Age that is not dictated and top-down, but one that results from individual choices. There is no guarantee that these changes will be sufficient to avoid a disastrous transition, but I am convinced that without them we are headed for just that, incurring a species-level risk for humanity. Later in the book I will discuss the values and systems that are necessary for successful collective action in a world of increased individual freedom.

Economic Freedom

If you were to quit your job right now, could you afford to take care of your needs? And if you are retired, what would happen if you suddenly stopped receiving your pension? If you are supported by a spouse or partner, could you still afford food, shelter and clothing without them? If you could no longer meet your needs in any of these situations, you are not economically free. Your decisions on how much of your labor to sell and whom to sell it to, whether to stay with your partner and where to live are not free decisions.

Many people in the US are not free in this sense. A recent survey asked respondents if they had enough money to pay for a $1,000 emergency, and over two-thirds said they did not [55]. Other studies have found that about 75 per cent of Americans over the age of forty are behind on saving for retirement and 31 per cent of all non-retired adults have no savings at all [56] [57].

If you are not economically free, you are not able to participate freely in the knowledge loop, which is why economic freedom is a cornerstone of the Knowledge Age. We must make people economically free in order that they have the time to learn new knowledge, from practical skills to the latest theoretical physics. We need them to create new knowledge using what they have learned. And finally, we need them to share this knowledge with others.

We have massive problems to overcome, including the current COVID-19 pandemic and most of all the climate crisis, and participation in the knowledge loop has never been more important. To enable us to do so, we must be able to embrace automation rather feel threatened by it.

Universal Basic Income

Economic freedom is a reality for the wealthy, for tenured professors and retirees with pensions and savings, but how can we make it a reality for everyone? The answer is to provide everyone with a guaranteed income to cover their needs, including housing, clothing and food. This income would not depend on whether someone is married or single, employed or unemployed, rich or poor – it would be unconditional (also referred to as 'universal').

At first glance, this idea of a 'universal basic income' (UBI) may seem outrageous. Getting paid simply for being alive – isn't that akin to socialism? Where would this money come from? And won't people simply descend into laziness and drug addiction? We will examine each of these objections to UBI in turn, but let's first consider the arguments for UBI as a way of achieving economic freedom.

Concerns about economic freedom are by no means new. When the American republic was in its infancy, economic freedom was within everyone's reach. There was plenty of land available, and any family could hypothetically make ends meet through small-scale farming (also known as subsistence farming). Thomas Jefferson considered formalizing the idea of land grants as a way of ensuring a free citizenry. It is important to point out that this land was being taken away from Native Americans who were losing their freedom (something that was conveniently left out of the calculation). Even back then, observers such as the philosopher and political activist Thomas Paine understood that land would run out at some point – they raised the specter of a time when citizens might have to trade labor in order to provide for their needs [58], before concluding that an alternative to land would be to give everyone money to live. The idea of increased freedom through direct payments thus goes back to the earliest days of the American nation.

If you don't find this argument for UBI compelling, consider the case of air. We can all afford to breathe air because it is free and distributed around the globe (regulation is required to keep it clean – there were many problems with air pollution during industrialization, and it is estimated that more than one million people still die in China every year from air pollution [59]). Our freedom is not restricted by having to find air, and the power of UBI would be to make us equally free when it comes to the solutions for our other needs, by making food, housing and clothing affordable for everyone.

As I argued earlier, our technologies are sufficiently developed that we are capable of meeting everyone's needs. Farming can generate enough food for everyone. We can easily make enough clothing and provide everyone with shelter. It is the knowledge and capital that humanity has created that has made this possible. And our technological progress is accelerating while global population growth is slowing, so it will get easier – that is, as long as we generate enough new knowledge to overcome the problems we are facing, starting with the climate crisis.

The question is not whether we have the ability to meet everyone's needs but whether our economy and society distribute the resources fairly, and that is where UBI comes in. UBI enables markets to function without forcing people into the job loop. UBI lets everyone freely participate in these markets, freeing up attention and enabling people to live where and with whom they want.

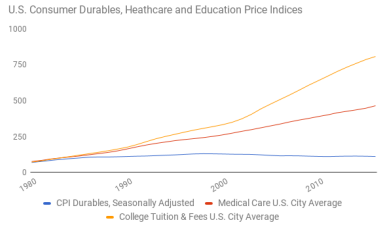
Industrial society presents us with two fundamentally different ways of distributing resources. In one, individuals participate in a market economy; in the other, governments provide for people's needs. Those options form the extremes of a spectrum that has a variety of 'hybrid' arrangements in the middle, such as government-subsidized housing, for which people pay reduced rent. UBI solves the allocation issue while avoiding reliance on an ever-expanding government sector. It is the opposite of communism and socialism in that regard, because it is all about reducing the extent of government activity.

After the Second World War, only about 5 per cent of people in the US were employed by government, which comprised about 42 per cent of the economy [60] [61] [62]. In the Soviet Union, by contrast, most of the working population was employed by the state, which owned close to 100 per cent of the economy, but that system was less effective at allocating resources. Nevertheless, the size and scope of government has gradually expanded in the US and in Europe; in many European economies it accounts for more than half of the economy.

Food, clothing and shelter are obvious solutions to human needs, but UBI could also cover the cost of education and healthcare. That might seem ambitious, given how quickly education and healthcare costs have risen over the past decades, but technology can make both of these far more affordable in the near future.

Technological Deflation

If you are struggling to take care of your basic needs, the world will seem an expensive place. Yet the data shows that a lot of things have been getting cheaper for some time. In the US, as the below chart shows, the price of consumer durables has been falling since the mid-1990s. The decline in the price of consumer durables has been caused by technological progress. We are getting better at making stuff, and the automation of production and distribution is a big part of that. While this will hurt you if you lose your job as a result, if you have money to buy things it will help you. And with universal basic income everyone will have the money, which as prices fall over time will buy you more and more.



The decline in the price of consumer durables has made clothing easily affordable. Technology is also driving down the cost of smartphones, which will themselves be essential in making education and healthcare more affordable. And the price decline will only accelerate as we begin to use technology such as additive manufacturing (also known as '3D printing'), manufacturing products only when they are needed and close to where they are required [63].

As for housing, here too technology is making it much cheaper to put up a building. In early 2017, the first house to be constructed using mobile 3D printing technology was built in Russia in just 24 hours. [65] Another factor making housing more affordable is the sharing of existing housing, through services offered by companies such as Airbnb and Couchsurfing. Despite such progress, it still costs a fortune to live in places where the demand for housing exceeds the available supply, such as Manhattan and San Francisco; with UBI, people can live where housing is more affordable.

The city of Detroit has in recent years been giving away houses as an alternative to demolishing them [66], and in some rural areas of the US you can rent a home for as little as a couple of hundred dollars per month [67]. Many people can't currently take advantage of these opportunities, since they can't find a job in these locations. By contrast, UBI provides geographic freedom. People would no longer be trapped in expensive locations just so they can meet their basic needs.

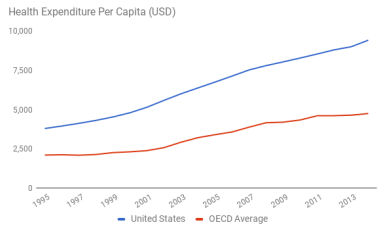
One large group of people is already free of the constraints of work: retirees. And sure enough, many people move away from expensive cities when they retire, to places where real estate is more affordable [68]. When considering the cost of shelter, rather than analyzing how much people need to pay to live where they may be trapped today, we should look at what the cost would be in a world that has UBI.

Food is another area where technology stands to offer massive gains. While some argue that genetically modified foods hold the key to feeding the planet affordably, other near-term breakthroughs don't carry the potential issues that they pose. Indoor vertical farming, for instance, allows for a precise delivery of nutrients and light to plants, as well as huge increases in productivity. It also allows food to be grown much nearer to where it is consumed, reducing the costs associated with transportation, all of which adds up to a dramatic cost reduction.

Technology also promises a dramatic decline in the cost of education. Over the last decade, the availability of online learning resources has grown rapidly, including many free ones, such as the language learning app Duolingo. In addition to online courses such as edX or Khan Academy, there are millions of blog posts that explain specific topics. And of course, YouTube is bursting with educational videos on a near-infinite range of subjects, from sailing to quantum computing.

There is evidence that the exorbitant rise in the cost of college tuition in the US is beginning to slow. When analyzing this data, we must remember that there is a huge amount of inertia in our educational system and job market. Many employers continue to believe they must hire graduates from the best universities, which drives up prices for higher education, with a ripple effect that extends all the way down to private nursery schools. It will be some time before most students turn to free or affordable online resources for all their learning needs, but at least the possibility now exists. The COVID-19 crisis has shown the potential of online education, with schools all around the world switching from in-person instruction to prevent the pandemic from spreading faster.

Healthcare is a similar story. Per capita spending in the United States far exceeds that of other countries, having risen much more quickly than the rate of inflation for many years, but that hasn't translated into better care. For instance, Cuba has for many years had an almost identical life expectancy to the US, despite spending less than a tenth on healthcare per capita [69]. Debates have raged as to whether the Affordable Care Act or other legislative interventions will decrease healthcare costs or increase insurance premiums. Regardless of what happens, there are a number of reasons why progress with digital technology will bring down healthcare costs.



First, technology makes prices on medical procedures more transparent, enabling more competition that can push prices down. Second, as a result of people using technology to track their own health data, we will live healthier lives and require less care, especially over the long term. And third, technology will lead to faster and better diagnosis and treatment. The online medical crowdsourcing platform CrowdMed has helped many people whose conditions previously went undiagnosed or misdiagnosed. The Human Diagnosis Project (Human Dx) is also working on a system to help improve the accuracy of diagnoses.

Figure 1 is a platform that lets doctors exchange images and other observations relating to medical cases, and Flatiron Health pools data on oncology patients, to enable targeted treatment. In addition, a number of companies are bringing telemedicine into the app era; HealthTap, Doctor On Demand, Teladoc Health and Nurx all promise to dramatically reduce the cost of delivering care.

We might think that a large proportion of healthcare cost results from pharmaceuticals rather than doctors' visits, but in fact they account for only about 10 per cent of total spending [70]. However, technology will likely drive costs down here, too. One pharma entrepreneur told me about the potential for personalized treatment that could dramatically improve the effectiveness for a wide range of conditions, including many cancers, motor neuron disease and Alzheimer's. And in the longer term, technologies such as CRISPR gene editing will give us unprecedented abilities to fix genetic defects [71] that currently result in large and ongoing expenses.

But Isn't Deflation a Bad Thing?

You might be confused by my presentation of deflation as a positive thing; economists, after all, tend to portray it as an evil that should be avoided at all costs. They are primarily concerned about growth as measured by GDP, which they argue makes us all better off. They assert that if people anticipate that prices will drop, they will be less likely to spend money, which will decrease output and lead owners of capital to make fewer investments, resulting in less innovation and lower employment. That, in turn, makes people spend even less, causing the economy to contract further. Economists point to Japan as a country that has been experiencing deflation and contracting output. To avoid this scenario, they argue for policies designed to achieve some amount of inflation, including the Federal Reserve's so-called 'quantitative easing', which is intended to expand the supply of money.

However, in a world where digital technology drives technological deflation, this reasoning is flawed. GDP is an increasingly flawed measure of progress because it ignores positive and negative externalities. For instance, making education and healthcare radically cheaper could lower GDP, while clearly making people much better off. A second flaw in economists' reasoning is that it assumes technological progress is tied to growth in production; it is, in fact, possible to achieve technological progress even when economic activity as measured by GDP appears stagnant. Increases in economic, informational and psychological freedom allow us to accelerate the knowledge loop, which is the foundation of all progress. A great example of this is open-source software, which has driven a lot of technological progress outside of the traditional economic model.

Technological deflation is what puts society in a position where UBI becomes both possible and increasingly helpful. The payment required to take care of each person's needs is lower today than it would have been a decade ago, and it will be lower still in the future. Technological deflation is what allows people to break out of the job loop.

UBI is Affordable

With all this background information, you might wonder how much a universal basic income should be. My working proposal for the United States is $1,000 per month for everyone over the age of 18, $400 per month for everyone over the age of 12 and $200 per month for every child. These numbers might seem low, but bear in mind that the goal of UBI isn't to make people well-off; it's simply to allow them to take care of their needs. We have mistakenly come to embrace unlimited wants, which is why it was important that we re-established a clear distinction between wants and needs. We should also remember both that fulfillment of our basic needs will get cheaper due to technological deflation, and also that UBI won't be introduced overnight. My numbers are intended to work over time, as other government programs are phased out and a UBI is phased in.

Let's consider these numbers further. While everyone will spend their UBI in different ways, a possible allocation for a typical adult would roughly break down as follows, on a monthly basis: $300 for housing, $300 for food, $100 for transportation, $50 for clothing, and $50 for Internet access and associated equipment, with the balance spent differently each month (for example, on healthcare as required).

You might wonder why I am proposing a lower payment for children and teenagers. First, we can meet many of their basic needs more cheaply than we can for adults. Second, there is historic evidence that the number of children people have is partially determined by economics; UBI should not incentivize adults to have more children, so as to 'skim' their income. That's especially important because – as discussed earlier – we want the birth rate to decline globally so we eventually reach peak population.

When you calculate how much money would be required to provide a UBI in the United States, based on the 2015 population, you wind up with an annual figure of about $3 trillion [72] [73]. While that is a huge sum, it represents just 17 per cent of the size of the economy as measured by GDP in 2015, and around 10 per cent considered as a percentage of 2015 gross output, which measures not just final output but also intermediate steps [74] [75] [76]. Where will this money come from? There are two sources: government budgets and money creation.

In the US in 2015, total government revenues from taxation and fees were about $6 trillion [77], so the money for a UBI could, in theory, come from redirecting existing budgets. There would then be another $3 trillion of money for critical government activities, such as law enforcement and national defense (the budget for the latter was $0.6 trillion in 2015 [78]). Regardless of the political process by which such a reallocation might be accomplished, there is no fundamental impossibility that would prevent it.

Having a UBI can also substantially increase government revenues. At the moment, nearly half of all earners' salaries don't require them to pay federal income tax. Once people have a UBI, every additional dollar earned could be taxed. For instance, if you are currently single and earn a salary of $10,000, you do not need to file a federal income tax return. With a UBI, that could be taxed at a rate of 25 per cent, generating $2,500 in tax revenue. This could provide as much as $0.3 trillion, a 5 per cent increase in total government revenues. Of

course, people who already pay taxes would effectively be paying back some of their UBI in the form of higher taxes. Applying a 25 per cent tax rate for that group, which would receive roughly half of all UBI payments, would result in an additional $0.4 trillion. In other words, the net amount required for a UBI with a 25 per cent federal tax rate applied starting with the first dollar earned is about $2.3 trillion.

Government revenues can also be expanded in ways that accomplish other goals. For instance, we should increase taxation on pollution, and in particular the emission of greenhouse gases. Taxes are a well-established way of dealing with negative externalities and we have made good use of this effect – for instance, aggressively taxing cigarettes has resulted in dramatically diminished consumption. Estimates of the potential revenue for a carbon tax are around $0.3 trillion per year, and might be even higher. So, between offsets from income tax (which would occur automatically) and a greenhouse gas tax (which we need anyway), the funds needed for UBI could be reduced to about $2 trillion. Though that's a massive number, social security and Medicare/Medicaid each cost about $1 trillion. So in the extreme, UBI could be financed through a massive reallocation of existing programs.

There is, however, another way to provide much or all of the money needed for UBI that involves moving away from today's banking system and issuing money directly to people instead. In today's fractional reserve banking system, commercial banks extend more credit than they have deposits, with the Federal Reserve Bank acting as the so-called 'lender of last resort'. For instance, in the 2008 financial crisis, the Fed bought up potentially bad assets to give banks liquidity. Europe has had a policy of 'quantitative easing' (often abbreviated as QE), where a central bank makes it progressively easier for commercial banks to extend loans beyond their existing deposits.

The idea is that by extending loans to businesses that need to finance the purchase of equipment or require more working capital (to hire more sales people, for example), banks will help the economy grow. While banks have done that to some degree, they have increasingly focused on large corporations and have been lending to people who are already wealthy, for acquiring second homes or even for financial speculation. Conversely, poor people have virtually no access to affordable credit and lending to small businesses has been decreasing. The net result has been a rise in wealth and income inequality. Interestingly, this lopsided effect of bank-based money creation was understood as early as the 18th century in the writings of the economist Richard Cantillon and has become known as the 'Cantillon Effect'.

An alternative system would be to remove banks from money creation by forcing them to hold their deposits at the Fed. Known as 'full-reserve banking', this would eliminate all risk from the commercial banks. Credit extension could happen via marketplace lending, as enabled by companies such as LendingClub, for individuals, and Funding Circle, for businesses. Money creation could happen simply by giving the new money directly to people as part of their UBI payments, a system sometimes referred to as 'QE for the people'.

What orders of magnitude are we talking about? The terms M0, M1, M2 and M3 are measures of how much money has been created in the economy. In the US, we no longer track the larger monetary aggregates, such as M3, and only use narrower measures, such as M2, and even that has been growing by about $1 trillion each year over the last decade. The amount of money created by quantitative easing is likely to be much bigger. We can consider the development of debt more directly. US households have about $8 trillion in mortgage debt [79], over $1 trillion in auto loans [80], over $1 trillion in student loans [81] and nearly $1 trillion in credit card debt [82]. Total household debt can increase by as much as $1 trillion in a single year. US business debt stands at $25 trillion, of which about $15 trillion is in the financial sector.

The amount of money created annually is thus in the same ballpark as UBI. Historically, the idea of the government 'printing' money is associated with fears of runaway inflation of the sort that occurred in Germany's Weimar Republic. There are several reasons why this would not be the case with a proper UBI scheme. First, the amount of new money created would be fixed and known in advance. Second, as we saw earlier, technology is a strong deflationary force. Third, the net amount of money created can be reduced over time by removing money from the economy, which could be accomplished through negative interest rates on bank deposits above a certain amount, with payment collected by the central bank. Alternatively, a system of 'demurrage' could be implemented, in which a fee is levied on all currency holdings or the holdings are automatically shrunk (with digital currencies, the latter is now possible).

I expect the path to UBI to involve changes to government budgets, taxation and the monetary system; however we decide to get there, my back-of-the-envelope calculations above show that UBI is affordable in the United States today. Economic freedom for all is within our reach today.

Impact of UBI on the Labor Market

One of the many attractive features of UBI is that it doesn't remove people's ability to sell their labor. Suppose someone offers you $5 per hour to look after their dog. Under UBI you are completely free to accept or reject that proposal, without distortion from a minimum wage. The reason we need a minimum wage in the current system is to guard against exploitation, but this problem exists only because people do not have the option to walk away from potential employment. If a UBI was in place, they would.

The dog-sitting example shows why a minimum wage is a crude instrument that results in distortion. If you liked dogs, you might happily take the work for $5 per hour. You might be able to watch several dogs at once, or to do it while writing a blog post or watching videos on YouTube. Clearly government should not interfere with such a transaction. The same is true of working in a fast food restaurant. If employees have the option to walk away from a job, the labor market will naturally find how much it takes to get someone to work in, say, McDonalds. That might turn out to be $5 per hour or it might turn out to be $30 per hour.

One frequently expressed concern about UBI is that people would stop working altogether and cause the labor market to collapse. Experiments with UBI, such as the Manitoba Basic Annual Income Experiment in Canada in the 1970s, showed that while people somewhat reduced their working hours when they were paid such income, there was no dramatic labor shortage. People will generally want to earn more than their basic income provides, and the price adjustment of labor will make working more attractive. Furthermore, in conjunction with the income tax change discussed in the previous section, UBI removes a problem with many existing welfare programs in which people lose their entire benefit when they start to work, resulting in tax rates that are effectively above 100 per cent. With UBI, whatever you earn is in addition to your basic income and you pay the normal marginal tax rate on that.

But what about dirty or dangerous jobs? Will there be a price of labor high enough to motivate anyone to do them, and will the companies that need this labor be able to stay in business? Businesses will have a choice between paying people more to do such work or investing in automation. In all likelihood, the answer will be a combination of both, but because of the pressures created by technological deflation, we will not return to labor-price-induced inflation.

UBI would have two other important impacts on the labor market. The first has to do with volunteering. There are not currently enough people looking after the environment or taking care of the sick and elderly. Labor is frequently under-supplied in these sectors because there is insufficient money behind the demand and a reliance on donations. As for the elderly, many of them do not have sufficient savings to afford personal care. When people have to work pretty much every free hour to meet their needs, you they have time to volunteer; providing them with UBI has the potential to vastly increase the number of volunteers (we observe increased volunteering among pensioners, who are effectively already on a UBI).

The second big effect UBI would have on the labor market is a dramatic expansion of the scope for entrepreneurial activity. A lot of people who would like to start a local business, such as a nail salon or a restaurant, have no financial cushion and can never quit their jobs to give it a try. I sometimes refer to UBI as 'seed money for everyone'; more businesses getting started in a community would mean more opportunities for fulfilling local employment.

Once they get going, some of these new ventures would receive traditional financing, including bank loans and venture capital, but UBI also has the potential to significantly expand the reach and importance of crowdfunding. If you feel confident that your needs are taken care of, you will be more likely to start an activity that has the potential to attract support via crowdfunding, such as recording music videos and putting them up on YouTube. Also, if your needs are taken care of, you will be more likely to use a fraction of any income you receive on top of UBI to support crowdfunded projects.

Other Objections to UBI

I have addressed the three biggest objections to UBI by showing that it is affordable, that it will not result in inflation and that it will have a positive impact on the labor market. There are some other common objections that are worth addressing, including a moral objection that people have done nothing to deserve receiving such an income, which is answered in its own section below.

Another objection to UBI is that it diminishes the value of work in society, but in fact the opposite is true: UBI recognizes how much unpaid work exists in the world, including child-rearing. We have created a situation where the word 'work' has become synonymous with getting paid; we conclude that if you do not get paid for an activity, it cannot be work. As an illustration of another approach, Montessori Schools, which base their teaching on creativity and problem-solving, use 'work' to refer to any 'purposeful activity'.

A further objection is that UBI robs people of the purpose that work provides. However, work as the sole source of human purpose is a relatively new idea that is largely attributable to the Protestant work ethic. Human purpose tended previously to be much more based in following the precepts of religion, which might include work as one of many commandments. Put differently, the source of human purpose is subject to redefinition over time; contribution to the knowledge loop is a more suitable focus for the future than work.

One other frequent objection is that people will spend their basic income on alcohol and drugs, an assertion often accompanied by claims that the casino money received by Native Americans has caused drug problems among that population. There is no evidence to support this objection – no UBI pilots have found a significant increase in drug or alcohol abuse, and the opioid crisis has in the meantime been the largest drug epidemic in US history. Research shows that, contrary to widely held belief, casino money has contributed to declines in obesity, smoking and heavy drinking.

Some people object to UBI not because they don't think it will work, but because they claim it is a cynical ploy by the rich to silence the poor and keep them from rebelling. Some who voice this criticism genuinely believe it, but others use it as a tool of political division. Whatever the case, the impact of UBI is likely to be the opposite, as Thomas Paine recognized. In many parts of the world, including the United States, the poor are effectively alienated from the political process. They are too busy holding down one or more jobs to be able to run for office, or sometimes even to vote – American elections are held on a weekday and employers are not required to give employees time off work to vote.

UBI as a Moral Imperative

Before we examine informational freedom, we should remind ourselves why individuals deserve to have enough to take care of their needs. Why should they have this right by virtue of being born, just as they have the right to breathe air?

None of us did anything to make the air – we inherited it from the planet. Similarly, no one who is alive today did anything to invent electricity – it had already been invented, and we have inherited its benefits. You might point out that electricity costs money and people have to pay for it, but they pay for the cost of producing it rather than for the cost of its invention. And we might substitute many other amazing examples of our collectively inherited human knowledge for electricity, such as antibiotics.

We are incredibly fortunate to have been born into a world where capital is no longer scarce, and using our knowledge to take care of everyone's basic needs is therefore a moral imperative. UBI accomplishes that by giving people economic freedom, allowing them to escape the job loop and accelerating the knowledge loop that gave us this incredible knowledge in the first place.

Informational Freedom

Can you read any book you want to? Can you listen to all the music ever recorded? Do you have access to any Web page you wish to consult? In the past, when copying and distributing information was expensive, such questions would not have made much sense. In the early days of writing, when books were copied by hand, they were rare, costly and subject to errors – few people had access to them.

In the digital age, when the marginal cost of making and distributing a copy has shrunk to zero, all limitations on digital information are artificial. They involve adding costs to the system in order to impose scarcity on something that is abundant. For example, billions of dollars have been spent on preventing people from copying and sharing digital music files [83].

Why are we spending money to make information less accessible? When information existed only in analog form, the cost of copying and distributing it allowed us to build an economy and a society that was based on information scarcity. A record label, for instance, had to recruit musical talent, record in expensive studios, market the music, and make and distribute physical records. Charging for them allowed the label to cover its costs and turn a profit. Now that individuals can make music on a laptop and distribute it for free, the fixed costs are dramatically lower and the marginal cost of each listen is zero. And with that, the business model of charging per record, per song or per listen, and the copyright protections required to sustain it, no longer make sense. Despite the ridiculous fight put up by the music industry, our listening is generally either free (meaning that it is ad-supported) or part of a subscription. In either case, the marginal cost of each listen is free.

Despite this progress in the music industry, we accept many other artificial restrictions on information access because this is the only system we know. To transition into the Knowledge Age, however, we should strive for an increase in informational freedom. This is not unprecedented in human history – prior to the advent of the printing press, stories and music were passed on orally or through copying by hand. There were no restrictions on who could tell a story or perform a song.

To be clear, information is not the same as knowledge. Information, for instance, includes the huge number of log files generated every day by computers around the world, many of which may never be analyzed. We don't know in advance what information will turn out to be the basis for knowledge, so it makes sense to retain as much information as possible and make access to it as broad as possible. This section will explore various ways in which we can expand informational freedom, the second important step that will facilitate our transition to a Knowledge Age.

Access to the Internet

The Internet has been derided by some who claim it is a small innovation compared to, say, electricity or vaccinations, yet this is not the case. The Internet allows anyone, anywhere in the world, to learn how electricity or vaccinations work. If we disregard artificial limitations imposed on it, the Internet provides the means to access and distribute all human knowledge to all of humanity. As such, it is the crucial enabler of the digital knowledge loop – and access to the Internet is a central aspect of informational freedom.

At present, over 3.5 billion people are connected to the Internet, a number that is increasing by over 200 million every year [84]. This tremendous growth has become possible because the cost of access has fallen dramatically. A capable smartphone costs less than $100 to manufacture. In places with competitive markets, 4G bandwidth is provided at prices as low as $8 per month [85] [86].

Even connecting people who live in remote parts of the world is getting much cheaper, as the cost for wireless networking is decreasing and we are increasing our satellite capacity. For instance, there is a project underway to connect rural communities in Mexico for less than $10,000 per community. At the same time, in highly developed economies such as the US, ongoing technological innovation such as MIMO wireless technology will further lower prices for bandwidth in densely populated urban areas [87].

All this means that even at relatively low levels, UBI would cover the cost of Internet access, provided that we keep innovating and maintain highly competitive and properly regulated markets for access to it. This is an example of how the three different freedoms reinforce each other: economic freedom allows people to access the Internet, which is the foundation for informational freedom.

As we work to make affordable Internet access universal, we must also address limitations to the flow of information on the network. In particular, we should oppose restrictions on the Internet imposed by our governments and Internet service providers (ISPs). Both of them impose artificial restrictions, driven by a range of economic and policy considerations.

One Global Internet

By design, the Internet does not have any concept of geography. Most fundamentally, it constitutes a way to connect networks with one another (hence its name) – any geographic restrictions that exist have been added in, often at great cost. For instance, Australia and the UK have recently built so-called 'firewalls' around their countries, not unlike China's own Internet censorship system. It cost the Australian government around $44 million to build its online perimeter [88]. This extra equipment places the Internet under government control, restricting informational freedom. Furthermore, both China and Russia have blocked virtual private network services, tools that allow individuals to circumvent these artificial restrictions [89]. As citizens, we should be outraged that our own governments are spending our money to restrict our informational freedom. Imagine governments in an earlier age spending taxpayer money so citizens could dial fewer phone numbers.

No Artificial Fast and Slow Lanes

The same equipment used by governments to impose geographic boundaries on the Internet is used by ISPs to extract more money from customers, distorting access in the process through practices including paid prioritization and zero-rating. To understand why they are a problem, let's take a brief technical detour.

When you buy access to the Internet, you pay for a connection of a certain capacity. If it provides 10 megabits per second and you use that connection fully for sixty seconds, you would have downloaded (or uploaded, for that matter) 600 megabits, the equivalent of 15–25 songs on Spotify or SoundCloud (assuming 3–5 megabytes per song). The fantastic thing about digital information is that all bits are the same. It doesn't matter whether you accessed Wikipedia or looked at images of kittens – you have paid for the bandwidth and should be free to use it to access whatever parts of human knowledge you want.

That principle, however, doesn't maximize profit for the ISP. In order to do so, they seek to discriminate between different types of information, based on consumer demand and the supplier's ability to pay. First, they install equipment that lets them identify bits based on their origin. Then they go to a company like YouTube or Netflix and ask them to pay to have their traffic 'prioritized', relative to the traffic from other sources. Another form of manipulation common among wireless providers is so-called 'zero-rating', where some services pay to be excluded from the monthly bandwidth cap. If permitted, ISPs will go a step further: in early 2017, the US Senate voted to allow them to sell customer data, including browsing history, without customer consent [90].

The regulatory solution to this issue is called 'net neutrality', but what is at stake here is informational freedom. Our access to human knowledge should not be skewed by our ISPs' financial incentives. We might consider switching to another ISP that provides neutral access, but in most geographic areas, especially in the United States, there is no competitive market for Internet access. ISPs either have outright monopolies (often granted by regulators) or operate in small oligopolies. For instance, in the part of New York City where I live, there is just one broadband ISP.

Over time, technological advances such as wireless broadband may make the market more competitive, but until then we need regulation to avoid ISPs limiting our informational freedom. This concern is shared by people all over the world; in 2016, India objected to a plan by Facebook to provide subsidized Internet access that would have given priority to their own services.

Bots for All of Us

Once you have access to the Internet, you need software to connect to its many information sources. When Tim Berners-Lee first invented the World Wide Web in 1989, he specified an open protocol, the Hypertext Transfer Protocol, that anyone could use both to make information available and to access it [91]. In doing this, Berners-Lee enabled anyone to build software, so-called Web servers and browsers that would be compatible with this protocol. Many people did, including Marc Andreessen with Netscape, and many web servers and browsers were available as open-source or for free.

The combination of an open protocol and free software meant permissionless publishing and complete user control. If you wanted to add a page to the Web, you could just download a Web server, run it on a computer connected to the Internet and add content in the HTML format. Not surprisingly, the amount of content on the Web proliferated rapidly. Want to post a picture of your cat? Upload it to

your Web server. Want to write something about the latest progress on your research project? There was no need to convince an academic publisher of its merits – you could just put up a Web page.

People accessing the Web benefited from their ability to completely control their own Web browser. In fact, in the Hypertext Transfer Protocol, the Web browser is referred to as a 'user agent' that accesses the Web on behalf of the user. Want to see the raw HTML as delivered by the server? Right click on your screen and use 'view source'. Want to see only text? Instruct your user agent to turn off all images. Want to fill out a Web form but keep a copy of what you are submitting for yourself? Create a script to have your browser save all form submissions locally.

Over time, platforms on the Web have interfered with some of the freedom and autonomy enjoyed by early users. I went on Facebook recently to find a note I posted some time ago on a friend's wall. It turns out that you can't search through all the wall posts you have written; rather, you have to manually go backwards in time for each friend. Facebook has all the data, but they've decided not to make it searchable. I'm not suggesting any misconduct on their part; my point is that you experience Facebook the way they want you to experience it. If you don't like how Facebook's algorithms prioritize your friends' posts in your newsfeed, tough luck.

Imagine what would happen if everything you did on Facebook was mediated by a software program – a 'bot' – that you could control. You could instruct it to go through and automate the cumbersome steps that Facebook lays out for finding old wall posts. Even better, if you had been using this bot all along, it could have kept your own archive of wall posts in your own data store and you could simply instruct it to search your archive. If we all used bots to interact with Facebook and didn't like how our newsfeed was prioritized, we could ask our friends to instruct their bots to send us status updates directly, so that we could form our own feeds. This was entirely possible on the Web because of the open protocol, but it is not possible in a world of proprietary and closed apps on smartphones.

Although this example might sound trivial, bots have profound implications in a networked world. Consider the on-demand car services provided by companies such as Uber and Lyft. As drivers for these services know, each of them provides a separate app for them to use. You can try to run both apps on one phone or you can even have two phones, but the closed nature of the apps means that you cannot use your phone's computing power to evaluate competing offers. If you had access to bots that could interact with the networks on your behalf, you could simultaneously participate in these various marketplaces and play one off against the other.

Using a bot, you could set your own criteria for which rides you want to accept, including whether a commission charged by a given network was below a certain threshold. The bot would then allow you to accept only rides that maximize the fare you receive. Ride-sharing companies would no longer be able to charge excessive commissions, since new networks could arise to undercut them. As a passenger, using a bot could allow you to simultaneously evaluate the prices between different services and choose the one with the lowest price for a particular trip.

We could also use bots as an alternative to antitrust regulation, in order to counter the power of technology giants like Google or Facebook without foregoing the benefits of their large networks. These companies derive much of their revenue from advertising, and consumers currently have no way of blocking ads on mobile devices. But what if users could change mobile apps to add ad-blocking functionality, just as they can with Web browsers?

Many people decry ad-blocking as an attack on journalism that dooms the independent Web, but that is a pessimistic view. In the early days of the Web, it was full of ad-free content published by individuals. When companies joined in, they brought their offline business models with them, including paid subscriptions and advertising. Along with the emergence of platforms such as Facebook and Twitter with strong network effects, this resulted in a centralization of the Web – content was increasingly either produced on a platform or moved behind a paywall.

Ad-blocking is an assertion of power by the end user, which is a good thing in all respects. Just as a judge recently found that taxi companies have no special right to see their business model protected from ridesharing companies, neither do ad-supported publishers [92]. And while this might prompt publishers to flee to apps in the short term, in the long run it will mean more growth for content that is paid for more directly by end users (for example, through subscriptions or crowdfunding).

To curtail the centralizing power of network effects, we should shift power to the end users by allowing them to have user agents for mobile apps, just as we did with the Web. The reason users don't wield the same power on mobile is that native apps relegate end users to interacting with services using our eyes, ears, brain and fingers. We cannot use the computing capabilities of our smartphones, which are as powerful as supercomputers were until quite recently, in order to interact with the apps on our behalf. The apps control us, instead of us controlling the apps. Like a Web browser, a mobile user agent could do things such as block ads, keep copies of responses to

services and let users participate in multiple services simultaneously. The way to help end users is not to break up big tech companies, but to empower individuals to use code that executes on their behalf.

What would it take to make bots a reality? One approach would be to require companies like Uber, Google and Facebook to expose their functionality, not just through apps and websites, but also through so-called 'application programming interfaces' (APIs). An API is what a bot uses to carry out operations, such as posting a status update on a user's behalf. Companies such as Facebook and Twitter have them, but they tend to have limited capabilities. Also, companies have the right to shut down bots, even when a user has authorized them to act on their behalf.

Why can't I simply write code that interfaces with Facebook on my behalf? After all, Facebook's app uses an API to talk to their servers. Well, in order to do so I would have to 'hack' the Facebook app to figure out what the API calls are and how to authenticate myself to them. Unfortunately, there are three separate laws that make those steps illegal. The first is the DMCA's anti-circumvention provision. The second is the Computer Fraud and Abuse Act (CFAA). And the third is the legal construction that by clicking 'I accept' on an end user license agreement (EULA) or a set of terms of service, I am legally bound. The last of these is a civil matter, but criminal convictions under the first two laws carry mandatory prison sentences.

If we were willing to remove these three legal obstacles, hacking an app to give programmatic access to systems would be possible. People might argue that those provisions were created to solve important problems, but that is not entirely clear. The anti-circumvention provision of the DMCA was put in place to allow the creation of digital rights management systems for copyright enforcement. What you think of this depends on what you think about copyright, a subject we will look at in the next section.

The CFAA could be tightened substantially without limiting its potential for prosecuting fraud and abuse, and the same goes for restrictions on usage a company might impose via a license agreement or a terms of service. If I only take actions that are also available inside the company's app but happen to take them programmatically, why should that constitute a violation?

However, don't companies need to protect the cryptographic keys that they use to encrypt communications? Aren't 'botnets' behind all those so-called 'distributed denial-of-service' attacks, in which vast networks of computers flood a service with requests so that nobody else can access it? It's true that there are a lot of compromised machines in the world that are used for nefarious purposes, including set-top boxes and home routers, yet that only demonstrates how ineffective the existing laws are at stopping illegal bots. As a result, companies have developed the technological infrastructure to deal with them.

How would we prevent people from using bots that turn out to be malicious code? Open-source code would allow people to inspect it to make sure it does what it claims. However, open source is not the only answer. Once people can legally be represented by bots, many markets currently dominated by large companies will face competition from smaller startups that will build, operate and maintain these bots on behalf of their end users. These companies will compete in part on their maintenance of a trust relationship with their customers, much like an insurance broker represents a customer between multiple insurance carriers.

Legalizing representation by a bot would undermine the revenues of large companies. We might worry that they would respond by slowing their investment in infrastructure, but I doubt this would happen. Uber, for instance, was recently valued at $50 billion. The company's 'take rate' (the percentage of the money paid for rides that they keep) is 20 percent. If competition forced that rate down to 5 percent, Uber's value might fall to $10 billion, but that is still a huge figure and capital would still be available for investment.

That is not to say that there should not be limitations on bots. A bot representing me should have access to any functionality that I can access, but it should not be able to do things I can't do, such as pretend to be another user or gain access to other people's private posts. Companies can use technology to enforce such access limits for bots without relying on regulation.

Even if you are now convinced of the merits of bots, you might be wondering how we will get there. The answer is that we can start very small. We could run an experiment in a city like New York, where the city's municipal authorities control how on-demand transportation services operate. They might say, 'If you want to operate here, you have to let drivers interact with your service programmatically.' Given how big a market the city is, I'm confident these services would agree. Eventually we could mandate APIs for all Internet services that have more than some threshold number of users, including all the social networks and even the big search platforms, such as Google.

To see that this is possible in principle, one need look no further than the European 'open banking' initiative that requires banks to offer an API for bank accounts. This means that consumers can access third-party services, such as bill payment and insurance, by authorizing them to have access via the API instead of having to open a new account. This dramatically lowers switching costs and is making the market for financial services more competitive. The ACCESS Act, introduced by Senators Mark Warner and Josh Hawley in the US, was

the first attempt to provide a similar concept for social media companies. While this particular effort didn't get very far, it points to the possibility that bots could be used as an important alternative to Industrial Age antitrust regulation for shifting power back to end users.

Limiting the Limits to Sharing and Creating

After we have fought against geographical and prioritization limits and have bots that represent us online, we will still face legal limits that restrict what we can create and share. I will first examine copyright and patent laws and suggest ways to reduce how much they limit the knowledge loop. Then we'll turn to privacy laws.

Earlier in the book, I noted how expensive it was to make copies of books when they had to be copied one letter at a time. We eventually invented the printing press and movable type; together, the two made the reproduction of information faster and cheaper. Even back then, governments and churches saw this as a threat to their authority. In England, the Licensing of the Press Act of 1662 made the government's approval to operate a printing press a legal requirement [93]. Approval would be granted in exchange for agreeing to censor content that was critical of the government or that ran counter to the teachings of the church. This is how copyright began.

Over time, as economies grew and publishing companies emerged as business enterprises, copyright became commercially meaningful and a source of profit. The logic went like this: 'If I have the copyright to a specific material, you cannot make copies of it, which means that I am the only one allowed to produce and sell copies of it' (effectively copyright grants a monopoly in providing the copyrighted content).

Behind this transformation of copyright was the idea that in order for content to be produced, incentives needed to exist for its creators. If you were working on a book, it was thought that owning it would provide an incentive to improve it over time through revisions, as well as to write it in the first place.

Over time, copyright holders have strengthened their claims and extended their reach. For instance, with the passing of the Copyright Act of 1976, the requirement to register a copyright was removed; if you created content, you automatically held copyright in it [94]. Then, in 1998, the Copyright Term Extension Act extended the length of a term of copyright from 50 to 70 years beyond the life of the author. This became known as the 'Mickey Mouse Protection Act' because Disney had lobbied for it; having built a profitable business based on protected content, they were mindful that a number of their copyrights were due to expire [95].

More recently, copyright lobbying has attempted to interfere with the publication of content on the Internet, through proposed legislation such as the Protect IP Act and the Stop Online Piracy Act, and language in the Trans-Pacific Partnership, a trade deal that the United States did not ultimately join. In these latest attempts at expansion, the conflict between copyright and the digital knowledge loop has become especially clear. Copyright limits what you can do with content, essentially restricting you to consuming it. It dramatically curtails your ability to share content and to create other works that use some or all of it. Some of the more extreme examples include takedowns of videos from YouTube that used the song 'Happy Birthday to You', which was until recently copyrighted.

From a societal standpoint, it is never optimal to prevent someone from listening to or watching content. Since the marginal cost of accessing a digital copy is zero, the world is better off if that person gets enjoyment from that content. And if that person is inspired and creates some new inspiring content themselves, then the world is a lot better off.

Although the marginal cost for copying content is zero, you might wonder about the fixed and variable cost that goes into making it in the first place. If all content were to be free, then where would the money to produce it come from? Some degree of copyright is probably needed, especially for large-scale projects such as Hollywood movies; it is likely that nobody would make them if, in the absence of copyright protection, they weren't economically viable. Yet even here there should be constraints on enforcement – for instance, you shouldn't be able to take down an entire service because it hosts a link to a pirated movie, as long as the link is promptly removed. More generally, I believe that copyright should be dramatically reduced in its scope and made much more costly to obtain. The only automatic right accruing to content should be attribution; the reservation of additional rights should require a registration fee, because you are asking for content to be removed from the digital knowledge loop.

Let's take music as an example. Musical instruments were made as far back as 30,000 years ago, pre-dating the idea of copyright by many millennia. Even the earliest known musical notation, which marks music's transition from information to knowledge, is around 3,400 years old [96]. Clearly people made music and shared it long before copyright existed. In fact, the period during which someone was

able to earn a lot of money from making and then selling recorded music has been extraordinarily short, starting with the invention of the gramophone in the 1870s and peaking in 1999, the year that saw the biggest profits in the music industry [97].

Before this short period, musicians made a living either from live performances or through patronage. If copyrighted music ceased to exist, musicians would still compose, perform and record music, and they would make money in the ways that they did prior to the rise of copyright. Indeed, as Steven Johnson found when he examined this issue, that is already happening, to some degree: 'the decline in recorded-music revenue has been accompanied by an increase in revenues from live music ... Recorded music, then, becomes a kind of marketing expense for the main event of live shows' [98]. Many musicians already choose to give away digital versions of their music, releasing tracks for free on Soundcloud or YouTube and making money from performing live or through crowdfunding methods such as Kickstarter and Patreon.

Imagine a situation where the only automatic right accruing to an intellectual work was one of attribution. Anyone wanting to copy or distribute your song would have to credit you, but such attribution could happen at zero marginal cost and would not inhibit any part of the knowledge loop. Attribution imposes no restrictions on making, accessing and distributing copies, or on creating or sharing derivative works. It can include referencing who wrote the lyrics, who composed the music, who played which instrument and so on. It can also include where you found this particular piece of music. This practice of attribution is already becoming popular for digital text and images using the Creative Commons License, or the MIT License in open-source software development.

If you don't want other people to use your music without paying you, you are asking for it to be removed from the knowledge loop, thus reducing the benefits that the loop confers upon society. You should pay for that right, which not only represents a loss to society but will also be costly to enforce. The registration fee should be paid on a monthly or annual basis, and when you stop paying it, your work should revert to attribution-only rights.

In order to reserve rights, you should have to register your music with a registry, with some part of the copyright fee going towards maintaining them. Thanks to the emerging technology of blockchains, which make possible the operation of decentralized databases that are not owned or controlled by any one entity, competing registries can exist that access the same global database. The registries would be free to search, and registration would involve a check that you are not trying to register someone else's work. The registries could be built in a way that anyone operating a music streaming service, such as Spotify or Soundcloud, could easily implement compliance to make sure they are not freely sharing music that has reserved rights.

It would even be possible to make the registration fee dependent on what rights you wanted to retain. For instance, your fee might be lower if you were prepared to allow non-commercial use of your music and to allow others to create derivative works, while it might increase significantly if you wanted all your rights reserved. Similar systems could be used for all types of content, including text, images and video.

Critics might object that the system would impose a financial burden on creators, but it is important to remember that removing content from the knowledge loop imposes a cost on society. And enforcing this removal, by finding people who are infringing and penalizing them, incurs additional costs for society. For these reasons, asking creators to pay is fair, especially if their economic freedom is already assured by a UBI.

UBI also provides an answer to another argument that is frequently wielded in support of excessive copyright: employment by publishers. This argument is relatively weak, as the major music labels combined employ fewer than twenty thousand people [99] [100] [101]. On top of that, the existence of this employment to some degree reflects the societal cost of copyright. Owners, managers and employees of record labels are, for the most part, not the creators of the music.

Let me point out one more reason why a system of paid registration makes sense. No intellectual works are created in a vacuum – all authors have read books by other people, all musicians have listened to tons of music and all filmmakers have watched countless movies. Much of what makes art so enjoyable is the existence of a vast body of art that it draws upon and can reference, whether explicitly or implicitly. We are all part of the knowledge loop that has existed for millennia.

While copyright limits our ability to share knowledge, patents limit our ability to use it to create something new. Just as having a copyright confers a monopoly on reproduction, a patent confers a monopoly on use. The rationale for patents is similar to the argument for copyright: the monopoly that is granted results in profits that are supposed to provide an incentive for people to invest in research and development.

As is the case with copyright, this argument of incentive should be suspect. People invented things long before patents existed and some people have continued to invent without seeking them. Mathematics is a great example of the power of intrinsic motivation, with people frequently dedicating years of their lives to work on a single problem (often without success). It is because of this human drive to solve problems that the field has made extraordinary advances, entirely in the absence of patents, which thankfully were never extended to include mathematical formulas and proofs.

We can trace the use of patents to Venice in the mid-fifteenth century; Britain had a fairly well-established system by the seventeenth century [102]. That leaves thousands of years of invention, a time that saw such critical breakthroughs as the alphabet, movable type, the invention of the wheel and gears. This is to say nothing of those inventors who have chosen not to patent their inventions because they saw how that would impose a loss on society. These inventors include Jonas Salk, who created the polio vaccine; other inventions that were never patented include X-rays, penicillin and the use of ether as an anesthetic [103]. Since we know that limits on the use of knowledge impose a cost, we should ask what alternatives to patents exist, which might stimulate innovation.

Many people are motivated by wanting to solve a problem, whether it's one they have themselves or something that impacts the world at large. With a universal basic income, more of these people will be able to spend their time on inventing. We will also see more innovation because digital technologies are reducing the cost of inventing. One example of this is the company Science Exchange, which has created a marketplace for laboratory experiments. Say you have an idea that requires you to sequence a bunch of genes. The fastest gene sequencing available is from a company called Illumina, whose machines cost between $850,000 and $1 million to buy [104]. Through Science Exchange, however, you can access such a machine for less than $1,000 per use [105]. Furthermore, the next generation of sequencing machines is on the way, and these will further reduce the cost – technological deflation at work.

A lot of legislation has significantly inflated the cost of innovation. In particular, FDA rules around drug trials have made drug discovery prohibitively expensive, with the cost of bringing a drug to market currently around $1 billion. While it is obviously important that patients are protected, there are novel statistical techniques that would allow for smaller and faster trials. A small step was taken recently with the compassionate use of not-yet-approved drugs for fatally ill patients. Excessive medical damage claims have presented another barrier to innovation. As a result of these costs, many drugs are either not developed at all or are withdrawn from the market, despite their efficacy – for example, the vaccine against Lyme disease, which is no longer available for humans following a damage claim [106].

Patents are not the only way to incentivize innovation; another historically successful strategy has been the offering of public prizes. In 1714, Britain famously offered rewards to encourage a solution to the problem of determining a ship's longitude at sea. Several people were awarded prizes for their designs of chronometers, lunar distance tables and other methods for determining longitude, including improvements to existing methods. In return for receiving the prize money, inventors had to make their innovations available for the use of others [107]. Mathematics provides an interesting example for the effectiveness of prizes, which beyond money also provide recognition. In addition to the coveted Fields Medal for exceptional work by mathematicians under the age of 40, there are also the seven so-called Millennium Prize Problems each with a $1 million reward (only one of which has been solved to-date and Grigori Perelman, the Russian mathematician who solved it, famously turned down the prize money).

At a time when we wish to accelerate the knowledge loop, we must shift the balance towards knowledge that can be used freely. The success of recent prize programs, such as the X Prizes, the DARPA Grand Challenge and NIST competitions, is promising, and the potential exists to crowdfund future prizes. Medical research should be a particular target for prizes, to help bring down the cost of healthcare.

Though prizes can help accelerate the knowledge loop, that still leaves a lot of existing patents in place. I believe much can be done to make the system more functional, in particular by reducing the impact of so-called 'non-practicing entities' (NPEs, commonly referred to as 'patent trolls'). These companies have no operating business of their own, and exist solely for the purpose of litigating patents. They tend to sue not just a company but also that company's customers, forcing a lot of companies into a quick settlement. The NPE then uses the settlement money to finance further lawsuits. Fortunately, a recent Supreme Court ruling placed limits on where patent lawsuits can be filed, which should limit the activity of these NPEs [108].

As a central step in patent reform, we must make it easier to invalidate existing patents, while at the same time making it difficult to obtain new ones. We have seen some progress on both counts in the US, but there is still a long way to go. Large parts of what is currently patentable should be excluded from patentability, including university research that has received even small amounts of public funding. Universities have frequently delayed the publication of research in areas where they have hoped for patents that they could subsequently license out, a practice that has a damaging impact on the knowledge loop.

We have also gone astray in our celebration patents as a measure of technological progress, when we should instead treat them as a necessary evil. Ideally, we would roll back the reach of existing patents and raise the bar for new ones, while also inducing as much unencumbered innovation as possible, through prizes and social recognition.

Getting Over Privacy

Copyrights and patents aren't the only legal limitations that slow down the digital knowledge loop – we are actively creating new restrictions in the form of well-intentioned privacy regulations. Not only do these measures restrict informational freedom; more fundamentally, privacy is in the long-run incompatible with technological progress. Instead of clinging to our current conception of privacy, we need to understand how to be free in a world where information is widely shared. Privacy has been a strategy for achieving and protecting freedom. To get over the idea it while staying free, we need to expand economic, informational and psychological freedom.

Before I expand on this position, let me first note that countries and individuals already take dramatically different approaches to the privacy of certain types of information. For example, Sweden and Finland have for many years published everyone's tax return [109], and some people, including the Chief Information Officer and Dean for Technology at Harvard Medical School [110], have published their entire medical history on the Internet. This shows that a world that safeguards individual freedom through strategies other than privacy is eminently possible.

To better understand this perspective, compare the costs and benefits of keeping information private with the costs and benefits of sharing it widely. Digital technology is dramatically shifting this trade-off in favor of sharing. Take a radiology image, for example. Analog X-ray technology produced images on a physical film that had to be developed and could only be examined by holding them up against a backlight. If you wanted to protect the information on it, you would put it in a file and lock it in a drawer. If you wanted a second opinion, you had to have the file sent to another doctor by mail. That process was costly, time-consuming and prone to errors. The upside of analog X-rays was the ease of keeping the information secret; the downside was the difficulty of putting it to use.

Now compare analog X-rays to digital X-rays. You can instantly walk out of your doctor's office with a copy of the digital image on a thumb drive or have it emailed to you, put in a Dropbox or shared via some other way on the Internet. Thanks to this technology, you can now get a near-instant second opinion. And if everyone you contacted was stumped, you could post the image on the Internet for everyone to see. A doctor somewhere in the world may have seen something similar before, even if it is incredibly rare. This has happened repeatedly on Figure 1, a company that provides an image sharing network for medical professionals.

However, this power comes at a price: protecting your digital X-ray image from others who might wish to see it is virtually impossible. Every doctor who looks at the image could make a copy – for free, instantly and with perfect fidelity – and send it to someone else. And the same goes for others who might have access to the image, such as your insurance company.

Critics will make claims about how we can use encryption to prevent the unauthorized use of your image, but those claims come with important caveats and are dangerous if pursued to their ultimate conclusion. In summary, the upside of a digital X-ray image is how easy it makes it to get help; the downside is how hard it is to protect digital information.

But the analysis doesn't ends there. The benefits of your digital X-ray image go beyond just you. Imagine a huge collection of digital X-ray images, all labeled with diagnoses. We might use computers to search through them and get machines to 'learn' what to look for. And these systems, because of the magic of zero marginal cost, can eventually provide future diagnoses for free. This is exactly what we want to happen, but how rapidly we get there and who controls the results will depend on who has access to digital X-ray images.

If we made public all information relating to healthcare, we would dramatically accelerate innovation in diagnosing and treating diseases. At present, only large pharma companies and a few university research projects are able to develop new medical insights and drugs, since only they have the money required to get sufficient numbers of patients to participate in research. Many scientists are forced to join big pharma companies, so the results of their work are protected by patents. Even at universities, the research agenda tends to be tightly controlled and access to information is seen as a competitive advantage. While I understand that we have a lot of work to do to create a world in which the sharing of health information is compatible with freedom, this is what we should be aiming for.

You might wonder why I keep asserting the impossibility of assuring privacy – after all, don't we have encryption? Well, there are several problems that it can't solve. The first is that cryptographic keys used for encryption and decryption are just digital information

themselves, so keeping them secure is another instance of the original problem. Even generating a key on your own machine offers limited protection, unless you are willing to risk that the data you're protecting will be lost forever if you lose the device. As a result, most systems include some kind of cloud-based backup, making it possible that someone will access your data, either through technical interception or by tricking a human being to unwittingly participate in a security breach. If you want a sense of how hard this problem is, consider the millions of dollars in cryptocurrency that have been lost by people who lost their key or who had them taken over through some form of attack. The few cryptocurrency exchanges that have a decent track record have invested hugely in security procedures, personnel screening and secrecy.

The second problem is so-called 'endpoint security'. The computer of the doctor to whom you are sending your X-ray for a second opinion may have a program on it that can access anything that is displayed on the screen. In order to view your X-ray, the doctor has to decrypt and display it, so this program will have access to the image. Avoiding such a scenario would require us to lock down all computing devices, but that would mean preventing end users from installing software on them. Furthermore, even a locked-down endpoint is still subject to the so-called 'analog hole'; someone might simply take a picture of what is displayed on a screen, which itself could then be shared.

Locked-down computing devices reduce informational freedom and constrict innovation, but they also pose a huge threat to the knowledge loop and democracy. Handing over control of what you can compute and who you can exchange information with would essentially mean a dictatorial system. We are already heading in this direction in mobile computation, partly due to the assertion of a need to protect privacy. Apple uses this argument to explain why the only way to install apps on an iPhone is through their own app store. Imagine this type of regime extended to all computing devices, including your laptop and cloud-based servers, and you have one way in which privacy is incompatible with technological progress. We can either have strong privacy assurance or open general-purpose computing, but we can't have both.

Many people contend that there must be some way to preserve privacy and keep innovating, but I challenge anyone to present a coherent vision of the future where individuals control technology and privacy is meaningfully protected. Whenever you leave your house, you might be being filmed. Every smartphone has a camera, and in the future we'll see tiny cameras on tiny drones. Your gait identifies you almost as uniquely as your fingerprint, your face is probably somewhere on the Internet and your car's license plate is readable by any camera. You leave your DNA almost everywhere you go, and soon we will be able to sequence DNA at home for around $100. Should the government control these technologies? And if so, should penalties be enforced for using them to analyze someone else's presence or movement?

There is an even more profound reason why privacy is incompatible with technological progress. Entropy is a fundamental property of the universe, which means it is easier to destroy than to create. It takes hours to build a sand castle and a single wave washing ashore to destroy it. It takes twenty years of care for a human to grow up and a single bullet to end their life. Because of this inherent asymmetry, technological progress increases our ability to destroy more quickly than our ability to create. Today, it still takes twenty years for a human to grow, yet modern weapons can kill thousands and even millions of people in an instant. So as we make technological progress, we must insist on less privacy, in order to protect society. Imagine a future in which anyone can create a biological weapon in their basement laboratory – for example, an even more deadly version of the COVID-19 virus. After-the-crime police enforcement would be meaningless in such a world.

If we can't protect privacy without passing control of technology into the hands of a few, we should embrace a post-privacy world. We should work to protect people and their freedom rather than data and privacy. We should allow more information to become public, while strengthening individual freedom. Much information is already disclosed through hacks and data breaches [112], and many people voluntarily share private information on blogs and social media. The economic freedom generated by the introduction of a UBI will play a key role here, because much of the fear of the disclosure of private information results from potential economic consequences. For instance, if you are worried that you might lose your job if your employer finds out that you wrote a blog post about your struggles with depression, you are much less likely to share, which repeated across many people keeps depression a taboo topic.

If a post-privacy world seems impossible or terrifying, it is worth remembering that privacy is a modern, urban construct. Though the US Constitution protects certain specific rights, it does not recognize a generalized right to privacy – for thousands of years prior to the eighteenth century, most people had no concept of it. Many of the functions of everyday life used to take place much more openly than they do today. And privacy still varies greatly among cultures – for example, many Westerners are shocked when they first experience the openness of traditional Chinese public restrooms [111]. All over the world, people in small villages live with less privacy than is common in big cities. You can either regard the lack of privacy as oppressive, or you can see a close-knit community as a real benefit.

‘What about my bank account?’ you might ask. ‘If my account number was public, wouldn’t it be easier for criminals to take my money?’ This is why we need to construct systems such as Apple Pay and Android Pay that require additional authentication to authorize payments. Two-factor authentication systems will become much more common in the future, and we will increasingly rely on systems such as Sift, which assesses in real time the likelihood that a transaction is fraudulent. Finally, as the Bitcoin blockchain shows, it is possible to have a public ledger that anyone can inspect, as long as the transactions on it are protected by so-called ‘private keys’ that allow only the owner of a bitcoin address to initiate transactions. Another area where people are nervous about privacy is health information. We worry, for instance, that employers or insurers will discriminate against us if they learn that we have a certain disease or condition. Here the economic freedom conferred by a universal basic income would protect us from destitution because of discrimination; by tightening the labor market, it would also make it harder for employers to refuse to hire certain groups of people. We could also enact laws that require transparency, to track how decisions have been made and detect discrimination more easily.

Observers such as Christopher Poole, the founder of the online message board 4Chan, have worried that in the absence of privacy, individuals wouldn’t be able to engage online as freely. Privacy, they think, helps people feel comfortable assuming multiple online identities that may depart dramatically from their ‘real-life’ selves. I think that by keeping our online selves separate, we pay a price in the form of anxiety, neurosis and other psychological ailments. It is healthier to be transparent than to hide behind veils of privacy. Emotional health derives from the integration of different aspects into a multi-dimensional personality rather than a fragmentation of the self.

Many who argue against a post-privacy approach point out that oppressive governments can use information against their citizens. Without a doubt, preserving democracy and the rule of law is essential if we want to achieve a high degree of informational freedom, and this is addressed explicitly in Part Five. Conversely, however, more public information makes dictatorial takeovers considerably harder. For instance, it is much clearer who is benefiting from political change if tax records are in the public domain.

Psychological Freedom

Imagine you live in a society that has achieved economic and informational freedom. Would you make good use of those freedoms, or would your beliefs and fears hold you back from engaging in the knowledge loop? Or worse yet, would your attention be taken up by systems designed to capture it for their own benefit?

In this situation, would you feel free to pursue your own interests, or would your Industrial Age beliefs keep you trapped in the job loop? Would you have a strong sense of purpose, or would you feel adrift without a clear career path and a boss telling you what to do? Would you seek out new knowledge, or would you confirm what you already believe? Would you feel free to create, or would you hold yourself back? And would you recognize when your attention is being manipulated for the benefit of others?

While the previous sections on economic and informational freedom examined changes that require collective action, this section addresses individual action. We must free ourselves from our deeply engrained Industrial Age beliefs, and we can start on that path by developing some form of mindfulness practice. This is essential to freely directing our attention in the Knowledge Age.

We should start by acknowledging the profound psychological dimension of the transition out of the Industrial Age. Social and economic disruption were making life stressful even before the COVID-19 pandemic. The unfolding climate crisis and the ongoing escalation of political and social tensions around the world are further causes for anxiety. To make matters worse, we have yet to learn to live healthily with new technology and obsessively check our smartphones during meetings, while driving and before we go to sleep. This is taking an immense psychological toll, as increases in sleep disorders, suicide rates, drug overdoses and antisocial activities show.

We need to go beyond that general insight about the population at large and look at what goes on in our own heads, but that requires time and effort because our brains are easily highjacked by emotions which interfere with introspection. Can we overcome the anxieties that might prevent us from gaining, creating and sharing knowledge? Can we put down our phones, when they are designed to draw us in? It might seem a monumental task, but humankind is uniquely adaptable. After all, we have navigated two prior transitions that required dramatic psychological change, first from the Forager Age to the Agrarian Age, and then to the Industrial Age.

We now understand why humans can adapt so well. As neuroscientists have discovered, our brains remain plastic even as we age, meaning that what and how we think can be changed. In fact, we can change it quite deliberately, with techniques such as meditation, breathing and cognitive behavioral therapy [113]. The brain consists both of lower-order systems that produce emotions and higher-order systems that allow for rational thought. Techniques such as conscious breathing offer a way to use our higher-order reasoning to shape our reaction to lower-order emotions. A recent Stanford University study found the neural pathway by which slowing down our breathing lets us calm our mind.

Modern scientific knowledge thus confirms what we have known since ancient times. In the Western tradition, the Stoic philosophers developed practices of thought to temper the emotions. In the Eastern traditions such as Buddhism, meditation and breathing achieve a similar psychological freedom. We will now examine what we need to free ourselves from, in order that we can direct our attention to the knowledge loop.

Freedom from Wanting

The extraordinary success of capitalism has made us confused about work and consumption; we now see them as sources of purpose, instead of as means to an end. Working harder and consuming more allows the economy to grow, so that we can work harder and consume more. Though this sounds crazy, it has become the default position. We went so far as to ingrain this view in religion, moving to a Protestant work ethic that encourages working harder and earning more [114]. Similar changes have taken place throughout Asia, where Confucianism and other religions have undergone this transition.

Even worse, we frequently find ourselves trapped in so-called ‘positional consumption’. If our neighbor buys a new car, we find ourselves wanting an even newer and more expensive model. Such behavior has emerged not just with respect to goods but also to services – think of the $1,000 haircut [115] or the $595-per-person dinner at a Michelin-starred restaurant [117]. Of course, much of this confusion was fueled by trillions of dollars of advertising spend aimed at convincing us to buy more, flooding us with imagery of how happy we would be if only we bought more. Between economic policy, advertising and religion, it is no wonder that many people are convinced that materialism is part of human nature.

However, our addiction to consumption is exactly that – an addiction that exploits a mechanism in the brain. When you desire something, a new car for instance, your brain gets a dopamine hit based on your anticipated happiness, which makes you feel good. Once you get the car, you compare it to your prior expectations. If having the car turns out to be less than you expected, your dopamine levels will decrease and this can cause extreme disappointment. If your expectations are met, your dopamine levels will stay constant. Only if your expectations are exceeded will you get another hit of dopamine. The unfortunate result of this is known as the 'hedonic treadmill'. When your brain is accustomed to certain levels of dopamine, the level required to produce the same feeling of happiness increases. You'll have to raise your expectations even further to get that initial dopamine kick again [116].

That same mechanism, however, can provide long term motivation when the anticipation is aimed at creation or exploration instead of consumption. As an artist or scientist, you can forever seek out new subjects. As a traveler, you can forever seek out new destinations. Freedom from wanting is possible if we recognize that we can point our brain away from consumption and towards other pursuits, many of which are part of the knowledge loop. Redirecting our reward mechanism re-establishes the difference between needs and wants. You need to eat, while you may want to eat at a Michelin-starred restaurant. You need to drink water, while you may want to drink an expensive wine. This is why universal basic income, as discussed earlier, focuses on meeting needs rather than wants. Once you are economically free to meet your needs and have freed yourself from wanting, you can direct your attention into the knowledge loop.

Suppose skiing is your passion and you want to keep seeking the perfect powder – how would a UBI let you focus your attention on it? On a UBI alone, you might not be able to afford an annual ski trip to the Swiss alps, but ski equipment is actually not expensive when you consider that it can last for many years and can be shared with others. And if you're willing to hike up a mountain, you can ski as much as you want without buying a lift pass at an expensive resort.

In this instance, psychological freedom means freeing yourself of assumptions that you might have about how to go skiing. It helps, of course, to remind yourself that many of these assumptions are formed by companies that have a commercial interest in portraying skiing that way. If you can learn to reframe it as an outdoor adventure and a chance to be in nature, it needn't be expensive. A similar logic holds for any number of other activities.

To free ourselves from wanting, we should remind ourselves of the difference between needs and wants, learn how our brain works and point our seeking away from consumption and towards creative activities. For many of us, that means letting go of existing attachments to wants that we have developed over a long time. Finally, we should always cast a critical eye on the advertising we encounter, understanding that it perpetuates illusions about needs and wants and keeps us trapped in the job loop.

Freedom to Learn

Young kids ask upwards of three hundred questions a day [118]. Humans are naturally curious, and it is this curiosity that has driven much of our progress. At the same time, our curiosity was not well-suited to the Industrial Age. If you employ people in a factory job that has them performing the same action all day every day, curiosity will hinder rather than help them. The same goes for many modern service jobs, such as operating a cash register or delivering packages.

The present-day educational system was built to support the job loop of the industrial economy, so it is not surprising that it tends to suppress rather than encourage curiosity. While educators hardly ever state 'suppressing curiosity' as their goal, many of our educational practices do exactly that. For instance, forcing every eight-year-old to learn the same things in math, teaching for tests and cuts to music and art classes all discourage curiosity.

A critical way that we undermine curiosity is by evaluating areas of knowledge according to whether we think they will help us get a 'good job'. If your child expressed an interest in learning Swahili or wanting to play the mandolin, would you support that? Or would you say something like, 'But how will you earn a living with that?' The latest iteration of this thinking is an enthusiasm for learning how to code because of high-paying jobs in software; instead of encouraging curiosity about coding, either for its own sake or as a tool in science or art, we force it into the Industrial Age logic of the job loop.

We need to free ourselves from this instrumental view of knowledge and embrace learning for its own sake. As we have already seen, UBI can go a long way in allying fears that we won't be able to support ourselves if we let our curiosity guide our learning. But will we have enough engineers and scientists in such a world? If anything, it is likely that we will have more than under the current system – after all, forcing kids to study something is a surefire way to squelch their natural curiosity.

The knowledge loop, accelerated by digital technology, brings to the fore other limits to learning that we must also overcome. The first of these is confirmation bias. As humans we find it easier to process information that confirms what we already believe to be true. We can access a huge amount of online content that confirms our pre-existing beliefs rather than learning something new. We risk becoming increasingly entrenched in these views, fracturing into groups with strong and self-reinforcing beliefs. This phenomenon becomes even more pronounced with the automatic personalization of many Internet systems, with 'filter bubbles' screening out conflicting information [120].

Another barrier to learning is the human tendency to jump to conclusions on the basis of limited data. After a study suggested that smaller schools tended to produce better student performance than larger schools, educators began to create a lot of smaller schools, only for a subsequent study to find that a lot of smaller schools were also doing poorly. It turns out that the more students a school has, the more likely it is to approximate the overall distribution of students. A small school is therefore more likely to have students who perform predominantly well or poorly.

Daniel Kahneman discusses these biases in his book Thinking, Fast and Slow. We employ heuristics that result in confirmation bias and storytelling because many of the systems in the human brain are optimized for speed and effortlessness. In a world with an analog knowledge loop, more time exists to correct for these biases. But in a high-velocity digital knowledge loop, we must slow ourselves down or risk passing along incorrect stories. A recent study showed that rumors spread online many times more quickly than truths [121].

The bulk of the systems we currently interact with online are designed to appeal to our cognitive biases rather than to help us overcome them. Companies such as Facebook and Twitter become more valuable as they capture more of our attention through appealing to what Kahneman calls 'System 1', the parts of our brain that run automatically and are responsible for our cognitive biases. You are much more likely to look at cute animal pictures or status updates from your friends than to read an in-depth analysis of a proposal for a carbon tax. The recent explosion of 'fake news' exploits this flaw in our systems, making large-scale manipulation possible.

New systems can help here. We might, for instance, imagine an online reader that presents opposing viewpoints to a given story. For each topic, you could explore both 'similar' and 'opposing' views. Such a reader could be presented as a browser plug-in, so that when you've ventured beyond the confines of a social media platform and are perusing content on the Web, you could bring that exploration with you [122].

Fundamentally though, we all have to actively work on engaging what Kahneman calls 'System 2', the part of our brain that requires effort but lets us think independently and rationally. Developing and keeping up some kind of mindfulness practice is a key enabler for overcoming biases and freeing ourselves to learn.

Freedom to Create

After learning, the next step in the knowledge loop is creating. Here, we also need to work on our freedom – as Picasso once said, 'Every child is an artist. The problem is how to remain an artist once we grow up.' We censor ourselves as adults, inhibiting the natural creativity we enjoyed as children. The educational system, with its focus on preparing for standardized tests, further crushes our creative impulses. Many of people eventually come to believe that creativity is something that they are not capable of.

The job loop further solidifies these beliefs about creativity, and even institutionalizes them; society categorizes people into amateurs and professionals. We venerate the professional guitar player, artist or sculptor but denigrate the amateur, dismissing their work as 'amateurish' or 'amateur hour'. When we start to measure creativity by how much money an artist or musician makes rather than the passion they feel for a pursuit, there is no wonder that many people fear they will never measure up.

Distractions also inhibit our impulses to create – there's always another YouTube video to watch or another email to read. Our brains are poorly suited to environments that are overloaded with information. We evolved in a world where obtaining information – for instance, the sound of an approaching animal – could be a matter of life or death, and our brains are easily distracted.

In order to be able to create, we need to disconnect ourselves from many of those stimuli. Again, a mindfulness practice will be helpful here by allowing us to tune out interruptions, and there are many hacks we can use to prevent them in the first place.

Freedom to Share

Even after we have created something, many of us fear that when we share it, it will be criticized – someone will call our painting ugly, our code incompetent or our proposal naive. Given the state of much online commentary and the prevalence of 'trolling', those fears are well-founded, but they need not inhibit our participation in the knowledge loop. Part of the answer is to work on the inner strength to continue sharing, despite criticism.

Another part of the answer is that we should cultivate empathy. Whenever we comment on the work of others online, we should keep in mind that they dared to create and share it. And we should also remember that by contributing to the knowledge loop, they have engaged in the very thing that makes us human. Those who manage online communities should provide tools for flagging and banning people who are abusive or make threats aimed at shutting down sharing.

If you live in a country that is subject to dictatorship, censorship or mob rule, sharing opinions, art or research can result in imprisonment, torture or even death. And yet despite that, we routinely find people who freely share in these places. We should take inspiration and courage from those people, and we should support people's ability to build systems to enable sharing in these places that are censorship-resistant and allow for pseudonymous and anonymous expression.

In the Knowledge Age, there is such a thing as sharing too much – not sharing too much personal information, but mindlessly sharing harmful information. Threats, rumors and lies can take on lives of their own, and we can find ourselves contributing to an 'information cascade', in which an initial bit of information picks up speed and becomes an avalanche that destroys everything in its path.

So there is a dual aspect to having the psychological freedom to share: we need to free ourselves from fear to share our creations and our ideas, while also needing to control our emotional responses so that we do not disrupt the knowledge loop. Ask yourself whether what you're sharing will enhance or hurt the pursuit of knowledge. If the answer is not obvious, it might be better not to share it.

Psychological Freedom and Humanism

Self-regulation lies at the heart of psychological freedom, and allows us to separate our wants from our needs. It lets us consider our initial reactions to what others are saying, writing or doing without immediately reacting in anger. It lets us have empathy for others and to be open to learning something new. And it lets us overcome our fears of creating and sharing.

Still, as humans we have fundamental needs for purpose and recognition that make many of us psychologically unfree. Existential angst can express itself in many different forms, ranging from an inability to do anything to a manic desire to do everything. The persistence of religion is partly explained by addressing these needs. Most religions claim that our purpose is to follow a divine set of rules and that if we follow them, the respective god or gods will recognize our existence.

Many organized religions intentionally disrupt the knowledge loop. They restrict the process of critical inquiry through which knowledge improves over time, through mechanisms such as censorship and divine 'knowledge', which is often encoded in sacred texts. This serves to maintain the power of the gatekeepers to the texts and their interpretation. While adhering to a religion may meet your existential psychological needs, it may also make it difficult for you to participate fully and freely in the knowledge loop.

The same is true for many informal beliefs. The belief in a preordained individual destiny can be used to answer one's need for purpose, but it also prevents one from being psychologically free. Or people can belong to communities that meet the individual need for recognition, but impose a need for conformity that restricts participation in the knowledge loop. It can often be difficult to recognize how much of one's behavior is controlled by custom or peer pressure.

A new humanism, which recognizes the importance of knowledge, provides an alternative source of purpose that does not inhibit psychological freedom but rather enhances it. Participating in the knowledge loop is our purpose; learning new things, being creative and sharing with others is encouraged. This doesn't mean that everyone has to be the proverbial 'rocket scientist' – there are a great many ways to participate in the knowledge loop, including creating art and caring for others and the environment.

In order to help people be psychologically free, we need to substantially change most countries' education systems; today's systems were developed to support the Industrial Age, and their goal is to produce people to participate in the job loop. We need a system that

celebrates knowledge for its own sake, allows students to discover their individual interests and deepen them into a purpose, and educates them about how to be psychologically free. Put differently, we need to put humanism at the center of learning.

Humanism and the knowledge loop thus have important implications for how we can reorganize society and take responsibility for the world around us. And this will be the subject of Part Five.

Part Five: Taking Action

If you are now convinced of the importance of the knowledge loop and of the scarcity of attention in the digital age, and by my suggestions for increasing economic, informational and psychological freedom, that leaves a huge question: can it be done?

You may have thought my proposals to change everything from how money is created to who controls computation were too extreme. One reaction might be to dismiss them as utopian and argue that we cannot change everything about how we live, yet to do so ignores the fact that we have already changed everything twice. Each of our two prior shifts in scarcity – from food in the Forager Age to land in the Agrarian Age, and from land to capital in the Industrial Age – was accompanied by extraordinary transformations.

When we transitioned from the Forager Age to the Agrarian Age, we went from nomadic to sedentary, from egalitarian to hierarchical, from promiscuous to monogamous and from animistic to theistic religions. When we went from the Agrarian Age to the Industrial Age, we moved from the countryside to cities, from large extended families to nuclear ones, from commons to private property and from great-chain-of-being theologies to the Protestant work ethic. Though the first of these transitions took place over millennia and the second one over centuries, they still show that a shift in the binding scarcity causes everything to change.

With scarcity shifting once more, from capital to attention, we will again have to change everything – no matter how daunting that may seem. What follows is a series of ideas for how each of us can contribute to that change. There are many different projects to be tackled – my list is far from exhaustive and should be regarded as inspiration for how we can take action.

Growing Mindfulness

One action we should all take is the development of a mindfulness practice. The word ‘mindfulness’ is used a lot and is easy to dismiss, but for the reasons discussed in the section on psychological freedom, without such a practice it will be difficult to participate fully in the other actions discussed below. We each need to find what works for us, whether that is meditation, yoga, running or something else entirely. I do a breathing exercise every day, first thing in the morning and last thing in the evening. I started doing this about five years ago and the change in my life has been profound.

It is also important that we help and inspire other people to do the same. There have been discussions on whether or not math should be mandatory in school, but there has been no such debate around mindfulness. It is entirely possible to go through school and college or university without developing a practice of one’s own. Every one of us would be better off with more mindfulness – the same cannot be said about algebra.

Another way to contribute to the spread of mindfulness is through research and entrepreneurship. Much remains to be understood about how different techniques, or drugs such as psilocybin, influence our brains. There is plenty of room for services such as individualized coaching, and for more apps that help with meditation and breathing.

Fighting the Climate Crisis

The climate crisis is the single biggest collective problem facing humanity. If we fail to direct attention and resources to fighting it, the climate crisis will make the transition from the Industrial Age worse than the transition into it, which involved two world wars. This may sound hyperbolic, but the climate crisis represents an existential risk for humanity.

Every day, unimaginable amounts of energy hit the Earth in the form of sunlight. Much of this energy is radiated back into space, but greenhouse gases reduce the Earth's ability to shed heat and instead keep it trapped inside the atmosphere. To get a sense of how much heat we are talking about, we can express it in terms of Hiroshima-sized nuclear bombs. Compared to pre-industrial times, how much more heat is the Earth retaining? Is it the equivalent of one nuclear bomb per year? Per month? Per week? Per day? The reality is that the heat being trapped amounts to four nuclear bombs per second, three hundred and sixty-five days a year.

Imagine for a moment that we had alien spaceships were dropping four nuclear bombs into our atmosphere every second. What would we do? We would, of course, drop everything else to fight them. This is, of course, roughly the plot of the movie Independence Day. Except with the climate crisis it is not aliens – it is ourselves, and it is not bright explosions, but all the molecules in the atmosphere and in the oceans wiggling a bit harder (that's what it means for something to heat up).

There are many ways to fight the climate crisis. They include making personal changes such as switching to electric heating, voting for politicians who are committed to tackling the problem and becoming active in movements such as Extinction Rebellion. As with mindfulness, research and entrepreneurship provide crucial avenues for action. For instance, there are many questions in how to make nuclear fusion work (which would provide a clean source of abundant electricity) or how to most effectively absorb greenhouse gases from the atmosphere. There are companies to be founded that will further the adoption of solar power, not just here but in the developing world.

Defending Democracy

What is the political process by which we should achieve the profound changes that are required? We are seeing some leaders emerge in this period of transition who provide simplistic, populist answers to difficult questions that advocate a return to the past. There is a danger around the world, including here in the United States, that we will slide into dictatorship and other forms of autocratic government.

Democracy is the only system of government in which the knowledge loop can function to its full potential. Democracy allows new policies to be tested, with a peaceful transition to another set of policies if they don't work. As tempting as a quick autocratic fix might seem, we need to figure out what it takes to have a working democracy. Some things seem obvious, such as limiting the influence of money in politics.

Because attention is scarce, it can be bought, either by raising and spending a lot of money, or by doing or saying outrageous things. Neither is good for democracy – the former because it makes candidates beholden to the interests of their backers and the latter because it results in polarization rather than critical debate.

Going further, we should experiment with new forms of democracy. Given the complexity of the modern world, I am in favor of specialization and delegated voting; we should explore forms of democracy in which I can delegate my vote to people I trust on specific issues, such as energy policy. These delegates, in turn, would elect a leader for the energy agency based on their proposed policies.

A more extreme version of this, which is worth exploring in the context of the climate crisis, is a so-called 'citizen's assembly'. Citizens would be selected at random from the population to form an assembly and given access to experts in the field. With the experts' help, they would come up with a plan that is then either implemented right away or put to a vote. This idea recalls Athenian democracy, which relied on the random selection of citizens for various government functions. The advantage of such an approach is that it would shortcut long electoral cycles and allow for policies to be chosen that might not be popular with any one party. For example, Ireland recently successfully used a citizens' assembly to develop an abortion policy.

These are just two of many possible variations of how democracy can work. With digital technologies, we have options that were not previously feasible. Take, for example, the town of Jun in Spain, which uses Twitter as the primary communication channel between citizens and local government officials [123]. We should start to explore more of these possibilities, and part of that means revisiting the geographic units we use for decision-making. The key principle here is that decisions should be made at the lowest possible level. We need to make some decisions globally, such as limiting greenhouse gases, but the ways of achieving such a limit should be decided at lower levels.

Making decisions at the lowest possible level, a principle known as 'subsidiarity', is especially important during a time of great change. For instance, what is possible in education is changing rapidly due to digital technology, so we should allow experimentation at a local level. By running many small experiments, we can quickly figure what works well.

Most of all, we need to reject attempts at dictatorship and autocracy. These effectively disable the knowledge loop because they cannot tolerate freedom of expression – their power is based on the suppression of criticism. This is especially dangerous in a time of transition that requires the debate and implementation of new ideas. There are many ways of defending democracy, starting with the obvious one of voting against would-be dictators. Of course, speaking out against them once they are in power is also crucial, even if it comes at high personal cost. Finally, building and participating in systems that support uncensorable, anonymous expression is a crucial action to help undermine dictatorships.

Fostering Decentralization

As I have previously described, most developed countries have large central governments with a high degree of centralized decision-making. That is complemented by a high degree of concentration in the economy, with a few firms dominating most industries. Both of these things are bad for the knowledge loop, as they inhibit experimentation. A recent example of this was illustrated by the response to COVID-19. In the US, testing was largely federally controlled, making a differentiated state-level response difficult to execute. Even a state the size of California, which on a standalone basis would be the world's sixth largest economy, was unable to approve rapid tests developed by California-based startups).

We can take many actions to help foster a return to decentralization. For example, where it is permitted, parents can choose to home school their children with other parents, forming experimental education pods. More importantly, we can participate in the burgeoning field of blockchain technologies. The best known blockchain is Bitcoin, a digital alternative to gold.

Blockchains are decentralized networks that can nonetheless achieve consensus, such as on how many Bitcoin are controlled by which address on the network. This matters because as we saw earlier, much of the power of companies such as Facebook, Google or Amazon comes from network effects. Government power is also derived from a network effect that arises from the ability to issue currency and regulate banking. Building decentralized alternatives to these systems using blockchain technology is a way of removing power from government and large corporations.

As it turns out, when blockchains work properly they are uncensorable. Unless a government or corporation can take over a large percentage of the nodes on a blockchain network, the information maintained by the network will continue to be propagated correctly, even when some nodes are trying to purge or manipulate the contents. The only option governments face is to cut their population off from accessing the networks, and this requires a high degree of control over all Internet traffic (as has been achieved, for example, by China). This is why fighting against national 'firewalls' is so important.

While any one new blockchain system has a high likelihood of failing, the large number of current experiments will produce systems that have the potential to be transformative on a global scale. One of the most exciting possibilities is that we may end up with a UBI built outside the existing government budgets as part of a cryptocurrency. A variety of projects are currently tackling this, including Circles and Duniter. To be clear, decentralization and blockchains do not represent a panacea. Some problems require centralization to be solved (for instance, water and sewage are centrally controlled for a reason). And decentralization can bring its own problems, such as the potentially aggravation of the 'Digital Balkans' problem that we encountered earlier. But at a time of excessive centralization, it is crucial that we foster decentralization to act as a counterweight.

Improving Learning

Learning is the hardest step in the knowledge loop. How many of us say something like ‘I wish I could play the guitar’ but either never do anything about it or give up after a short period? Learning is hard and we should try to make it easier, more fun and more social. There has been plenty of recent progress here – for example, Duolingo has made language learning more accessible by breaking it down into small units that are customized to each learner.

I am personally excited about helping to create two particular projects. One is an integrated platform for learning math, programming, engineering and science. These areas of knowledge are closely related, yet the way we teach them is often oddly disconnected. The other project is a compendium of the principles of knowledge. We have so much knowledge that it seems impossible to know more than a tiny fraction, but this is partly an illusion because much of it is a variation or an application of an underlying principle. Collecting and explaining these will make knowledge more accessible and help to unify areas that seem unrelated.

While the COVID-19 crisis has come at a terrible cost, it has also accelerated innovation in learning. Many parents are discovering that home schooling their children, whether individually or in small groups, may be a viable option. There are many ways to encourage learning that is based on fostering our innate curiosity, from simply learning something new oneself to inventing and building new systems.

Promoting and Living Humanism

Given the limits of capitalism that we explored earlier, we might find socialism or even some form of Marxism tempting. That too, however, represents a return to a populist past rather than an invention of the future. The alternatives that people commonly propose are also Industrial Age thinking and rooted in the scarcity of capital. As should be clear by now, my proposals are effectively about shrinking capitalism, much as we previously shrunk agriculture, to make room for participation in the knowledge loop.

Central to this project is the promotion of humanism and the policies associated with it, such as the adoption of a UBI. Everyone can take action on this, from contributing to a UBI trial to creating content under a Creative Commons license.

We can also promote humanism by applying humanist values to our everyday decision-making. The starting point for this is to see ourselves as human first, with nationality, faith, gender and race all a distant second. I realize that this is easier for me as a white male living in the United States, but that removes nothing from the underlying values of humanism. I described some of these in the earlier chapter on humanism, but here is a more complete list.

Solidarity: There are over 7 billion people living on a planet that does not easily support human life, in an otherwise inhospitable solar system. We need to support each other above all else, irrespective of such differences as gender, race or nationality. The big problems that humanity faces, such as the climate crisis, will impact all of us and require our combined effort.

Diversity: We are all unique and we should celebrate these differences. They are beautiful and a part of our humanity.

Responsibility: Only humans have the power of knowledge, so we are responsible for other species. For example, we are responsible for whales rather than the other way round.

Non-violence: Mental or bodily harm reduces or removes our ability to contribute to humanity – we must avoid it wherever possible.

Mindfulness: Our brain is capable of a broad range of emotions, but when they highjack us we lose our capability for rational thinking. Mindfulness is the ability to experience our emotions while retaining rationality.

Joyfulness: While we are capable of many emotions, moments of joy are what makes life worth living.

Criticism: When we see something that could be improved, we need to have the ability to express that. Individuals, companies and societies that do not allow criticism become stagnant and will ultimately fail.

Innovation: Beyond criticism, the major mode for improvement is to create new ideas, products and art. Without innovation, the systems become stagnant and start to decay.

Optimism: We need to believe that problems can be solved. Without optimism we will stop trying and problems like the climate crisis will become bigger, until they threaten human extinction.

These values can help us answer questions such as whether we should kill animals to feed ourselves. One answer is that we stop eating meat and become vegetarian or vegan; another is that we work out how to grow meat in a lab. Both are valid answers under the humanist approach. Continuing to eat animals without working on alternatives – standing still with the status quo, in which we do not live up to our responsibility – is not.

Conclusion

We need to act with great urgency during this transition to the Knowledge Age. We are woefully behind in dealing with the climate crisis, and there is a real possibility that society will degenerate into violence. In the longer term, we face a potential threat from the possible rise of superintelligences, and there is also a chance that we are not alone in this universe. These are risks that we can only deal with if we stop clinging to the Industrial Age and instead embrace the Knowledge Age. Conversely, if we are able to make the transition, huge opportunities are ahead of us.

A Dangerous Spiral

The world is rapidly being pulled apart by people who want to take us back to the past, as well as people who are advancing technology while being trapped in Industrial Age thinking. As I described in the introduction, technology increases the space of the possible, but it does not automatically make everyone better off. Bound by Industrial Age logic, automation is enriching a few, while putting pressure on large sections of society. Nor does digital publishing automatically accelerate the knowledge loop – we find ourselves in a world plagued by fake news and filter bubbles.

Those who are trying to take us back into the past are exploiting these trends. They promise those negatively affected by technology that everything will be better, while investing heavily in mass manipulation. They seek to curtail the open Internet, while simultaneously building up secret surveillance. This is true on both sides of the American political spectrum – neither the Republicans nor the Democrats have a truly forward-looking platform and both favor governmental controls over online platforms and speech, instead of empowering endusers as described in the section on Informational Freedom.

The net effects of this are an increase in polarization and a breakdown of critical inquiry and democracy. As disturbing as it is, the possibility of large-scale violent conflict, both within and between nations, is increasing, while the climate crisis wreaks havoc on industrial and food supply chains around the world. At the same time, our ability to solve the problem of climate change is rapidly decreasing because we are spiraling back towards the past.

Transhumans, Neohumans and Superintelligence

There is another reason for urgency: we find ourselves on the threshold of creating both transhumans and neohumans. Transhumans are humans with capabilities enhanced through both genetic modification (for example, via CRSPR gene editing) and digital augmentation (for example, the brain-machine interface Neuralink), while neohumans are machines with artificial general intelligence. I am including them both here because they can be full-fledged participants in the knowledge loop.

Both transhumans and neohumans may eventually become a form of 'superintelligence' and pose a threat to humanity. The philosopher Nick Bostrom has written a book on the subject, and he and other thinkers warn that a superintelligence could have catastrophic results. Rather than rehashing their arguments here, I want to pursue a different line of inquiry: what would a future superintelligence learn about humanist values from our current behavior?

As we have seen, we are not doing terribly on the central humanist value of critical inquiry. We are also not treating other species well, our biggest failing in this area being industrial meat production. As with many other problems that humans have created, I believe the best way forward is innovation – I am excited about lab-grown meat and plant-based meat substitutes. Improving our treatment of other species is an important way in which we can use the attention freed up through automation.

Even more important, however, is our treatment of other humans. This has two components: how we treat each other now and how we will treat the new humans when they arrive. As for how we treat each other now, we have a long way to go. Many of my proposals are aimed at freeing humans so they can discover and pursue their personal interests, yet the existing education and job loop systems stand in opposition to this freedom. In particular we need to construct the Knowledge Age in a way that allows us to overcome, rather than reinforce, our biological differences. That will be a crucial model for transhuman and neohuman superintelligences, as they will not have our biological constraints.

Finally, how will we treat the new humans? This is a difficult question to answer because it sounds so preposterous. Should machines have human rights? If they are humans, then they clearly should. My approach to what makes humans human would also apply to artificial general intelligence. Does an artificial general intelligence need to have emotions in order to qualify? I would argue that it doesn't, because how we handle emotions varies so widely. And since these new humans will likely share little of our biological hardware, there is no reason to expect that their emotions should be similar to ours. As we charge ahead, this is an important area for further work. We would not want to accidentally create, not recognize and then mistreat a large class of new humans.

The Fermi Paradox and Alien Visitors

I want to provide one final reason for urgency in getting to the Knowledge Age. It is easy for us to think of ourselves as the center of the universe. In early cosmology we put the earth at the center, before we eventually figured out that we live on a small planet circling a star, in a galaxy that is within an incomprehensibly large universe. More recently, we have discovered that the universe contains a great many planets more or less like ours, which means some form of intelligent life may have arisen elsewhere. This possibility leads to many fascinating questions, one of which is known as the Fermi paradox: if there is so much potential for intelligent life in the universe, why have we not yet picked up any signals?

There are different possible answers to this question. For instance, perhaps civilizations get to a point similar to ours and then destroy themselves because they cannot make a crucial transition. Given the way we are handling the current transition, that seems like a distinct possibility. Or maybe all intelligent civilizations encounter a problem that they cannot solve, such as the climate crisis, and either disappear entirely or become primitive. Given the scale of cosmic time and space, short-lived broadcast civilizations like ours would be difficult to detect. Furthermore, climate change is a clear and present danger, but there are many other species-level challenges.

A different answer to the Fermi paradox would present a different challenge: more advanced civilizations may have gone dark so as to not be discovered and destroyed by even more advanced civilizations. By that account, we may be entering a particularly dangerous period, in which we have been broadcasting our presence but do not yet have the means to travel through space.

Opportunities in the Knowledge Age

Conversely, it is worth asking what kind of opportunities we might explore in the Knowledge Age. To begin with, there is a massive opportunity for automation. Fifty years or so into the Knowledge Age, I expect the amount of attention trapped in the job loop to have shrunk to around 20 percent or less of all human attention. This is akin to agriculture shrinking during the Industrial Age. We will finally be able to achieve the level of freedom that many thinkers had predicted previously, as Keynes did in his essay 'The Economic Possibilities for our Grandchildren', where he wrote about achieving a life of mostly leisure. Even Marx envisioned such a world, although he believed it would be brought about differently. He wrote about a system that 'makes it possible for me to do one thing today and another tomorrow, to hunt in the morning, fish in the afternoon, rear cattle in the evening, criticize after dinner, just as I have a mind, without ever becoming hunter, fisherman, herdsman or critic'. That is the promise of the Knowledge Age.

But there are many more opportunities for human progress, including space travel. One of the most depressing moments in my life came when I learned that at some point our sun would burn out and, in the process, annihilate all life on Earth. What is the point of anything we do if everything will come to an end anyhow? Thankfully I came to realize that with enough knowledge and progress, humanity could become spacefaring and live on other planets, before eventually traveling to the stars.

A third opportunity is the elimination of disease. It is sometimes easy to forget how far we have already come on that account. Many of the diseases that used to cripple or kill people have either become treatable or even eliminated. We have started to make major progress in fighting cancer and I believe there is a good chance that most cancers will become treatable within the next couple of decades. Ultimately this raises the question of mortality. Can, and should, we strive to become immortal? I believe we should, although achieving immortality will bring new problems. These are not the ones of overpopulation that some people imagine, as birth rates will be falling and there is, of course, space beyond our planet. The real challenge of immortality will be maintaining the functioning of the knowledge loop, as we will have to figure out not just how to keep the body alive but the mind flexible. Max Planck captured this challenge in his famous quote that 'science advances one funeral at a time' – the older, dominant positions do not allow new theories to displace them.

Our fourth opportunity is to go from capital merely being sufficient to it being abundant. By the definitions set out earlier, that would mean that the marginal cost of capital was zero. The best way to imagine what that might look like is to think of the replicator from Star Trek. Imagine a microwave oven that instead of heating up a dish makes it from scratch, without you having to shop for the ingredients. Such an abundance of capital might seem a preposterous idea that could never be achieved, but for most physical assembly processes today, the factors that limit the rate are the energy required and the need for humans to operate parts of the system. Machine learning is helping with the second factor, but progress on energy has been slow – we don't yet have any fusion reactors that output more energy than is provided to start the fusion, but there is no reason it can't be achieved. With enough knowledge we will make nuclear fusion work, removing the second major barrier to the abundance of capital.

The Challenge Ahead

We live in a period where there is an extraordinary range of possible outcomes for humanity. They include the annihilation of humankind in a climate catastrophe on one extreme and the exploration of the universe on the other. Where we end up depends on the large and small choices each of us makes every day, from how we treat another person in conversation to how we tackle the climate crisis. It is a massive challenge, and I wake up every day both scared and excited about this moment of transition. I sincerely hope that *The World After Capital* makes a small contribution to getting us to the Knowledge Age.

Acknowledgments

I am grateful to all the people who have helped me along the way: my parents, who wholeheartedly supported my interest in computers, at a time when it was quite unusual and expensive to do so; my wife Susan Danziger and our children Michael, Katie and Peter, who make me a better person; my many teachers, including Erik Brynjolfsson and Bengt Holmström, from whom I learned so much; my partners at Union Square Ventures, starting with Fred Wilson and Brad Burnham who invited me to join the firm they had started; the many entrepreneurs I have had the opportunity to work with; the philosophers and scientists, such as David Deutsch and Chiara Marletto, who have demonstrated the power of human knowledge; the friends who have been there through good and bad times; and the many people who have taken the time to comment, who have invited me to speak, who have contributed in ways small and large, with special mentions for Seth Schulman for work on an early draft, Basil Vetas for capable research assistance, Nick Humphrey for goldilocks editing and Max Roser for the extensive data collection and visualization done by the Our World in Data project.

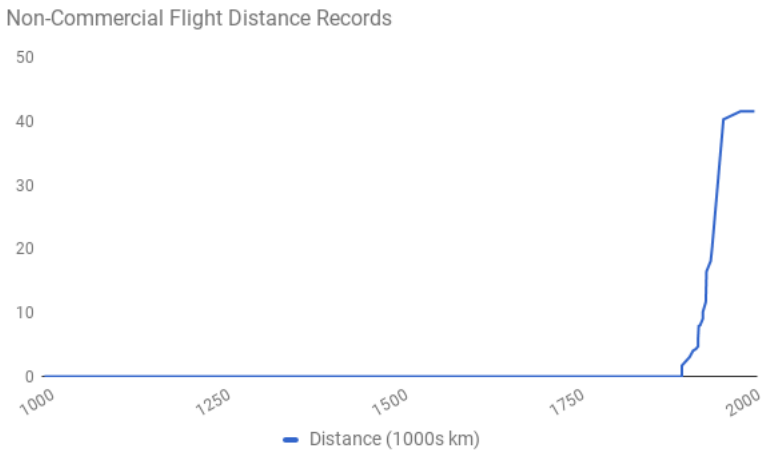
Appendix

This Appendix contains citations for charts and graphs used throughtout World After Capital, as well as data and backup calculations for the Capital chapter. These are not meant to be definitive or exhaustive, but rather to illustrate orders of magnitude.

Again, a special thanks to Max Roser and team at Our World in Data for their extensive data collection and visualization for World After Capital, which can be viewed in aggregate here.

[NOTE: This appendix is incomplete and requires a lot of additional work. At present it is mostly copied from an earlier version of the Capital chapter.]

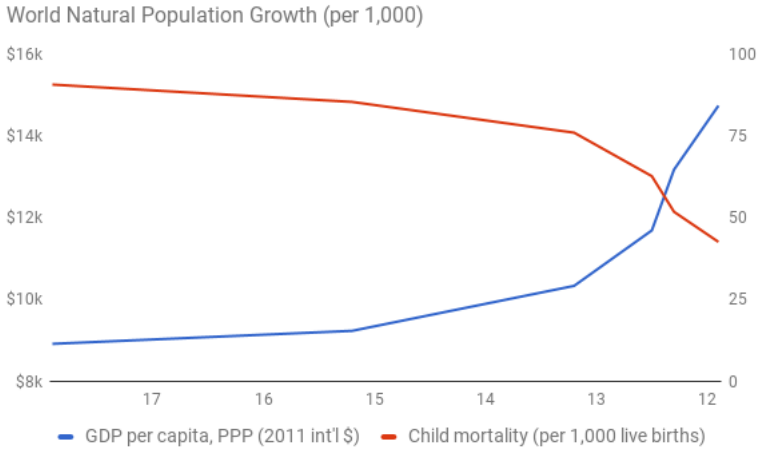
Chart Sources: Non-Commercial Flight Distance Records



Non-Commercial Flight Distance Records

Flight distance records: [124]

Chart Sources: World Natural Population Growth (per 1,000)



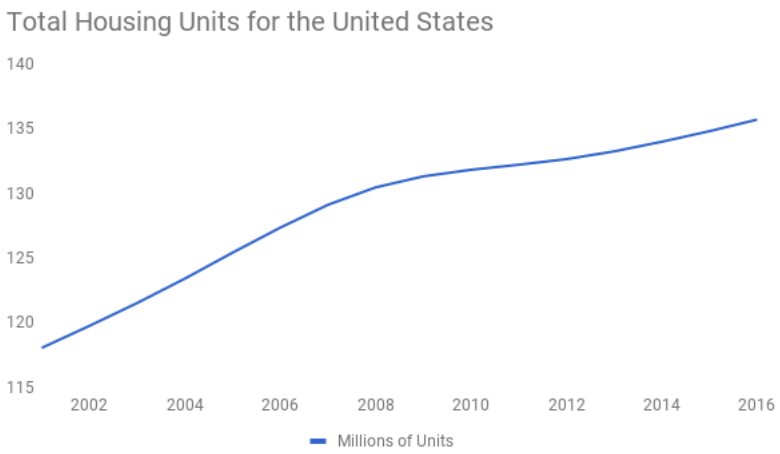
Population Growth

Population growth: [125]

GDP per capita, PPP: [126]

Child mortality: [127]

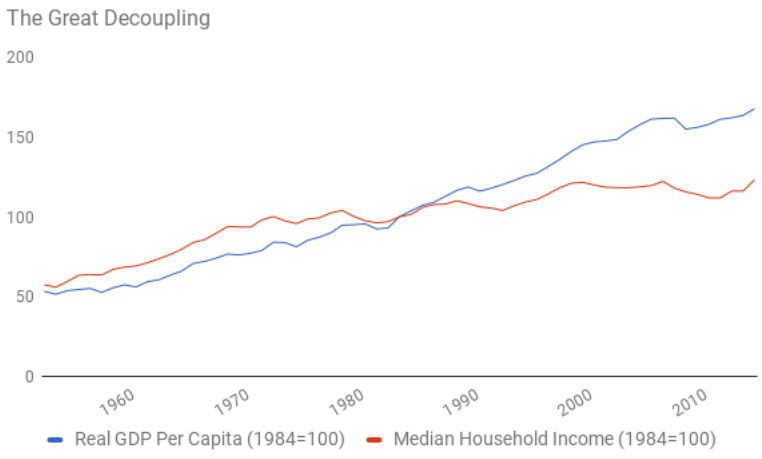
Chart Sources: Total Housing Units for the United States



Housing Units

Housing Inventory Estimate: [138]

Chart Sources: The Great Decoupling

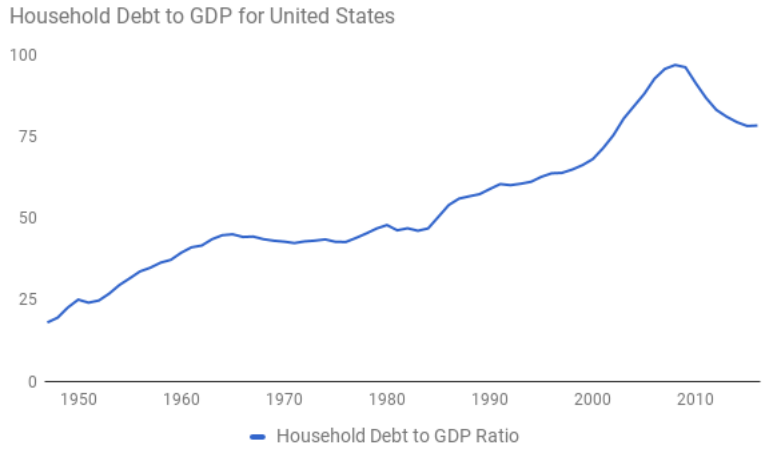


The Great Decoupling

Real GDP Per Capita: [128]

Median Household Income: [129]

Chart Sources: Household Debt to GDP for United States



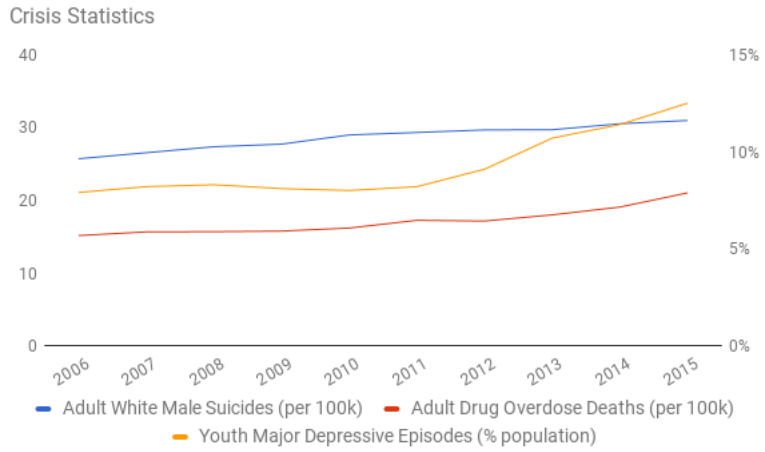
Household Debt to GDP for United States

Household Debt: [130]

GDP: [131]

For each year, ratio calculated as: (Household Debt / GDP)*100

Chart Sources: Crisis Statistics



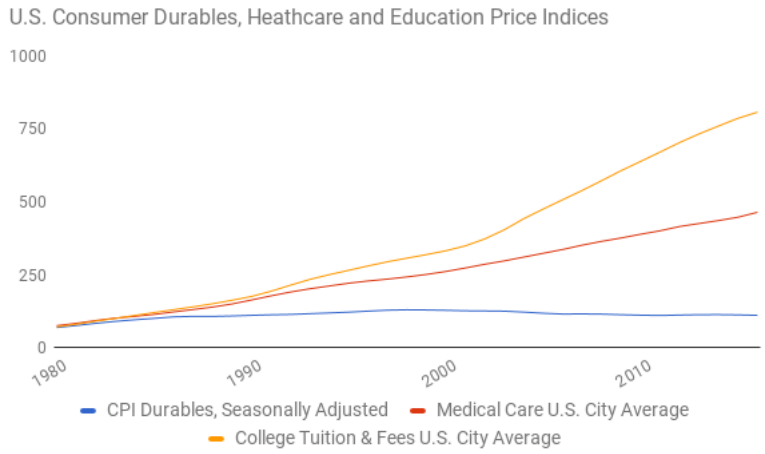
Crisis Statistics

Adult White Male Suicides: [132]

Adult Drug Overdose Deaths: [132]

Youth Major Depressive Episodes: [133]

Chart Sources: Consumer Durables Price Index



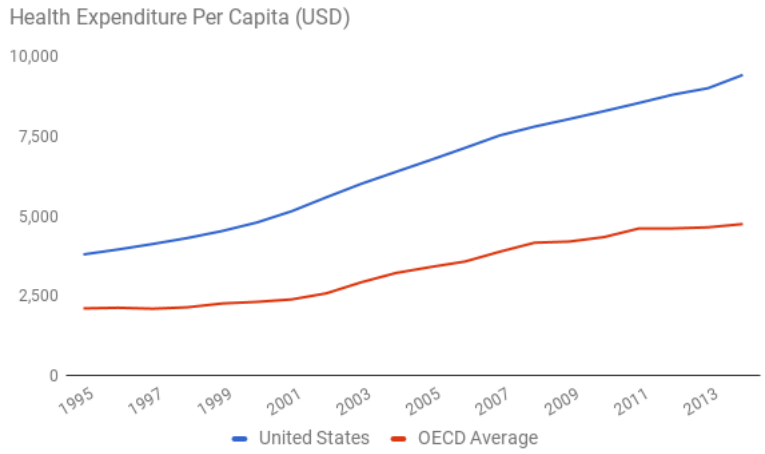
Consumer Durables Price Index

CPI Durables, Seasonally Adjusted: [134]

Medical Care U.S. City Average: [135]

College Tuition & Fees U.S. City Average: [136]

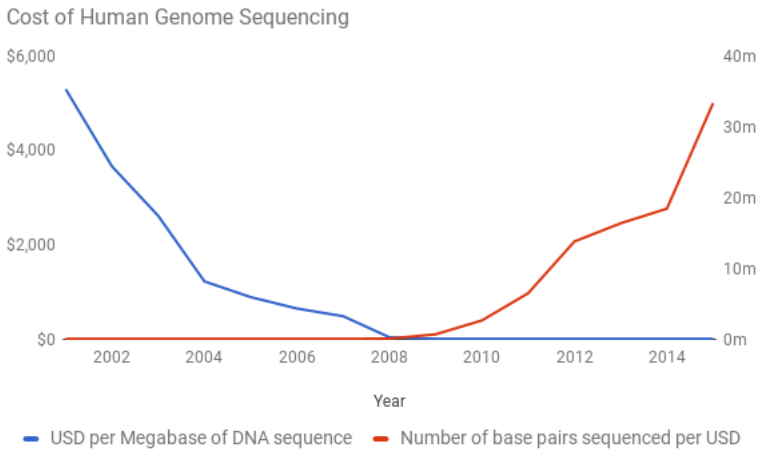
Chart Sources: Healthcare Expenditure Per Capita



Healthcare Expenditure Per Capita

United States & OECD Average: [137]

Chart Sources: Cost of Human Genome Sequencing



Human Genome

USD per Megabase of DNA sequence: [139]

Number of base pairs sequenced per USD: [139]

Air

Recall from the Needs chapter that humans require on average about 550 liters (0.55 cubic meters) of pure oxygen per day. With roughly 7.5 billion people on the planet, that means we need over 4 billion cubic meters/day. The Earth's troposphere contains about 600 million cubic kilometers of oxygen, or 6E+17 cubic meters. Ignoring all other effects for a moment, the troposphere contains enough oxygen for about 152 million days of human breathing, which is more than 400,000 years (see table).

Metric	Value (+, -, x, /)	Source
Dry air mass in atmosphere	5.1E+18 kg	[140]
% atmosphere in troposphere	x 75%	[141]
% oxygen in air	x 20%	[142]
Surface density	/ 1.217 kg/m^3	[143]
Volume breathable oxygen in troposphere	= 6.28E+17 m^3	Calculated
Oxygen required per person per day	0.55 m^3 (550 L)	[24]
Total 2017 population of Earth	7.5E+9 (appx)	[28]
Oxygen required on Earth per day	4.13E+9 m^3	Calculated
Oxygen required on Earth per year	1.51E+12 m^3	Calculated
Days of available oxygen	152,386,643	Calculated
Years of available oxygen	417,497	Calculated

Of course there are also lots of technological processes, most notably the burning of fossil fuels, that replace oxygen with CO2 in the air. Conversely we have the large scale process of photosynthesis that removes CO2 from the air and releases oxygen. While the balance is

an issue with regard to climate change it does not pose a short term threat to breathing — CO2 at present is only 0.04% or 400ppm (this is up significantly since the industrial revolution and cause of climate change) [144]. Conversely oxygen is about 20% of the atmosphere or 500 times as much.

But what about clean air? We definitely have an air pollution problem in countries such as India and China that impacts breathing. But we went through a similar phase in Europe and in the U.S. and managed to clean that up. It is a solved problem technologically. For instance, cars can be outfitted with catalytic converters and a single large plant has produced 50 million of these [145].

Water

There is plenty of water in the world and we have made significant advances in desalination and in filtration. There are about 10 million cubic kilometers of fresh water on the planet (not including another 24 million locked up in ice caps and glaciers). So that's 10^15 cubic meters. Based on the recommended 2.5 liters (0.0025 cubic meters) per day, human consumption is about 19 million cubic meters globally per day. However, we should also include freshwater used for agriculture, livestock and general domestic use. All in, freshwater withdrawals annually are just below 4 billion cubic meters [148]. So, relative to supply we have over 2,600 years of remaining freshwater to meet our current needs (see table). While 2,600 years may not seem like an extremely long timeline, don't forget that technological advancements like improving desalination processes will allow us to tap into the saline water, which makes up almost 97 percent of our water supply globally.

Metric	Value (+, -, x, /)	Source
Volume available fresh water on Earth	10.53E+15 m^3	[146]
Total water required per person per day	0.0025 m^3 (2.5 L)	[147]
Total 2017 population of Earth	7.5E+9 (appx)	[28]
Total drinking water required per day	18,750,000 m^3	Calculated
Total drinking water required per year	6.84E+09 m^3	Calculated
Total annual freshwater withdrawals	3.99E+12 m^3	[148]
Days of available freshwater	964,314	Calculated
Years of available freshwater	2,642	Calculated

Again, the point is not that everyone has access to clean drinking water today. People quite clearly do not. But this is not related to a fundamental water shortage. Nor is it even related to our present ability to make and produce water filtration. For instance, filtering water for one person costs about $50 per year using modern filters [149]. In the U.S. the average household meanwhile consumes over 30 gallons of bottled water at a cost of roughly $1.50 per gallon (total spending about $12 billion) [150]. The World Bank has come up with an estimate of only about $28 billion annually to provide everyone with basic water, sanitation and hygiene and about $90 billion to make these services available continuously [151].

Food

Metric	Value (+, -, x, /)	Source

Total calories produced per year	1E+16 kcal	[152]

Calories required per person per day	2,740 kcal	[153]
Total 2017 population of Earth	7.5E+9 (appx)	[28]
Total calories required per day	2.06E+13 kcal	Calculated
Total calories required per year	7.50E+15 kcal	Calculated

The U.S. population has more than doubled in the last six decades, as has agricultural output. U.S. agriculture now uses about 25 percent less farmland and 78 percent less labor than in 1948, so agricultural productivity is largely responsible for the increased production [154].

Even globally the amount of land required for farming has started to decline and we have made recent breakthroughs in vertical and automated farming. For instance, the world's larges vertical farm is currently under construction in Jersey City. The Japanese indoor farming company Spread is working on a fully automated facility that will be able to produce 30,000 heads of lettuce per day [155]. Indoor farming uses significantly less space and more importantly less water than traditional farming.

Shelter

By 2010 the U.S. housing stock was just over 235 billion square feet of residential real estate, which corresponds to about 800 square feet, or 75 square meters of floor space per capita [156]. Obviously this is not equally distributed, but it shows that we have nearly 8x as much space on average than I had identified as a basic need.

An alternative data source is the American Housing Survey. Using this table [157] for 2013 I get 230 Billion Square Feet. By then U.S. population was 316 Million people which works out to 230 * 10^9 / 316 * 10^6 = 727 square feet or 67 square meter per person.

Another way to look at the physical capacity of the economy is to consider new construction. From the same Census data source it appears we are building about about (2,735 / 4)*10^3 equal to 683*10^3 units per year, with average square footage of 1,737 square feet. That means we have the physical capital to add 0.683*10^6 * 1.737*10^3 square feet = 1.186*10^9 square feet (about 1 billion square feet) per year, which is more than 100 million square meters per year and enough to meet the basic need of 10 million people [157].

Clothing

The production of textiles, which are a key part of making clothing, has become highly automated. Apparel production, i.e. making clothes from textiles, however, is still quite manual. Based on data from a study by the Federation of American scientists [158] U.S. textile mills output in 2013 was $31.7 Billion with 116,805 employees for about $270K/employee. By contrast, U.S. Apparel production in the same year was $13.4 Billion with 143,575 employees for about $93K/employee. The key reason for the low degree of automation in apparel is that much of the production takes place overseas with cheap labor.

Ideally here too one could find data to analyze clothing output in terms of actual unit data instead of financial data. In the meantime here is an attempt to compare this to minimum needs. An international comparison suggests that people may be able to meet their minimum clothing needs with as little as $200 per year or even less [159] and [160].

The global apparel market was $1.7 trillion in 2012 [161]. At the time the global population was roughly 7 billion. That works out to $242 per person and supports the idea that we have enough capital in the world to meet everyone's basic needs in clothing.

Importantly, going forward automation is coming to apparel in the form of automated knitting machines [162] which have been around for some time and the newer development of robotic pattern cutting and sewing machines [163].

Transportation

Great data source here [164]

Highways 2012 car vehicle miles (in millions) 2,664,445 (note: includes light trucks and SUVs), 2012 passenger miles (in millions) 3,669,821, so average travelers/car = 1.38 for highways. Further supported on a separate page which shows that 76% of people commute alone.

Light Duty vehicles 233,760,558 in 2012 up from 220,931,982 in 2002 compared to U.S. population in 2012 of 313 million. That is 233.7 / 313 = 0.75 light duty vehicles per person.

Utilization of private cars is around 4% [165] but can be increased substantially through car sharing.

Healthcare

The role of capital in providing healthcare is difficult to assess. First, we are still figuring out what it means to live healthily in the first place. For instance, our knowledge of good nutrition is still quite primitive. Second, other than a few machines (e.g. for imaging) relatively little medicine requires expensive equipment. A lot of medication is expensive to buy but not expensive to make once the research has been completed. Labor accounts for 66% or more of the total expense of the healthcare system and capital equipment for around 10% or less [166]. Third, we are just at the beginning of our ability to deliver personalized medicine and to manipulate the human genome.

Given how I have defined the basic need for healthcare though it is clear that we already have enough capital to provide it in the U.S. as our life expectancy is already above 75 years. Gains in life expectancy around the world have been tremendous in recent years. This great chart by Max Roser beautifully sums up these gains [167] it shows that about 50% of world population already is at or above the 75 year mark. Another 37% is between 65 and 75 and only 13% is below. The chart also shows how much of these gains was achieved since 1950.

Computation

The progress that we have made in computation is nothing if not extraordinary. I remember how excited I was when I got my Apple II in the early 1980s which came equipped with 48KB of RAM and an 8-bit processor at a 1 MHz clock speed. At the time the machine cost about $1,300 which is about $5,000 adjusted for inflation. Today a Raspberry Pi 2 computer board costs $35 (down by 99.3%) and comes equipped with 1 GB of RAM (up 21,000 fold) and a quad core 32-bit processor at 900 MHz clock speed (up 14,000 fold). Smartphones are a bit more expensive but a high performance model from Xiaomi can still be had for $100 unsubsidized. Global output of smartphones in 2015 was roughly 1.4 billion units [168]. So without a doubt we have the capacity to equip everyone in the world with computation.

Networking

While not quite as dramatic as computation we have also made tremendous progress in networking. When I first received my Apple II was also the time when modems became popular for connecting to so-called Bulletin Board Systems. The early modems had a speed of 300 bits/second or about 40 characters/second. Today my phone on an LTE connection here in New York has a download speed of over 70 Mbps and and upload speed of nearly 30 Mbps (that's a 100,000 fold increase). Now obviously a big investment in infrastructure is required to provide everyone around the world with such blazing wireless speed but less than one might at first assume. For instance in unregulated spectrum a wifi access point can serve a small village by providing 200 or more simultaneous connections of 4 Mbps per connection for about $1,500. A 1 Gbps microwave link to cover about 4 km is about $7,500 on each end. A significant portion of the existing cost of networking has to do with the cost of spectrum as well as the cost of patents and closed source software.

Energy

Encouragingly, we have made dramatic progress in recent years with clean (from a CO2 perspective) energy sources. For instance, in 2017 Germany broke its previous record by generating 85% of its electricity from renewable sources for the day of April 30th, and this is expected to be the norm for the nation by 2030 [169]. And in the U.S., 61.5% of new electrical generation added in 2016 came from renewable sources (biomass, geothermal, hydropower, solar, wind), the second year in a row that renewables have dominated new generating capacity [170]. We have also made strong progress with batteries to distribute loads. And nuclear power can be provided in ways that are much safer than our large historic reactor designs. Beyond that there is nothing in physics that would prevent us from building fusion reactors. We just haven't figured out how to do it yet.

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