Innovation – How Technology Can Reconcile Progress and Economic Justice

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Abstract—*In this paper the nature of innovation will be defined and explored especially as it relates to Economic outcomes such as wealth and income distribution. The nature of innovation, its lifecycle, and its methods are presented and discussed. Key concepts such as the S-curve of innovation, the "Innovator's Dilemma", and Scientific Revolutions are also presented. Following this an exploration of how Economics views Innovation especially by Henry George who saw innovation as key to our survival and Joseph Schumpeter who saw it as required by capitalism. This discussion will show the connection between innovation cycles on a product or technology level and on the long-range economic scale. Examples of expanding and declining technologies demonstrate these cycles. Finally, data is shared around innovation, wealth, and income distribution across societies. Conclusions of the talk include the relationship between policy and innovation, the linkage between R&D and wealth creation, and the correlation between innovation and reduced wealth disparity.*

Index Terms—*Innovation, Science, Engineering, Technology, History of Science, Henry George, Nikolai Kondratiev, Joseph Schumpeter, Thomas Kuhn, Gini Coefficient, R&D Investments, Innovation Index, Income Distribution, Wealth Distribution.*

I. Introduction

This paper found its genesis in a presentation for the Seminar Series of the Henry George School of Social Science (HGS)[1]. In studying economic concepts at the school, the author noticed that many discussions centered around the impact of emerging technologies such as Artificial Intelligence and robotics and their potential impact on the future economy especially as it might impact employment. Having worked in Information Technology for several decades the author's perspective on this leaned towards the positive. When an opportunity developed to present on this subject a focus began to emerge on how to communicate several broad ideas. The story of technical innovation, economics, and wealth impacts flowed from the research on this topic and resulted in a presentation given in February of 2019 at HGS and this paper (Cusick, 2019).

This paper covers three broad areas:

1. Innovation Defined – the Innovation Lifecycle and its impacts.
2. Innovation and Economics – views of key thinkers in Economics on Innovation.
3. Innovation, Growth, & Equity – how R&D and Innovation impact Economic measures.

In beginning our investigation our aim will be to discover if and how innovation and technology drives progress and economic growth. In terms of technology lifecycles, we will review how these

[1] The Henry George School can be found online at this location: https://www.hgsss.org/.

patterns relate to economic change and put that into the context of some key economists starting with Henry George and Joseph Schumpeter and their theories. Finally, we will explore several data sets and findings which can be used to demonstrate the linkage between innovation, wealth, and wealth distribution. We will also look at some data indicating that Innovation can reduce the wealth disparity which has been increasing in many countries in recent decades. Thus, the major objectives of this paper include the definition of Innovation, its impact on the Economy, and how this can relate to the distribution of wealth.

II. Science, Innovation, and Technology

Defining Innovation can be straightforward. An innovation at its simplest reflects something new whether a process, a technology, or a method. What can help in understanding Innovation is looking at the lifecycle of Innovation and the characteristics of the innovative process. To do that we first need to define some basic terms. It is common for people to use the terms Science, Engineering, and Technology together when discussing Innovation. These terms are in fact related and they have specific definitions. *Figure 1* (Cusick, 2013) provides definitions for these key terms supporting our discussion. This diagram also shows that these domains overlap which is a crucial part of the definitional scope.

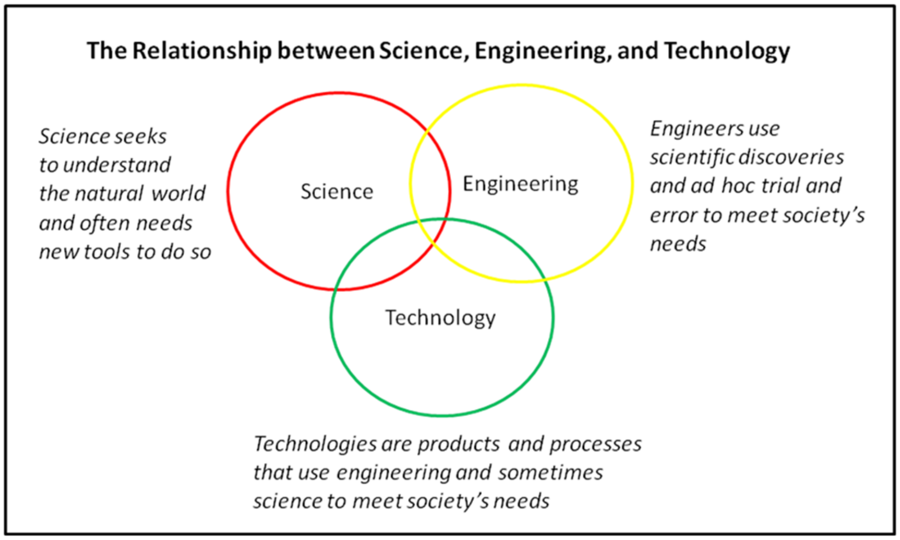


Figure 1 – Definitions of Science, Engineering, and Technology

A. The Scientific Method

An important starting point is to discuss innovation, what it means, and how it's related to science and engineering. In *Figure 1* several interesting elements of the relationships between science, engineering, and technology as well as their definitions are presented. Keeping the above diagram in mind lets first explore scientific process. As we know science is a process and set of techniques intended to understand the natural world empirically. The key principle in Science is to expand our understanding of nature through the observation of natural phenomenon, demonstrate this understanding experimentally, and communicate the results for other to replicate. This process often leads to discovery and the expansion of methods and technology which imbed innovation or drive later innovations.

In fact, each of us are Scientists in our own way. To simply stay alive humans developed methods of inquiry innately (Orzel, 2014). That is, the steps of hypothesizing, testing, and passing on knowledge are informally followed in our everyday lives. Think of approaching a frozen lake in the woods. How do you know if it's safe to go ice skating on the lake? Do you hypothesize that it is safe, test it by throwing a rock or stepping at the edge? These methods were formalized by Sir Francis Bacon in 1620 as the Scientific Method (Laudan, 1968). It has been shown as early as Adam Smith's time that economic growth emerges from either innovation or productivity gains developed via these inventive and Scientific based methods (Stephan, 1997). These methods flow from scientific development, engineering advances, and technology application (either craft based or formal in nature).

The approaches within the Scientific Method give us the structure of observable evidence, formal deduction and logic, as well as reproducibility. These proofs determine whether something is true. This eliminates the need to "believe" in Science or Scientific results. Instead since the methods are empirical and observable the data and results demonstrate an understanding of nature through rational deductive and inductive logic. Anyone can read such results and reproduce them to understand or challenge their meaning. This is what drives knowledge forward.

The science side of the diagram above is then related to the engineering side by taking what we know of nature and working to solve problems. Engineering might mean building a bridge, a building, or an airplane, but these are all problems to solve and we use both Scientifically derived engineering methods, heuristics, as well as mathematics, and tools to accomplish this.

When we start to talk about tools we are now talking about technology. Science and Engineering are activities whereas technology represents artifacts. Technology are basically the means by which we solve problems as guided by Scientific understanding and Engineering methods. As an example, we might use a telescope (a technology) as built through engineering (approaches) to study Astronomy (a Science) and advance our understanding of the universe. The interaction of these domains strongly relates to changes and growth in the economy as we will discuss.

B. A Life-Cycle Model for Inventions

Taking a closer look at innovation itself we will introduce an approach to the development, maturation, and decline of inventions. There are two ways to talk about this - one is as inventions another as an innovative process or the way in which you create something new. Invention then is really the result of inventiveness and innovation or basically the development of new ideas and new methods. What you see in the horizontal timeline in *Figure 2* is the representation of the life cycle of inventions (Sviedrys, 2007). Essentially, this model defines a process by which all inventions start with a declaration of a need or a wish. There must be a beginning to the invention process. Such an inventive desire would then generate some new knowledge to further this idea into a product which then they need to develop manufacturing capability. From there a prototype would be developed and then a commercial product. Consumers would then adopt the use of this technology or product and there some level of success. Eventually, nearly all technologies or products then enter a decline phase as it becomes obsolete or is replaced by other newer technologies.

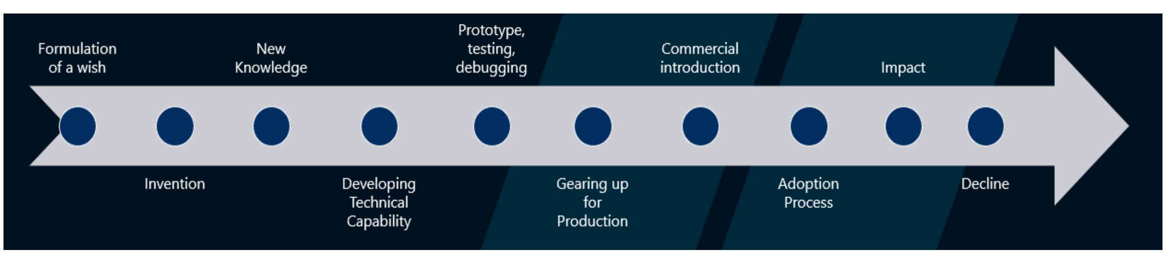


Figure 2 – Life-Cycle Model for Inventions

A good example of this is the VCR (Video Cassette Recorder) and its VHS tapes. Most people are familiar with this technology which was introduced into the market place in 1972. The VCR could play or record video and was a novel technology for its time due to its compactness, ease of use, and integration with TVs and camcorders. The VCR followed the exact lifecycle shown in *Figure 2*. Once it was developed and in production it was widely adopted. Due to competing technologies its use was eventually discontinued. The run of its useful life ended in 2006 when the movie production shops discontinued publishing on the VHS format. Thus, its effective lifecycle was 34 years from start to finish. Naturally, many VHS tapes remain in people's hands, but few people still maintain a VCR player and parts and repair might be difficult to obtain. This is a good example of how an innovation cycle can create revenue streams, manufacturing/production, and jobs. At the same time this wave of economic activity does not continue forever. Finally, VCR technology like many other technologies did not emerge from whole cloth but from frm existing technologies, in this case reel-to-reel tape recording.

C. Approaches to Innovation

Building on the innovation lifecycle model we can look at the nature and form of innovation itself. There are a few major styles or sources of innovation. We might first think of the lone inventor such as the character Doc from the movie "Back to the Future". In fact, that sole inventor model did exist and continues to exist. A good example of this lone inventor model might be Alexander Graham Bell who worked only with an assistant developing devices to assist the hearing impaired. There are numerous other cases like this. However, the bulk of modern Science and technology tends to be developed in larger environments. This is especially true as the complexity of the question at hand and technologies required grows.

To combat this complexity inventors turned to scale. The first to do this efficiently and significantly was Thomas Edison in 1871. In fact, aside from being awarded over a thousand patents, Edison's greatest invention was seen as the modern research laboratory (Hoadley, 1908). His lab had 40 or 50 technicians, engineers, and scientists working with him to invent and develop multiple technologies. This "idea factory" became the model for modern corporate and private research labs and led to numerous revenue streams and economic impacts such as electrification, illumination, communications, and entertainment. Other good examples of this industrial scale invention environment include Bell Labs which was founded in 1925 and produced one patent a day for 75 years and continues to innovate today. In addition, such R&D labs as IBM's Watson Labs and Xerox PARC also pursue core Science and applied technology.

In addition to the lone inventor and the private research laboratory there are also both government funded research institutes and academic labs. Significant Scientific progress, inventions, and new technologies emerge from government backed R&D. Especially in the US we see a wide array of such innovations and technologies emerging from NASA, NOAA, the defense sector, and other agencies (Mazzucato, 2015). The Internet itself and its precursor the Arpanet are good examples of this. It is fair to say that the economy at large has been greatly disrupted and impacted by the effects of the Internet which was first developed to provide for redundant data communications for the military. A further example is the GPS network (Global Positioning System) which was also built for the military but then opened to commercial use and now allows anyone with a smartphone the ability to navigate with precision and has introduced overlay products and services expanding economic activity and opportunities. Academic laboratories also contribute to fundamental research which also can produce products for commercialization. A good example of that is Cornell researcher Roger Griswold who invented the 3-point restraint (seatbelt) initially introduced by Volvo and now a near requirement on all automobiles (Rong, 2016).

D. Characteristics of Innovation

As we have seen, innovation develops from several different sources whether it is the lone inventor, corporate R&D, or government and academic laboratories. In addition, there are several key attributes to innovation that are important in helping us understand this process and its relation to the economy. First, most innovations arise from what are called "adjacencies". This means that most discoveries or inventions are related to existing knowledge or prior art. Typically, inventions do not come out of thin air but are generated by exploration of an existing area. A good example of this is Bell and the telephone. He was experimenting with multi-message telegraphy. He also was interested in developing methods to assist people like his wife and mother who had hearing impairments. Instead he discovered how to transmit audio signals over existing equipment and thereby discovered the telephone. This then translated into what has been called the single most profitable patent in history creating a million jobs at AT&T alone and billions of dollars of revenue for decades. Again, this was not done to intentionally discover the telephone but as a parallel to the development of the harmonic telegraph.

Other examples abound. An interesting one is around the microwave oven which is a ubiquitous device in today's world. Actually, Percy Spencer, an engineer for Raytheon (a US defense contractor) was experimenting with radar equipment. When he found a chocolate-bar melted in his pocket he realized something might be going on. This led to the creation of the "radar" oven or microwave oven (Maine, 2015). Other such tangential discoveries include the World Wide Web laid out by Tim Berners-Lee who was a physicist working at CERN laboratory in Switzerland. He attempted to build a computing environment to better manage documents and information supporting researchers there. This was built on earlier concepts of hypermedia first conceptualized by Vannevar Bush (1945) and which turned into a set of protocols which revolutionized computing, democratized online information access, and generated massive economic change.

A further key point relating to innovation is that platforms are self-reinforcing. In other words, when a technical environment exists and provides a platform for extension this enables further innovation. Many such examples exist. The phone system is a good example where it originally provided voice services but then later provided a wide array of data services. In fact, the phone network enabled the rise of the World Wide Web as many early users connected to the web via dialup modems. Another well-known example is Facebook. In this case it is through the continued increase in subscribers that more value is provided. The platform becomes increasingly useful and extensible the more people who are connected to it. In economics this is often called the network effect. This is defined as: "…a phenomenon wherein increased numbers of people or participants improve the value of a good or service" (Kenton, 2017). This is true not just with Facebook but with the Internet at large. The platform conditions further strengthen the network effect by allowing new innovations to plug in and gain from the prebuilt capabilities. Understanding the platform environment and the prior art in place is key to being able to take advantage of these scale effects and market reach. This leads to the conclusion that open and accessible fact based technical and scientific information is critical to an innovative culture.

Finally, innovation comes with failures. Few inventions are successfully developed without false leads and setbacks. In fact, Edison famously said that he did not invent the light bulb. Instead he found 1,000 ways not to make a light bulb and one that did work. This translates into the requirement for an organization that expects and tolerates failure. This is the path to innovative success. In the software development world today, there is a phrase that is often used where the goal is to "fail fast". What this means is that it is assumed that some paths will not work out especially at first. Thus, the teams need to rapidly move through those failure scenarios to be able to find the design that will work. Combined with an understanding of adjacencies, network effects, this failure acceptance is critical to an innovation engine.

E. The Innovator's Dilemma

Assuming an inventor is successful in developing an idea and creating a technical solution it must be matured and adopted by the marketplace. There is an excellent and foundational treatment of the innovation process written in the early 1990s by Moore (1991) called "Crossing the Chasm". In this book he introduced the concept of a "Chasm" separating the invention, its early adopters, and the broader marketplace (see *Figure 3*). As we discussed earlier there is a lifecycle to inventions from initiation to distribution to decline. What Moore points out is that this lifecycle is not always a contiguous line of advancement as opposed to our earlier lifecycle of innovation model. Instead there are challenges to the progression and some inventions never make it across the chasm into broader adoption. While there may be some people who will be very eager to try your new technology there will be a number of people who will be slow adopters which creates this chasm between the visionaries and the rest of the population. In some cases, an inventor may not ever cross the chasm even though they have a very good piece of technology. Furthermore, at times the developer or innovator will create a technology or product but for various reasons whether it is related to financing, marketing, timing, business control, or other factors, the original inventor does not see the rewards of the invention and never crosses that chasm. A case in point is Percy Spencer who we mentioned earlier. He invented the microwave oven a commonly used device around the world yet he never saw any commercial benefit from this as his employer did not see the potential and did not develop it or bring it to market in his lifetime.

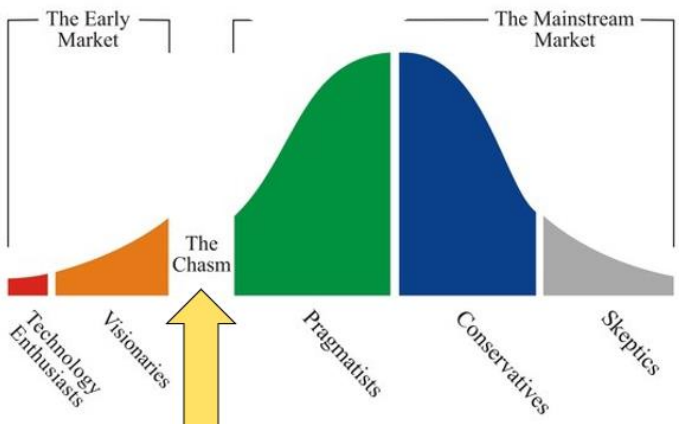


Figure 3 – The Innovation Life-cycle and its "Chasm"

A more Scientific related example of this phenomenon is the case of the radio. Electromagnetic Radiation including radio waves were first discovered by a German scientist named Heinrich Hertz in 1886 and it is well known that we measured frequencies of such waves in units called Hertz as these waves were named after him (Asimov, 1972). However, regarding his discovery of radio waves he did not make use of them. In fact, when asked what they might be good for he replied "Nothing, I guess". Thus, his research with radio waves mostly stopped from a development perspective. However, the Italian engineer Guglielmo Marconi picked up this work and within a decade in 1896 he had a working transmitter. Ten years later, working with the Royal Navy, Marconi was communicating with ships across the Atlantic and before long, had coast to coast radio broadcasts. Marconi is a good example of both a scientific mind who developed new laws to explain the nature of radio wave signaling, an inventor who created new devices, and an engineer who built and demonstrated those new technologies. He was also able to cross the chasm into wide spread success. Even today, anyone using a wireless phone is using RF (Radio Frequency) signals which is essentially the same technology Marconi pioneered (Hoadley, 1908). This is then a perfect case of the original inventor not benefitting from discovery. Fortunately, both Hertz and Marconi were awarded Nobel Prizes separately for their contributions to Science. While this situation of not crossing the chasm does happen many inventors do make it over such as Bell or Edison.

III. Innovation and Change

Following a slightly different direction we will now explore a key concept in how changes to Scientific understanding propagate. This will help bridge us into discussing the relationship of technology change and economic effects. We have presented about how innovations occur and examples of some innovations we have seen ourselves and how we can think about those innovations in terms of examples of the process of innovation. Let's now turn to a higher-level concept related to the evolution of Scientific theories and frameworks.

A. Kuhn on Change and Innovation

Thomas Kuhn obtained a PhD in Physics but turned to the study of the History of Science. It is Kuhn who introduced the term "Paradigm Shift" In his book on Scientific Revolutions (Kuhn, 1962). This will be helpful in our thinking further on Economic impacts. The concept here is that Science develops a point of view or a set of theories in a given area. It then can be very rigid in protecting those ideas until significant anomalies are observed bringing the agreed to status quo into question. This is what can then precipitate a "paradigm shift". It is Kuhn's supposition that Science moves forward in this way and not always in small incremental additions.

As mentioned early on, science is an empirical process which is based on observation and data and reason in order to determine truth about nature. While that is all true, however, people are people and what happens according to Kuhn is that we often will limit our progress because we will agree to assert that everyone will support a framework of ideas until it starts to breakdown and sometimes breakdown rapidly or almost overnight which can then lead to a paradigm shift. A great example that Kuhn provides is where Copernicus overturned more than 1,300 years of traditionalist thinking on astronomy where Ptolemy had said that the Sun revolved around the Earth. When Copernicus used new and better observations to understand the nature of the universe more clearly, he came to understand that that the Earth centric view was not true that instead that the Earth revolved around the Sun. When this became known and accepted this was a revolution in Science (Cusick, 2007) and it is what Kuhn called a paradigm shift replacing the entire old paradigm as incorrect. This model is useful in understanding changes to Science, innovations in technology, and the rhythms of the economy where it is driven by technological changes as well.

B. Kondratiev Theory of Supercycles

At this point we can begin linking the technical and innovation concepts and processes introduced thus far to some key Economic theories. The first step is to introduce the ideas of Kondratiev and consider how these can be viewed as similar to Kuhn's Paradigm Shifts. Nikoli Kondratiev's book published in 1925 (Kondratiev, 1925) introduced a concept which he called the "Supercycle" or otherwise known as a K-Wave for Kondratiev. His idea was that while there certainly were business cycles impacting the economy there were also underlying long range cycles that also drove economic growth and decline (*Figure 4*). Kondratiev put special emphasis on how technologies like the steam engine, railroads, or electrical engineering cause large scale changes to the economy over long periods of time. The phases within these Supercycles he labeled: prosperity, recession, depression, and improvement. His other observation was that no matter what happened to capitalism in terms of these degradations and downturns it had always found a way to regenerate and it always would. Unfortunately for him this put him out of favor with the Communists in the Soviet Union his home country.

The Supercycle model can be a useful construct when looking at the development and introduction of technology over the long term and then trying to understand the relationship of these technologies as drivers to the macro changes in the economy to the extent that technology introduction can be seen as a causal factor. If we take both the ideas of Khun and Kondratiev together we can see that they address related phenomenon. For Kuhn, the anomalies observed around an existing theory leads Science to yield to a new model via a Paradigm Shift or Scientific Revolution. For Kondratiev similar transformations can occur in industry and within the technology base which might also set off a Scientific change. These Scientific or technological changes can then lead to a burst of Economic activity in a given area. Paired with this there may be a linked decline in a prior technology or product area. This can occur simultaneously and over long periods of time thence the Supercycle.

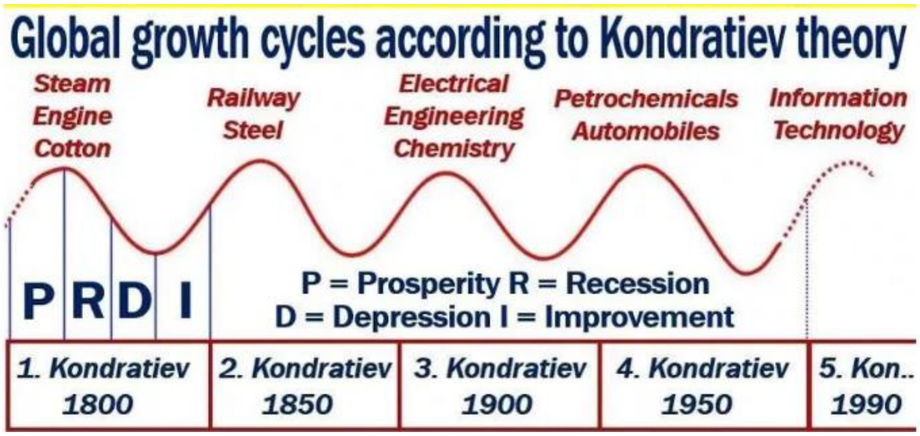


*Figure 4 – Illustration of Kondratieff Waves (*Nefiodow, 2019)

For both Kuhn and Kondratiev these changes can take a long time to develop and play out even though they might take hold in a very brief interval. Additionally, the Supercycles can be seen to parallel or support the Innovation Cycle as laid out in Figure 2 above. Again, technologies have a birth-maturation-phaseout cycle which can mirror's the phases of Kondratiev's Supercycles. Examples of the technologies and innovations provided by Kondratiev included the steam engine giving way to modern steel railway engines or manufacturing purposes then giving way to electrical engineering and chemistry giving way to petrochemicals and automobiles and then finally into the modern day in information technology. What we will see shortly is another economist named is Schumpeter who adopted the Supercyles as well and built on them to explain additional features of the innovation cycle and their economic effects.

It is important to point out the Supercylce model does have its critics. Some economists say that Kondratiev was seeing patterns in the statistics where such patterns simply did not exist. Others said that these K-Waves cannot be used to predict anything. It is common for most Economic theories or models to have their detractors and that is a healthy thing for the discipline. However, when taking an aggregate look at the lifecycle of invention established through the History of Science, the concept of Scientific Revolutions established by Kuhn, and practical examples of real-world Supercycles (which we will explore next), this model may not be mathematically provable, but it does provide for a useful construct for understanding Economic events over time.

C. Growth Technologies

In order to help demonstrate both the lifecycle of innovations and how they can be viewed through Kondratiev's the Supercycle model let us explore a few examples of first growing technologies and then declining technology areas and their impacts on the economy. Obviously, the listing of technology developments over human history represents a major undertaking far beyond the scope of this paper. However, some authors have sketched this out including Pacey (1991) and Headrick (2009). The conclusions from this history is that the development of layers upon layers of technology and engineering knowhow have produced our modern world and improved our daily life from agriculture, to transportation, to medicine. The explosion of new technologies in the last 150 years has been especially breathtaking in their number, speed, and impact. Touching on just a couple of these major innovations and the industries they spawned will help illustrate the link from technology to the economy.

A useful example which most people can relate to is the automobile. Karl Benz is credited with inventing the automobile in 1885. However, in the early years of the car you had to be a mechanic to own one due to the complexity of operations and unreliability of the machine. Additionally, most roads were unpaved so simply getting from point A to point B could be extremely challenging. In the ensuing century and a quarter this technology has completely changed. Today we even have autonomous vehicles and for standard cars we have significant performance, range, efficiency, safety, and conveniences. Over the last decade, sales of automobiles totaled nearly 100 million each year worldwide. This volume translates into an industry worth over $1.5 trillion per year (Franco, 2011). Looking back on the initial innovation and then a century of refinement and further invention this is a significant economic impact for millions of people not just in the utility of the invention but also in the livelihoods it provides. This can be seen as a Supercycle all on its own.

Air travel is also an industry where we have seen a massive democratization of access. For a relatively reasonable price one can travel nearly anywhere in the world at almost a moment's notice. This is really quite amazing because if you think back to the state of long-distance travel 100 or 200 years ago, to get from New York, for example, to England or to Hong Kong you would really have to invest some time and probably substantial money to make such a global trip. When we look at the Wright brothers pictured here in *Figure 5* at the time of their very first flight in 1903 what is interesting about them from an innovation stand point is what they are innovating on is actually not the airplane, but it is on what we call controlled flight (McDougall, 1985).

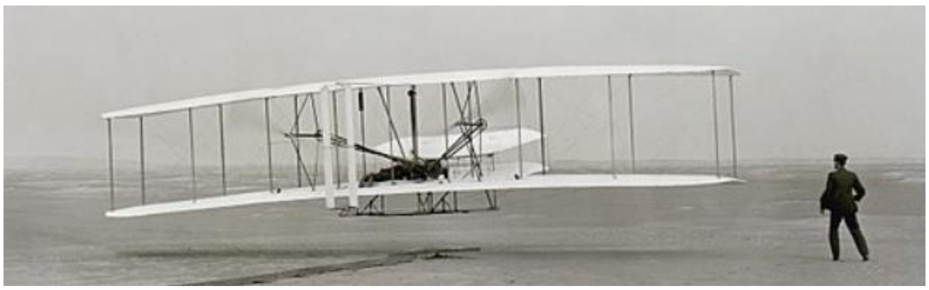


Figure 5 – Wright Brothers demonstrate controlled flight in 1903

Up until the Wright brothers many people had built kites, gliders, and even airplanes, but no one quite understood how to control a powered airplane. The Wright brothers were the first ones to do this. Within a decade, with the onset of World War I, the skies were full of military aircraft. Following the war commercial airline services developed all over the world. Today the airline industry drives nearly 4% of global GDP (AAG, 2019). Again, we can trace a significant economic impact from the original series of innovations and a century of optimization and growth, once again, this can be seen as a K-Wave effect in action and continuing today.

Other key inventions of the 20th century include the discovery of penicillin which launched an entire new branch of medical treatment and has provided for longer healthier lives. Discovered in 1928 it has led to a sizable economic impact as well. Finally, the expansion of the mobile phone and smartphone has been unprecedently fast. From its introduction in the 1980s we now have nearly 7 billion such devices in use nearly equivalent to the entire population of the planet. This is also revolutionary in other ways as these devices can be accessed in remote areas and also allow for Internet access with rich hypermedia applications being made available to anyone nearly anywhere. Again, this is a perfect example of a network effect taking place. With all of these technologies being introduced and growing so fast there can be negative side effects and unintended consequences as well. Certainly, the automobile industry has been a source of pollution and the Internet and mobile phone platforms a source of distraction or worse. Such downstream effects often come with innovation and the social costs of advancement need separate consideration.

D. Declining Technologies

On the flip side of these growth scenarios, there are numerous examples of declining technologies which we can think of over the past decades. We can focus on just a few here for illustrative purposes. Many readers may recall not so long ago using a camera with film. Today most people who are not professionals or serious hobbyists take all of their pictures on smartphones. These devices were only introduced recently and due to their convenience, ubiquity, and ability to leverage the multifunction nature of the phones themselves, the embedded cameras have essentially eliminated traditional cameras and the associated film sales that went with it. This has devastated such companies as Kodak who lost nearly $2B in 2015 and has reduced many other traditional camera makers as well as film producers.

Other relatable examples are the rise and fall of LP records and of the floppy drive. The original floppy drive was used to store digital information offline. The first format was 8 inches in diameter. Later formats were 5 ¼ inches and then 3 ½ inches each with a different data storage capacity. These formats are shown in *Figure 6* below. The lifecycle of this technology began in the 1960s with the first product available in 1971. They were mostly phased out in the early 2000s and in fact current Windows operating systems do not support their use. However, as is typical in the decline phase for a technology some legacy systems do continue to rely on these devices. There are many other full lifecycle examples in the technology field. In each case these technologies drove large revenue streams, factories, and jobs but they are either not used today or are in very limited use. With their decline the businesses and economies built around them have dissipated as one would see in a K-wave.

Figure 6 – generations of floppy storage technologies all of which are now obsolete

A clear economic example of the decline of a particular industry in recent years can be seen with printing and publishing. Examining the data in *Figure 7* we see print industry revenue growing during the post war period all the way up to the year 2000 with limited corrections. Suddenly in the year 2000 this revenue drops off precipitously from $60 Billion to $10 Billion in a ten-year period (Edmonds, 2015). If you are familiar with the technologies introduced at this time, you would know that the World Wide Web came into its own at the end of the 1990s and with-it online magazines, news outlets, blogs, and publishing of many kinds. Thus, the introduction of web-based publishing not only cut into the established print business but nearly eliminated it. This industry specific boom and bust can also be seen as a K-Wave localized to publishing. Certainly, if you were working in this part of the economy during the 2000's you would have felt the end of an era and the beginning of a new one.

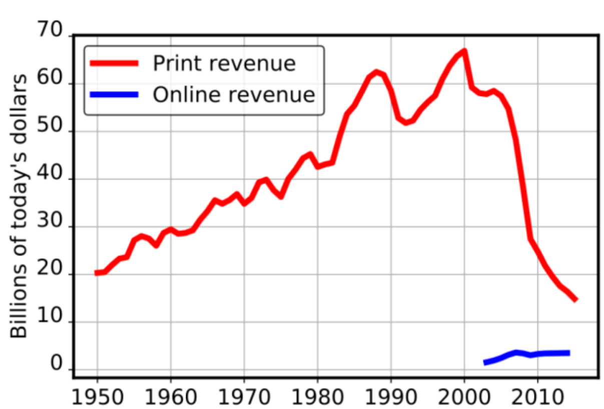


Figure 7 – Revenue growth and decline since 1950 (Edmonds, 2015)

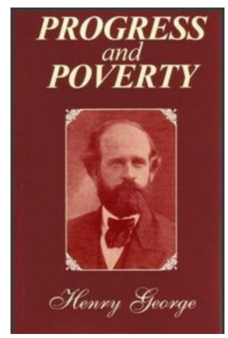
This very sharp decline of course impacted people who were in the publishing industry and not just the revenue levels. Many of these people adapted to the change and went from working on a traditional print publication to an online "zine" or blog or burgeoning social media platform. Entirely new sectors were also created at this time in reaction to these changes including on-line ad sales and ad analysis tooling. This is probably one of the most significantly impacted sectors in the wake of the Internet revolution but there are others such as retail shopping, banking, and more. In fact, most businesses have encountered some degree of impact whether positive or negative from the growth and explosion of the Internet. While many of these technologies were at one point innovative and they were in fact new at some point, later they have declined or disappeared, or they have needed to morph in a significant way. From an economic standpoint dropping from billions of dollars of revenue to just a small percentage of that level means that you have to adapt.

IV. Innovation and the Economy from an economists view

Now that we have firmly established the lifecycle and economic impacts of technological innovation we can turn to further concepts of innovation from key economists of interest. The first we will add to this discussion is Henry George. Then we will look at Schumpeter to further examine economic change and apply the metric provided by Corrado Gini to understand the effects of economic conditions on income equality.

A. Henry George on Innovation

George discussed innovation at some length in his landmark treatment "Progress and Poverty" (1879). To ground the discussion of George's view on innovation we can review some of his thoughts on this area. First, George said that innovation is a natural form of endeavor across cultures. This is not an unusual thing and not something to be afraid of as instead it is central to what humans do. He says that innovation gave us religion, architecture, engineering, and more. He also states that it is because of innovation we move quickly as a society and that is how it has been. Thus, George provides us an interesting starting perspective on where innovation fits in society and the economy. However, he also said that no matter how much we innovate we still see poverty in society which remains true today. Innovation by itself is not a solution but it can help improve economic conditions. George would argue that if we couple innovation with economic reform, appropriate policy, and use of a land tax, then society could both achieve technical and economic progress as well as avoid the social pitfalls of the current capitalistic models.



Building on this George goes further to say that despite these limitations on output and wealth distribution that it is only through change and innovation that we can survive. Thus, the introduction to the innovation cycle and the innovator's approach earlier all flows into what George expected from a growing economy. Furthermore, George supports the idea that we need to continue to be creative and look for new ways to solve problems, that we cannot be backward looking. He emphasizes that as a species we are naturally focused on moving forward. He says at one point that "The Earth is the tomb of dead empires…" which seems to indicate that we cannot rest on our accomplishments but must always reinvent ourselves. This has a very modern feel to it. This point also links back to the first part of this paper in talking about how all of us are Scientists and use empiricism to understand the world and improve it to our own ends such as crossing that frozen lake.

George also makes the point that resistance to innovation is common. This has impacts for the economy directly but also in the adoption of new ideas around the economy or policy. This is something that can be seen even today in our current society which generally embraces new technology. In the case of certain technologies people are less eager to embrace them such as AI (Artificial Intelligence) and robotics. There is a fear of what these technologies may mean to the future of jobs and employment. George says this resistance will be especially found in guarded industries meaning those places that are well established and don't see a benefit from a change. This is precisely what Kuhn would say as well. Kuhn made the argument that the established leaders of the current paradigm will protect their positions and this established class of managers or academic deans would basically try to put a halt to changes if the new ways might challenge their authority and power. This connection between innovation, economics, and Kuhn's model continues building a useful set of supporting ideas to understand the nature of this evolution.

Finally, George's thinking around innovation also focused on entrepreneurship (Ellerman, 2015). He also believed this to be a very important role in the society and that actually within cities you would see more innovation and more entrepreneurship as this is really how civilization is further developed. He believed that the density of population generates more interactions and possibilities. Again, he does mention the idea that economic growth is driven by innovation. These are not new ideas as people have been talking about this for a long-time including Henry George. To conclude our discussion of Henry George we can go back to the idea of land ownership. Essentially, George wrote that if land is not managed well then it will actually work against innovation.

B. Schumpeter, Innovation, and Creative Destruction

The concept of the Supercycle (or K-Wave) introduced by Kondratiev was presented in some detail earlier. The economist Schumpeter built upon this idea and his ideas provide further insight into innovation and the economy. Schumpeter was attracted to the ideas developed by Kondratiev but he went quite a bit further and developed a concept called "Creative Destruction" (Schumpeter, 1942). The idea of creative destruction is that innovation is actually not just an activity in the economy but instead it is a necessary force to further develop the economy. This process in fact generates waves of creation or innovation which can simultaneously produce economic destruction or dislocation. This is the meaning of Creative Destruction.

We have already seen numerous examples of this earlier in this paper. Probably the clearest example was the significant displacement of revenues from print media with the rise of the Internet. This is a classic example of Creative Destruction. One sector of the economy growing at the expense of another and the economy in fact morphing into something else entirely over time often following a traceable K-Wave or Supercycle phenomenon. Schumpeter goes so far as to say that "Anyone seeking profits must innovate." He states that Creative Destruction impacts the economy by "destroying the old one, … creating a new one" from within. More than that, Schumpeter claims that it is not only the economy that is impacted by these "gales of change" but also the surrounding societal frameworks of "Capitalism, Socialism and Democracy" as well. Essentially, since the innovations, technology base, and economy are radically shifting, this leads to instability in overarching social institutions and approaches as well requiring new social solutions.

The force behind much of this change is the entrepreneur. The entrepreneur is focused on reforming or revolutionizing the pattern of production through invention (Heilbroner, 1999). Just as an idea such as that from Copernicus swept away the Ptolemaic cosmology, we now see technological change revolutionizing the economy on a regular basis. Creative Destruction then produces new technology and so essentially it is through the free market economy that this innovation takes place and propels some very powerful ideas and their economic impact.

A good example of this is Netflix. At its prime in the early 2000s, Blockbuster was a dominate video rental company and had more than 9,000 stores across the US. As of March 2019, there is now only one Blockbuster store remaining anywhere on the planet located in Oregon (Lou, 2019). To retrace what happened here, as a case of Creative Destruction, Blockbuster was a $6B company in the year 2000. At that time Netflix had a market capitalization of only $50M. In fact, Blockbuster had an opportunity to purchase Netflix but passed on it. Now, about 20 years later Netflix is worth $54B, has grown its revenue to above $60B, and Blockbuster has gone bankrupt *Figure 8*.

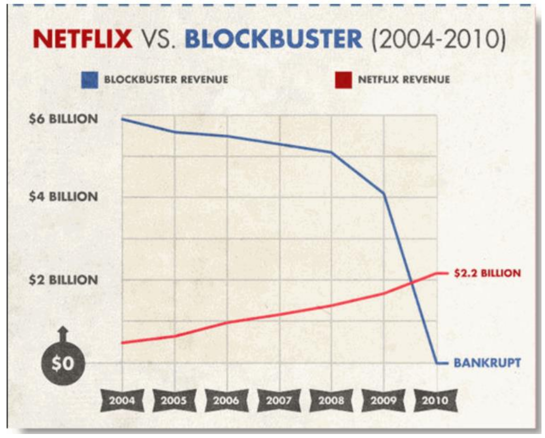


Figure 8 – Rise of Netflix and Fall of Blockbuster (Chhabria, 2017)

This is sometimes referred to as the Netflix effect or the Amazon effect where upstart technology-based companies drive established companies out of business through rapid and aggressive growth. Finally, in the case of video rental stores, there had been 150,000 jobs in this industry in 1995. Today there are less than 10,000. These jobs have primarily migrated to innovative operators utilizing on-line technology solutions like Netflix, however, Netflix only employs a total of 7,100 people. Thus, this type of technical disruption has resulted in more than a 10-fold decrease or dislocation and repurposing of direct employment for this industry function.

In the end what Schumpeter provides is further explanation around how innovation is not only vital to economic development but how it is in fact central to its furtherance. Creative Destruction as in the case of video rentals clearly shows how innovation via online technologies led to the destruction of the traditional approach of over the counter tape rentals. Moreover, we now see many of the concepts we have introduced thus far beginning to fit together. We have Scientific Revolutions creating Paradigm Shifts with these then allowing for new innovations such as over the wire digital services. These innovations then drive economic Supercycles which are also evidenced in waves of Creative Destruction. At this point we can now look at some economic data that will help put these patterns in relief.

C. Innovation and Reduced Gini

A useful place to start is by introducing the Gini Coefficient. The Gini Coefficient was created about 100 years ago by an Italian economist named Corrado Gini. In his 1912 paper he offered a mathematical and statistical representation which showed whether or not and to what degree income distribution is fairly disbursed across a country's residents (Risso, 2018). When looking at innovation, income, and wealth we will find the Gini Coefficient a useful measure to understand the impacts of economic conditions on income disparity. To begin with we can look at R&D spending as a % of GDP versus the Gini Index and that same R&D spending (*Figure 9*). This study covered 74 countries over a period of 20 years. The results essentially showed that as R&D spending goes up, the Gini Index goes down (meaning a more even distribution of income). Where an equitable economy is desired this should be a useful indicator. This also leads us to believe that innovation (as driven by R&D spending) can stimulate not only economic growth as we have seen before but also growth that results in economic fairness.

Other studies have focused on the effects of innovation and social mobility (Aghion, 2015). In addition to income distribution social mobility is a key factor in economic fairness. Within the US innovativeness accounted for around 17% of the total increase in the top 1% income share between 1975 and 2010. However, this has regional effects. California's top 1% has 20% of income but also high mobility. In Alabama, income is also concentrated (in the top 15%) but innovation and mobility rates are low. As might be expected there is also a correlation between innovation &

social mobility. For most areas social mobility is driven mainly by entrant innovators (Creative Destruction) and less so by incumbent innovators.

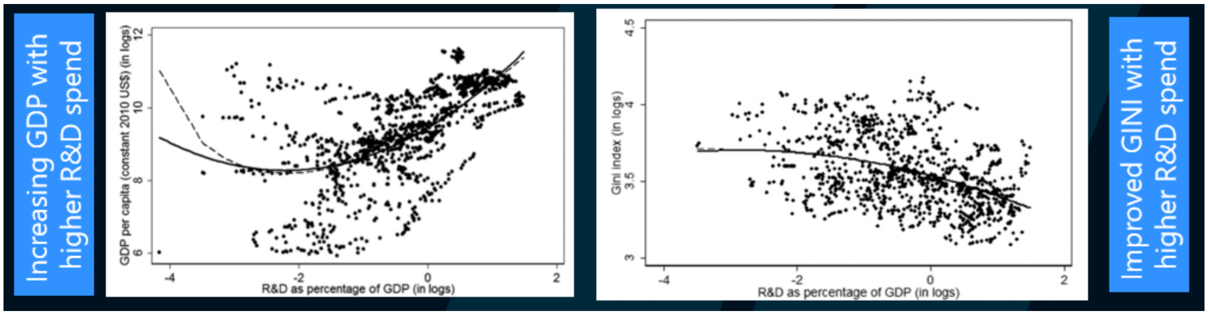


Figure 9 – R&D Spending and effects on Gini Index

V. INNOVATION, WEALTH & INCOME DISTRIBUTION

A. Top 20 Innovative Countries

In order to put innovation into a global context Figure 10-a lists the results of the recent International Innovation Index analysis. While there are many reports on innovation by country this is a good baseline view. As you can see it provides at least a couple of surprises. South Korea being ranked above the US may be one of them. The strength of Sweden and the Netherlands may also be a surprise. In a supporting view we see innovation vs GDP (Areppim, 2011) in Figure 10-b. This data provides an alternate innovation rating per country and adds a useful contrast to the additional key data point of GDP per capita as reported for 35 leading countries within the High-Income as classified by the World Bank. Some observations can be made such as the strength of Switzerland, Norway, the Netherlands, Finland, and Sweden. Close behind is a cluster including the US, Ireland, Japan, the UK, and Spain. In general, the economies with the higher innovation levels also have higher per capita GDP realized. This correlation provides some support to our discussion that innovation can drive economic growth and well-being. Another characteristic we may note is that most top countries are small while few are large. Finally, there is high correlation between top 100 Universities and Top Innovation countries. More recent surveys have also reconfirmed this data. In fact, on a current report the US actually dropped out of the top 10 most innovative countries due to limitations in the education sector.

Rank	Country	Overall
1	South Korea	2.26
2	United States	1.80
3	Japan	1.79
4	Sweden	1.64
5	Netherlands	1.55
6	Canada	1.42
7	United Kingdom	1.42
8	Germany	1.12
9	France	1.12
10	Australia	1.02
11	Spain	0.93
12	Belgium	0.86
13	China	0.73
14	Italy	0.21
15	India	0.06
16	Russia	-0.09
17	Mexico	-0.16
18	Turkey	-0.21
19	Indonesia	-0.57
20	Brazil	-0.59

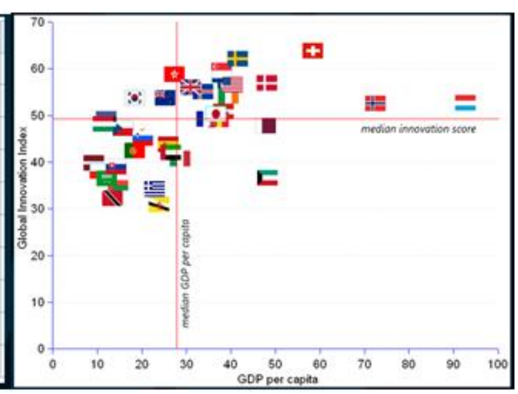


Figure 10 a and b – Top 20 Most Innovative Countries[2] and Innovation vs GDP per Capita

[2] *International Innovation Index is a global index measuring the level of innovation of a country, produced jointly by The Boston Consulting Group (BCG), the National Association of Manufacturers (NAM), and The Manufacturing Institute (MI), the NAM's nonpartisan research affiliate.*

B. 300 years of GDP Share

As we begin to talk about GDP, income, and wealth, it is instructive to take a long view of this history. The major economies and these top innovators in many cases have been dominating global production for centuries. This also plays into the state of affairs in the global economy today. When looking at the long run history of GDP in *Figure 10* we see some interesting historic trends (Roser, 2016). For example, China has long held a significant piece of the global economy along with India.

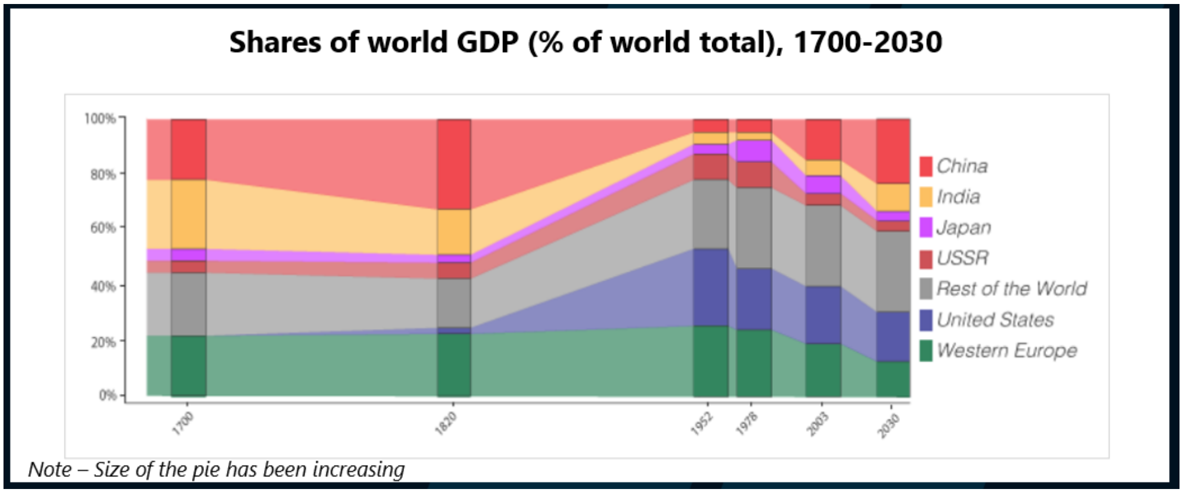


Figure 10 – 300 Years of Global GDP Share

Both countries only scaled back during the peak of the colonial period after hundreds of years of large-scale dominance. We also see the US emerge essentially from nowhere to become a major economic force. However, we also see that its share has been declining in the postwar period as other global economies emerged strongly. This dynamic is also important as it is an underlying change which impacts the sense of economic decline in the US. In fact, that decline is real for the economy at large with respect to the full global economy and certainly for many classes of workers. In the US the job and money pinch they feel is real. We will also see this in the Gini Index review of the US and global competitors.

C. Per Capita Income Inequality

Shifting our focus more specifically to income distribution we can explore the rates of Gini Coefficients across the world (*Figure 11*). The per capita income distribution per country is provided by data from the UN, the World Bank, and the CIA Fact Book (Gini, 2019). The map below indicates this per capita income distribution where a low is where incomes are more evenly distributed and higher numbers are where income is less evenly distributed. Think in terms of how golf is scored, thus a low score is good. That is to say that if the Gini Index was zero there would be absolute uniform distribution and a score of 100 would mean essentially only one person in the society had all income. Examining the map, we see a number of dark green countries such as Japan, Norway, Sweden, Germany, Ukraine, and some of the Central Asian Republics. These countries have the most evenly distributed income. The light green countries of Western Europe, Canada, Australia, India, and parts of Africa are less evenly distributed. In pink we see the US, Argentina, Russia, and parts of West Africa. Finally, in red are Central America, South America, Sub-Saharan Africa, and China who have the least even distribution.

A valid question here is why we see Afghanistan in the same category as Norway and Japan. The answer is that we need to keep two figures in mind. The Gini Index addresses income distribution only not wealth or the size of the economy or relative living standards. For example, if we look at the median income in Japan, it ranges around $45,000 per year. In Afghanistan the same metric is about $2,000 per year. Furthermore, the highly developed economy of Japan has universal healthcare, advanced nationwide transportation systems, and universal education. This places the comparison of the two countries into fuller light. Essentially, income distribution is an important view, but it is not the only view to indicate the living standard of a country. Finally, one can ask the question - why is the US not higher in the equitable distribution of income? The great middle class of the post war era did in fact enjoy a significant boom and improvement in living standards. But as we can see this had not been sustained leaving Americans in the middle of the pack relative to the rest of the world. A key factor to the US success in the immediate postwar period was the near destruction of the global industrial plant. Once this was rebuilt the demand for US good declined, US imports increases, and debt financing increased. For anyone who plays golf it is easy to understand this is not a good showing.

D. Income Disparity since World War II – Selected Countries

Taking a deeper view into the Gini findings, let's review the results for a few specific countries over a longer period of time. In *Figure 12* we can see about a dozen selected countries and their Gini performance from World War II until just recently (Citynoise, 2008).

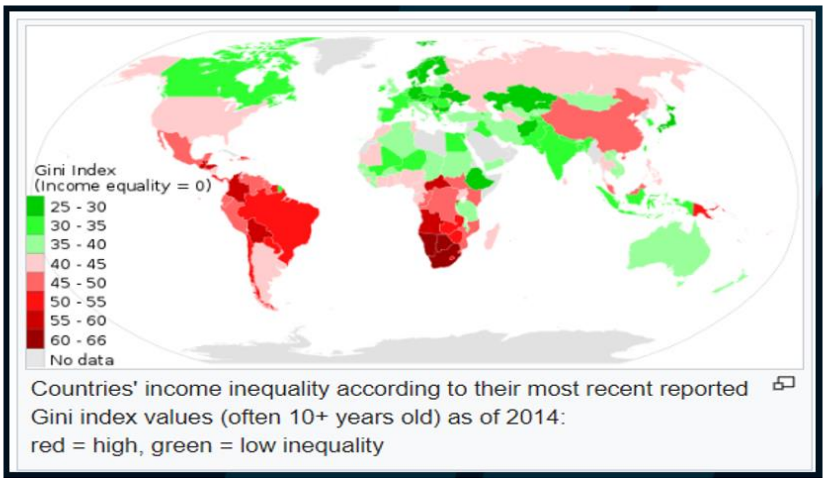


Figure 11 – A Recent Calculation of Gini Indexes per Country

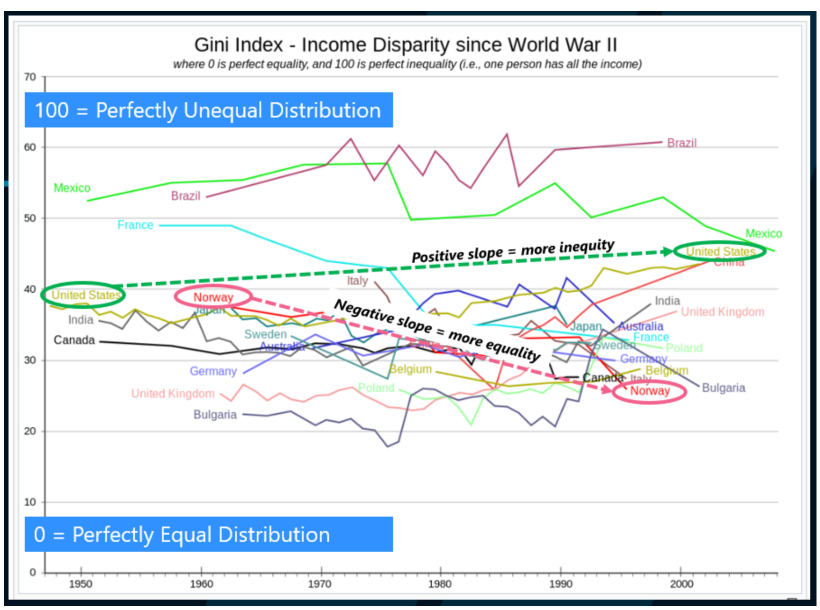


Figure 12 – Gini Index for Selected Countries Since World War II

The chart allows for a number of observations. Firstly, it is clear that different countries have different outcomes. Whatever you may think of having a more evenly distributed set of incomes it is clear that not all economies produce this consistently over time. Secondly, it is also clear that some countries have seen significant change in the postwar period while others have remained relatively in the same range. Thus, policies seem to matter. Thirdly, for illustrative purposes Norway and the United States are highlighted. As is clear, Norway moves from a score of 40 to one of 25 during this time period. Thus, a more equal distribution of income is being realized perhaps due to several factors including tax policies and the Norwegian oil industry. At the same time in the US the Gini Index climbed from 40 to 45 indicating a growing inequality in income distribution. This may also be driven in part by tax policies which have favored top earners as well as the decline in middle class incomes overall in part driven by global labor completion as heightened by the pursuit of low wages by US multinationals. We will now dive into additional data that supports these findings and tie this back to our discussion on innovation.

E. Median Wealth per Capita by Country

Switching from income distribution for a moment to view wealth distribution we can see a very different picture globally than we saw with income distribution (*Figure 13*). First of all, what is meant by wealth is not annual income but real property, savings, and investments. Right away we can see that the developed economies like the US, Europe, Japan, Korea, and Australia are mostly on par and hold leading positions in the amount of wealth held per capita (Davies, 2018). However, once again we see that the US lags some of its global competitors. We can also note that many countries which have relatively well distributed income, as in *Figure 11*, however they may have very minimal per capita wealth. Good examples would be Afghanistan, the Central Asian Republics, and most of Africa. This chart sets the context for our next focus where we combine a view of wealth with other factors like the Gini Index and innovation.

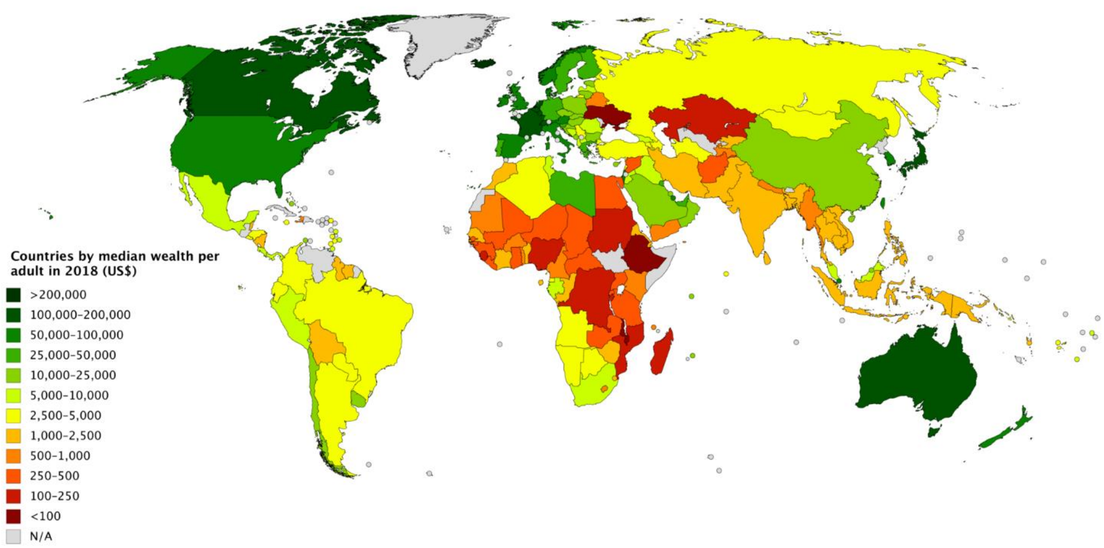


Figure 13 – Median Wealth per Capita by Country

For the United States the skewing of both income and wealth is now more pronounced than at any time since the 1920s (Alvaredo, 2019). For the top 1% in the US the income share is now over 50% of the total. This compares to 7.5% in Norway, 10% in Japan, and 13% in Germany. As we can see in *Figure 14* below this income inequality also extends into wealth inequality where since 1980 the top 1% has seen their share of the total wealth grow from just approximately 25% to nearly 40% today largely at the expense of the middle class.

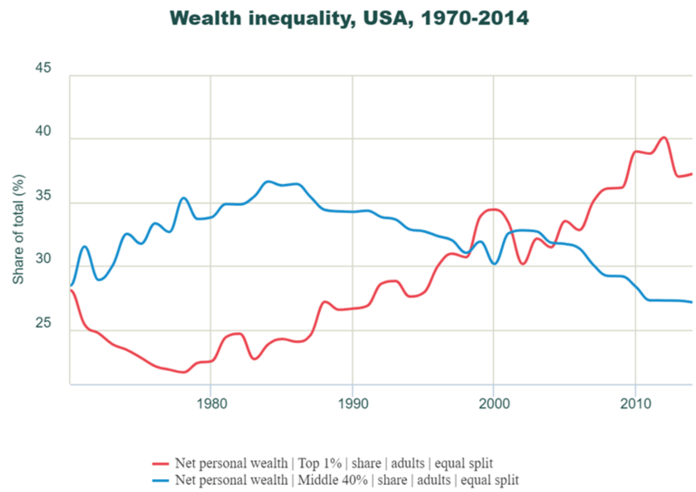


Figure 14 – change in wealth share distribution

F. Median Net Worth per Capita by Country (Top 25)

Finally, in an attempt to tie together the themes of this paper and the data we have been reviewing, the below chart depicts median net worth per capita by country (*Figure 15*). The Top 25 countries in Median Net Worth per Capita are displayed in descending order. However, this chart is annotated to denote how innovation may play a role in both wealth creation and income distribution (Cusick, 2019). Iceland, Switzerland, and Austria claim the top 3 spots. We know from our earlier data that Switzerland has a high innovation ranking so that may play a role. But there could be other societal factors at play there as well. Interestingly, Norway comes up as number 7 on Net Worth per Capita. We have also seen Norway rank very highly on each innovation survey. We also know that it's been reducing its Gini coefficient level for the last 60 years. This seems to be an interesting combination and places them in a leading position overall. The Netherlands comes up #5 on innovation and 14 on this list of net worth. South Korea is also very interesting as it ranks #1 in innovation, has a very low Gini, and lands at 20th for net worth. For a small country recently developed as a technical powerhouse they seem to have done well. Finally, the US is #24 in net worth, high in Gini, and is high in innovation although no longer in the top 10. One may ask if this is an anomaly or a new reality for the US. It is probably a safe conclusion from all of this data that encouraging innovation can drive more equitable income and wealth distribution, but innovation may not be the only factor to impact economic outcomes.

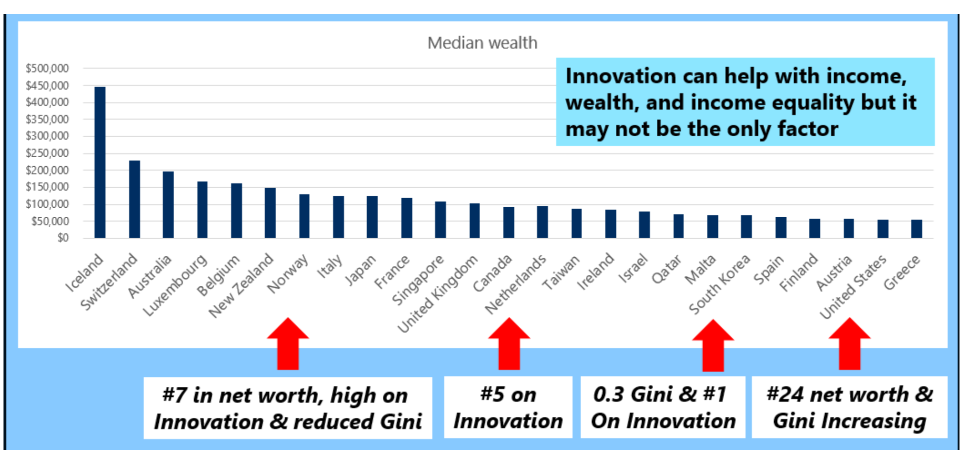


Figure 15 – Median Net Worth per Capita by Country (Top 25)

VI. Conclusions

We began this discussion by saying we would cover three general areas: defining innovation; exploring innovation and the economy; and reviewing the relationship of innovation, economic growth, and economic equity. We provided a full lifecycle model for innovation and explained the key aspects to innovation methods and approaches. We also introduced such concepts as the K-Wave or Supercycle, Kuhn's Paradigm Shift, and Schumpeter's Creative Destruction. These tools along with the economic context provided by a summary of Henry George's views on innovation led us to a discussion of extensive data on the economy, income, wealth, and its relation to innovation as well as to its equitable distribution. As we finish, consider that first diagram defining Science, Engineering, and Technology and that fact that all of us are Scientists in our own right. Thus, just like we form a hypothesis around that frozen lake we may encounter, we can now form our own considerations around the ideas and data presented here. Have they been sensible and convincing? If so, there is much to act on to take a deeper look into these ideas and consider what might be applied from them.

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James Cusick is an IT leader with over 30 years of experience in Software Engineering, Information Security, IT Operations, Process Engineering, and Project Management. He is currently Director of IT Service Management Process with a global information services firm. Previously James held leadership roles with Dell Services, Lucent Bell Laboratories, and AT&T Laboratories. James was also an Adjunct Assistant Professor of Computer Science at Columbia University and has published widely in his fields of interest including two recent books on Software Engineering and over 75 related articles. James is currently exploring concepts in Political Economy at the Henry George School of Social Science. Contact James at j.cusick@computer.org.

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