Chainlink Investment Thesis

Critical Infrastructure for the 4th Industrial Revolution

Abstraction Capital

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Abstract

This paper urges the reader to consider investing through the lens of intellectual capital, energy, and efficiency. These are the core variables of work output, or productivity growth. This model of thinking about intrinsic value is most easily understood through analyzing past periods of rapid growth, most notably the Industrial Revolutions. Looking forward to the 4th Industrial Revolution and its foundational technologies: The Internet of Things, Artificial Intelligence, and Distributed Ledger Technology, it becomes clear which core variables will generate a new step-change variance in productivity growth. This transformation is dependent on low-level blockchain infrastructure. Chainlink, a blockchain middleware protocol, is a necessary component to this infrastructure. It will help enable the 4th Industrial Revolution as well as capture the most value from it.

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1 Introduction

Periods in human history with rapid productivity growth, most notably the Industrial Revolutions, have core innovations that create a positive feedback loop of expansion. These innovations, such as steam power, the internal combustion engine, electricity, the transistor, or the Internet Protocol, create a fundamental change in the way humans interact with the world. They then lead to a proliferation of technologies which rely on them. For example, steam power was a foundational component of the textile industry, iron industry, and the production of advanced tooling. Smart phones and computers are only possible due to advancements in digital electronics, most notably the transistor. The Internet protocol provides the network infrastructure for the largest software companies today, such as Google, Amazon, and Facebook. These highly disruptive technologies don't interface with consumers directly. Instead, they exist as base-level infrastructure, ultimately enabling technology that impacts consumers lives.

Humanity is sitting on the precipice of the 4th Industrial Revolution (4IR). This revolution will be defined by automation of many industries today, as well as cyber-physical systems which interact with humans throughout their daily lives. The foundational technologies that will enable this are the Internet of Things, Artificial Intelligence, and Distributed Ledger Technology, or Blockchain. They make up what will be called the 4IR stack. These core innovations are necessary, base-layer infrastructure to the automated systems of tomorrow.

We believe the investible assets that will appreciate the most during this revolution are the native tokens of various Blockchain protocols. The following thought experiment frames this assumption.

> What if one could have invested in the hypertext transfer protocol, HTTP/S? Imagine there were 1 million shares of the protocol, called $HTTP. If there was a small fee users had to pay whenever they typed in "http**s**://www...," then owning 1% of $HTTP shares would yield 1% of all fees generated. The market cap of this protocol would likely be more than Amazon, Facebook, or Apple, as the estimated market cap of internet reliant companies is over $30 trillion.

This though experiment helps when attempting to define a blockchain protocol. These protocols are not owned by anyone – they are effectively public utilities, like the internet, which are accessible to all. Because they are open-source and decentralized, they rely on a token to become economically self-sustaining, using game-theory to incentivize rational economic actors to participate in the network. Although these protocols are created by companies who hold the tokens as a means to incentivize adoption and bootstrap the network, the company will ideally offload governance to its users through a decentralized autonomous organization (DAO)[1], enabling self-governance through voting. Because blockchain protocols are effectively globally accessible public utilities which economically incentivize users to provide services, their potential market cap is significantly higher than any single company. Since inception, the Dow Jones has risen approximately 200,000% including dividends. Microsoft, Apple, and Amazon have risen 330,000%, 88,000%, and 138,000% respectively. Bitcoin has risen 105,000,000% since 2010. Bitcoin was the fastest investible asset to ever reach a 1 trillion-dollar valuation, and its market cap will likely be larger than any company by the end of this market cycle.

[1] There still exist a power law distribution in control the protocol, but this diminishes over time in winning protocols as adoption increases. Today there are also means by which a protocol can launch *as* a DAO

Blockchain is a key component to the 4IR Stack because the properties provided by permissionless distributed computing systems – security, privacy, and trustlessness – are critical to the growth of an automated, machine-based economy. The potentially millions of interactions per second between machines in this economy must be auditable, traceable, and secure, with privacy preserving optionality. Blockchains appear to be the only viable solution for this transition. Having entire smart-cities or self-driving car networks operate on a single private company's servers would be disastrous for human privacy, agency, and safety.

The defining use-cases of the 4IR will roll out in waves. The first wave will be defined by the automation of various software-based services: Money, Finance, Insurance, Global Trade, and Enterprise Business Services. The second wave will be the gradual roll out of automated, cyber-physical systems which will begin to power an autonomous economy.

The defining invention of the 4IR will be Blockchain based smart contracts. Smart contracts allow the execution of any scriptable business logic in an automated and tamperproof manner. Although some smart contracts only consist of an on-chain component[2], over 90% also require an off-chain component. This off-chain component usually exists in the form of a data input, such that the smart contract can execute based on a real-life event, e.g. a market price fluctuations, an insurance event, or a sensor detecting the temperature at a specific location. A *hybrid smart contract* is a smart contract which has both an on-chain and off-chain component, and is capable of interacting with data and infrastructure outside of blockchains. Smart contracts will also need off-ramp rails in order to pay out in any currency in any bank account in the world.

Chainlink, a blockchain agnostic middleware protocol, provides all off-chain services necessary for the execution of hybrid smart contracts. Chainlink will also act as a blockchain abstraction layer, giving enterprises and governments the ability to access hybrid smart contracts and other blockchain based services without upgrading their current legacy infrastructure. Ultimately, Chainlink aims to create a *decentralized metalayer* which will allow seamless development of any decentralized application while maintaining interoperability with every blockchain and legacy system. This will abstract away any complexities of interacting with the blockchain layer and allow developers to easily create cross-chain hybrid smart contract services, which will power the automated systems of tomorrow.

Abstraction Capital believes that the Chainlink Protocol is the most critical piece of infrastructure for the widespread adoption of hybrid smart contracts. With an intelligent cryptoeconomic[3] design and growing network effect, the LINK token is well positioned to capture the most value from the 4IR.

[2] Bitcoin transactions, for instance

[3] Can find the definition here: https://ce.mit.edu/

2 Productivity Growth

In physics, energy is defined as the capacity to do work. Work is most commonly defined as the measure of energy transfer when an object is moved over a distance by an external force [1]. These terms are abstract in nature and, interestingly, entangled with one another. By defining one, the other can then be defined.

For the common definition, Oxford defines work as, "activity involving mental or physical effort done in order to achieve a result." This definition accounts for energy expenditure, but it leaves "result," undefined. A result is subjective – it has a different meaning depending on the person. In the case of any economic transaction, if work is performed and a result is achieved, then the worker receives payment. Therefore, work can be defined as doing something that someone else is willing to pay for. And why do people pay for things? To survive or live more comfortably. In a society, humans are fundamentally incentivized to complete tasks or create technologies that help others survive. The better those services or technologies, the more others are willing to pay for them. This is the virtuous cycle which gives the term work significance – to be productive in relation to the fundamental human condition of survival. Work is productivity, and hence energy is the capacity for one to be productive.

Productivity growth, in economics, is the measure output per unit of input (such as labor, capital, or any other resource), and it is typically calculated for the GDP of an economy as ratio of hours to work [2]. This is very similar to the aforementioned definition of work, however here, productivity is specified in terms of labor or capital. Thus, there is an innate connection between money and energy: leading to the next critical assumption.

Money, or a unit of value, is effectively potential energy[4]. By intelligently spending energy on a productive action, that energy is converting into work plus a storable form of potential energy (money) that can be transferred through space and time. The more work is done; the more potential energy there is to "spend," or convert into new work. Note that an intelligent actor must have access to energy at a specific point in time and space to be able to produce work.

$$[INT + E_O * \eta]_{s_0} = W + E_P \qquad \textit{Equation 1}$$

$$-E_P + [INT + E_O * \eta]_{s_0} = W \qquad \textit{Equation 2}$$

INT = Intellectual Capital/Intelligent Actor

E_O = Ordered, or usable, Energy

η = Efficiency

s_0 = Location and Time dependency

W = Work, or Productivity

[4] There is some research on tangential subjects relating energy to money, such as the thermodynamic power theory of value

E_P = Potential Energy, or Money

Note that work and potential energy must be conserved[5]. This means that if the total amount of intellectual capital, ordered energy, and efficiency stay the same, then it is impossible for net productivity to change. If there is an increase in E_O, INT, or η, then theoretically productivity growth should occur. The opposite is true as well. This process creates a self-reinforcing cycle, which can be visualized with this feedback loop:

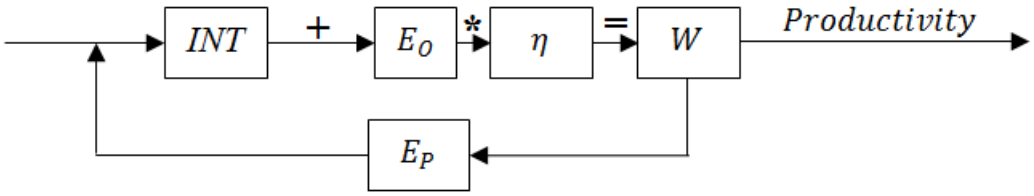


Figure 1 – Productivity Feedback Loop

When one of these variables increase, the economy expands in an accelerating fashion. Due to human emotion and secular changes in our political, technological, or natural environment, this feedback loop can reverse once a variable is depleted. Once reversed, the cycle will accelerate in the opposite direction. This process describes debt cycles, which lead to the market being overvalued or undervalued. Due to the invention of loans, or credit, potential energy can be created without work occurring. This introduces leverage into the system, which further accelerates any positive expansion or contraction. Given enough time, net economic growth will regress to the productivity growth curve.

[5] The 1st law of thermodynamics

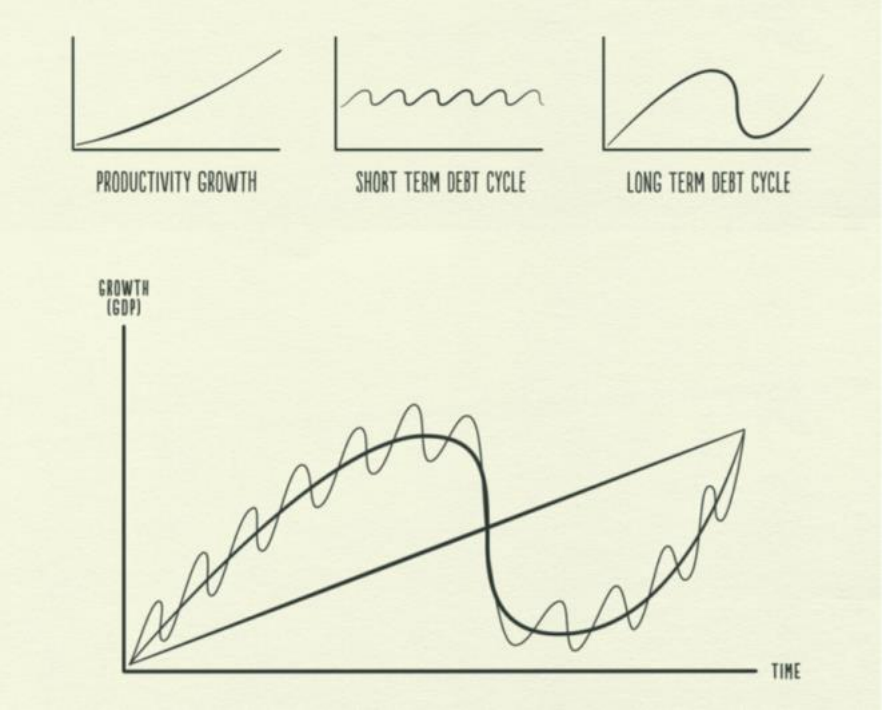


Figure 2 – Visualization of the long term debt cycle

Now that this model of money and energy has been established, it will be used to analyze the past industrial revolutions. This model is an incredible simplification when viewing productivity, and certainly for some specific technologies it might not fit as intuitively as others. By breaking down productivity to these core variables, though, insights can be found from past examples which will help identify future trends.

3 The Industrial Revolutions

This section will focus on how some of the most important technologies were influenced by the key variables: Intellectual capital, usable energy, efficiency, and spacetime dependency.

Klaus Schwab, founder and executive chairman of the World Economic Forum, describes an industrial revolution as the appearance of "New technologies and novel ways of perceiving the world that trigger a profound change in economic and social structures "[3]. By viewing the industrial revolutions through the lens of energy and work, we can deduce similarities between each and begin to evaluate the potential to use this model to predict future outcomes.

3.1 The 1st Industrial Revolution

"The 1st Industrial Revolution is widely taken to be the shift from our reliance on animals, human effort and biomass as primary sources of energy to the use of fossil fuels and the mechanical power this enabled" [4]. Goods and items which used to be created by hand were now produced in mass by machines in factories. It was defined by a few key innovations: textile production, iron making, and machine tools. The final, and most important innovation which powered the 3 innovations above, was steam power. It provided the capability to convert useless or disordered forms of energy (heat and coal) into useful energy (mechanical) which could be used to perform work. Although less critical than steam power, waterpower was also widely used [3].

Steam and water engines would be used to power textile machines. Similarly, steam engines greatly increased the efficiency of iron making because they allowed the pumping of water and air in blast furnaces, which enabled an exponential increase in iron production by overcoming limitations of waterpower. This increased rate of iron production led to a vast increase in the number of machine tools that could be produced to further manufacture products. Finally, the steam engine allowed coal miners to mine much deeper and faster for more coal to power steam engines.

Due to this increase in usable energy, the working population could mass produce goods for the first time ever. The agrarian economy evolved into an industrial one, where urbanization led to the diaspora of people into cities. Higher wages led to increased life span and a steady growth in the total size of the global work force. The tools yielded from the expansion of iron production led to human capital being able to produce goods more efficiently.

The first industrial revolution was enabled through an incredible increase in E_0 which drove the revolution and the productivity growth that followed.

3.2 The 2nd Industrial Revolution

Beginning in the late 19th century and spanning to the early 20th century, the 2nd Industrial Revolution was defined by a period of rapid industrial development and scientific discovery. It was characterized by the vast expansion of railroads, large scale iron and steel production, the supply chain, the internal combustion engine and petroleum, and the beginning of electrification [8].

The creation of railroads allowed cheap transportation of human capital as well as materials and products, in turn leading to the propagation of more railroads. Trains were powered by coal, whose cost dramatically decreased due to the ease of transportation of large quantities of it via railroads – further accelerating growth. Similarly, efficiency increases in steel and iron production (and the ability to

transport this material by trains) ensured that the growth of railroads was not bottlenecked by the production rate of the rails. Work began to centralize in factories, where supply chains greatly increased the efficiency by which work could be performed.

The petroleum industry began in the mid-19th century and was originally useful for various chemicals and oils. After the invention and commercialization of the internal combustion engine by the 1870s, it found another use. Oil, which was originally an unusual byproduct of the petroleum refining process, was critical to power internal combustion engines. By the early 20th century oil was utilized to power automobiles, trains, boats, and large ships, which very quickly were being mass produced. Finally, electrification was developed in the late 19th century and became common within homes by 1920. Electrification greatly improved factory working conditions by replacing gas lighting, but most importantly was used to power DC motors (invented in 1886) [8]. Three years later, 110 electrical steel railways had already been constructed, and by 1920 the electric street railway had become major infrastructure across most industrialized cities [8]. Electricity allowed for coal to be burned in centralized locations, and to easily distribute vast amounts of energy across cities at effectively the speed of light.

The 2nd industrial revolution brought about a new form of potential energy in Oil and the ability to harness it with the combustion engine (E_O). The 2nd Industrial revolution also encapsulates the incredible growth in the ability to transport intellectual capital and energy to locations where it could be utilized more efficiently (η). By allowing intellectual capital and energy to move around more freely (trains and electrification), this provided a large increase in the secondary variable within the energy equation, s_0. For work to be performed, an intelligent actor must have access to energy and the tools required to perform said work. The ability to bring intelligent actors and energy together further increases the productivity growth. Workers followed the jobs and moved into cities for higher paying factory jobs. Advances in the sciences were being applied to industry, and directly impacted the efficiency of factory assembly lines.

3.3 The 3rd Industrial Revolution

Beginning around 1970, the 3rd Industrial Revolution is defined by the shift from mechanical and analog technology to digital electronics. This would lead to the adoption and proliferation of digital computers, as well as the development of open-source standards which we now know of today as the internet protocol suite (TCP/IP, HTTP/S). Although energy technologies continued to progress[6], they did not define the 3rd industrial revolution. As such, this revolution differed than the first two in the sense that there was not some new energy related discovery which provided a step change in productivity growth[7]. Instead, it was the invention of computers as either levers on human intelligence or outright capable intelligent agents which led to growth.

Pioneered by the invention of the transistor in 1947, semiconductor research began to progress through the 50s. By 1959, silicon semiconductor devices were mass produced. In the 60s, integrated circuits were developed, and by 1971 the first microprocessor was released by Intel [9]. These technologies laid the foundations for the modern home computer. Although the scope of their intelligence is extremely narrow compared to humans, computers are hyper efficient in specific verticals. As such they can act as a standalone or supplemental lever on human intelligence. Computers allow humans to process large

[6] Nuclear, alternatives, fracking, high efficiency regenerative gas turbines

[7] Fracking likely should be considered here, though

amounts of information extremely fast, which before was never possible. Because they can be programmed to make decisions with pre-defined algorithms, they can act indefinitely with almost no rest. This gave the rise to automation, which takes many forms today.

The other great invention of the 3rd industrial revolution was the internet. The internet allows humans and machines to communicate with one another at near instant speeds across the globe. Not only does this allow for high degrees of automation, but quite simply it allows all intelligent actors to respond more quickly to any events. It allows businesses to make decisions faster and generally accelerates the rate of economic growth. This shows that information is critical to productivity, and hence an important part to the work equation we defined earlier. We will discuss this further in the next section.

To conclude, the 3rd Industrial Revolution can be characterized by the vast expansion of intellectual capital, INT, on planet earth in the form of computers that drove the productivity growth produced by the digital revolution. Computers generated a massive increase to the efficiency variable as well, as they can accomplish specific tasks significantly faster than humans. Finally, with the ability to send information instantaneously anywhere on the globe, there are specific classes of work which could be performed regardless of location dependency, translating to an increase in s_0 as well.

4 The 4th Industrial Revolution

4.1 Data is the New Oil

A clear trend emerges upon reviewing the past industrial revolutions. Once humans understood the laws of thermodynamics and mastered the physics underlying heat engines, our capability to generate energy ran up against a ceiling bound by the laws of the universe, as well as access to energy sources. Pending the long-awaited implementation of fusion reactors, humans are doing just about as good as we can get. Our grid could be more environmentally friendly through renewables or with a political shift enabling nuclear and micro nuclear reactors, but that won't necessarily provide a sizeable increase to our usable energy stock. The larger problem today is not generating energy, but instead storing it.

Innovation in the world of atoms has stalled considerably since the early 1970s, in what some refer to as the Great Stagnation[8]. Aside from a period of 3% growth in the mid-1990s to the early 2000s – which can be attributed to the 3rd industrial revolution – the growth rate has hovered around 1.2% [7]. This is an interesting trend, as it appears that new step change variance in productivity growth is coming from novel digital discoveries, not physical. This statement is a generalization, but we contend this trend is real. Although energy is needed for everything and there will still be plenty of innovations that lead to efficiency increases moving forward, it seems that energy innovations will not continue to *scale* with productivity as heavily as data driven innovations. Through advances in renewables, battery technology, nuclear, and eventually fusion, it appears that the cost of energy is actually trending towards zero over time.

From a World Economic Forum survey of industry strategy officers in 2015, "88% of automotive strategy officers agree that by 2030 at least one major automaker will earn more revenue from selling data and mobility services than from selling cars and auto parts. 70% of professional services strategy officers agree that by 2025, digital solutions will generate more revenue for professional services firms than services delivered by people" [6]. It doesn't seem possible that a car OEM could make more money selling data than cars, but that is the reality we are heading towards. Manufacturing as a percentage of GDP has declined over the decades as well, specifically in the more advanced westernized nations.

[8] Tyler Cowen – The Great Stagnation

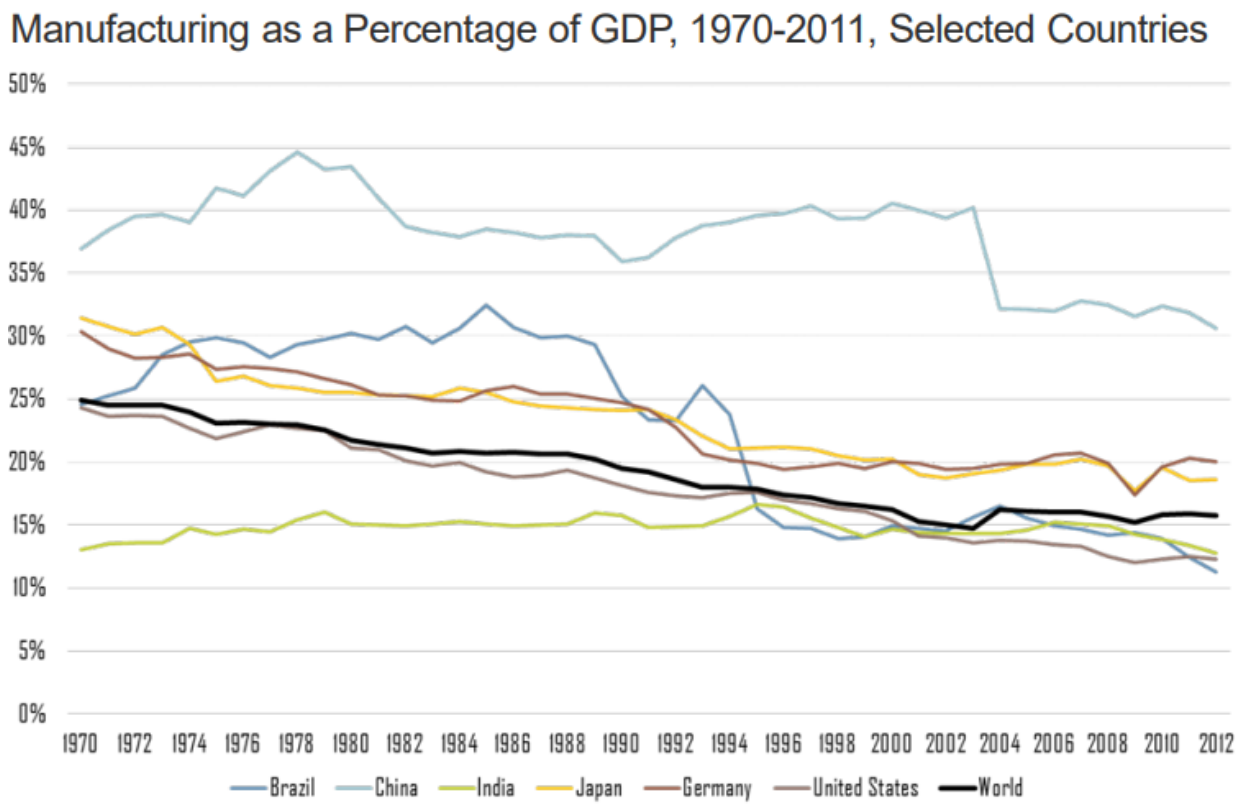


Figure 3 – Manufacturing as a percentage of GDP has declined over time [6]

This chart is even more impressive when you realize total manufacturing has increased – it's just digital/data driven GDP increases have been that significant[9]. Similarly, in the last decade or so there has been a clear shift in the worlds' top companies from energy to software/hardware and data businesses.

[9] It is worth noting that due to globalization, much manufacturing in developed countries has moved to undeveloped ones. Note the World trendline is still heading down, though

Largest Global companies in 2018 vs 2008

2018				2008			
Rank	Company	Founded	USbn	Rank	Company	Founded	USbn
1.	Apple	1976	890	1.	PetroChina	1999	728
2.	Google	1998	768	2.	Exxon	1870	492
3.	Microsoft	1975	680	3.	General Electric	1892	358
4.	Amazon	1994	592	4.	China Mobile	1997	344
5.	Facebook	2004	545	5.	ICBC (China)	1984	336
6.	Tencent (China)	1998	526	6.	Gazprom(Russia)	1989	332
7.	Berkshire	1955	496	7.	Microsoft	1975	313
8.	Alibaba (China)	1999	488	8.	Royal Dutch Shell	1907	266
9.	J&J	1886	380	9.	Sinopec (China)	2000	257
10.	JP Morgan	1871	375	10.	AT&T	1885	238

Source: Bloomberg, Google

Figure 4 – The worlds' largest companies are data driven, AI competent big tech companies

With this trend in mind, what does the 4th Industrial Revolution have in store? Per the World Economic Forum, "The Fourth Industrial Revolution can be described as the advent of "cyber-physical systems" involving entirely new capabilities for people and machines. While these capabilities are reliant on the technologies and infrastructure of the Third Industrial Revolution, the Fourth Industrial Revolution represents entirely new ways in which technology becomes embedded within societies and even our human bodies. Examples include genome editing, new forms of machine intelligence, breakthrough materials and approaches to governance that rely on cryptographic methods such as the blockchain." [5] Other technologies include sensor networks, internet communication infrastructure, intelligent real-time processing and event management, actors for mechanical activities, embedded software, big data and data provisioning, automated operations and management of system activities, advanced robotics, and 3D/4D printing [6].

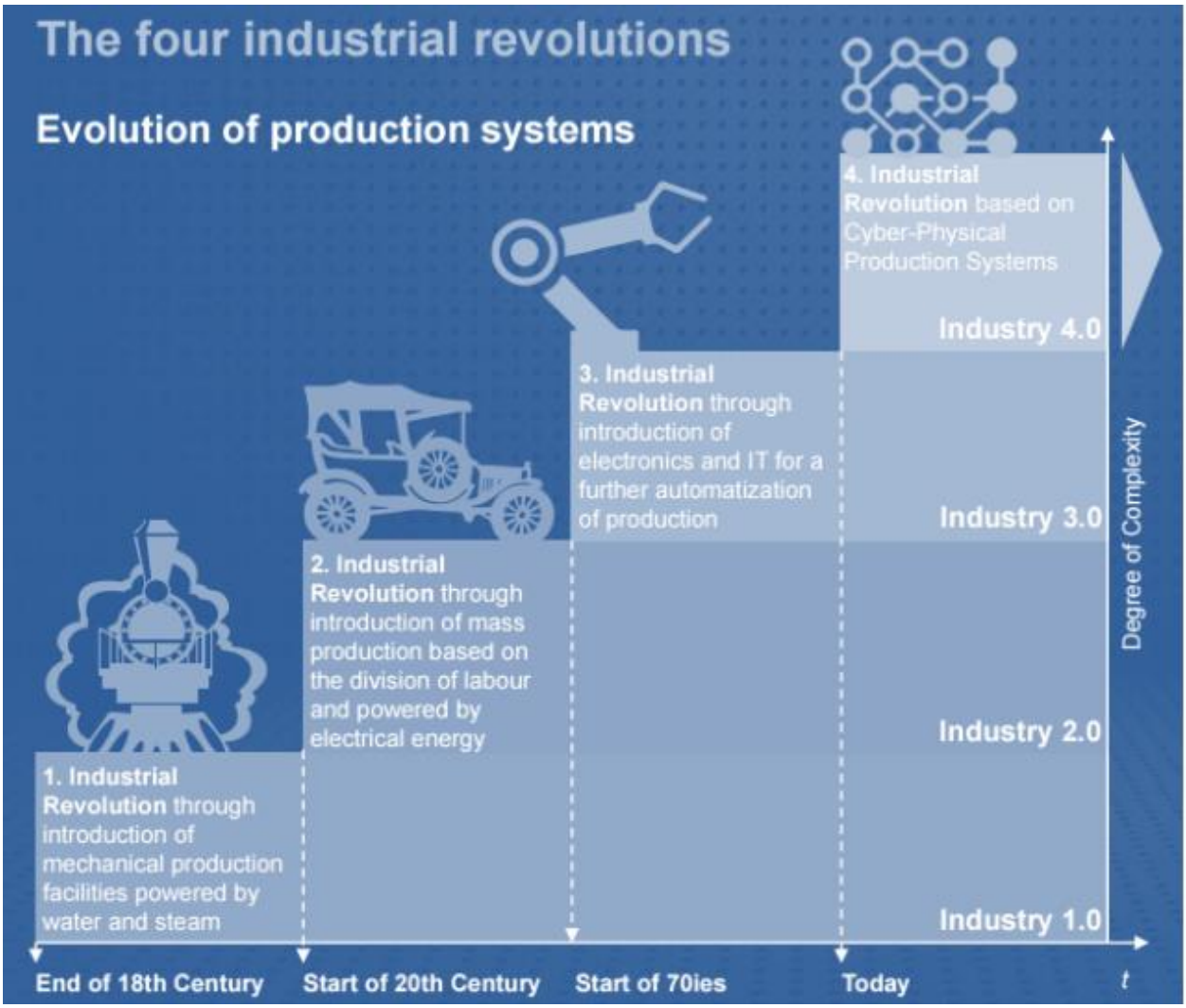


Figure 5 – The four industrial revolutions [6]

Many of these technologies are interesting because in the domain of atoms, they are not groundbreaking achievements. The mechanical portion of a self-driving car is, literally, just a car. A robot is just a combination of metal rods, motors, and electrical wiring – all simple technologies. The complexity exists in the domain of computer control of mechanical system. Hence, the foundational technologies to this revolution will be the Internet of Things (IoT), Artificial Intelligence (AI), and Distributed Ledger Technology (DLT). Clearly there are emerging technologies that don't fall into one of these buckets[10], explicitly, but it is very likely that one of them (specifically AI) enabled their development.

Tying this back to the productivity equation, when one takes a closer look at the INT variable it can be broken down into a few different processes. For something to be considered intelligent, it must be able to consume information, process that information, decide, and then act.

[10] Exotic materials, genome technologies, etc.

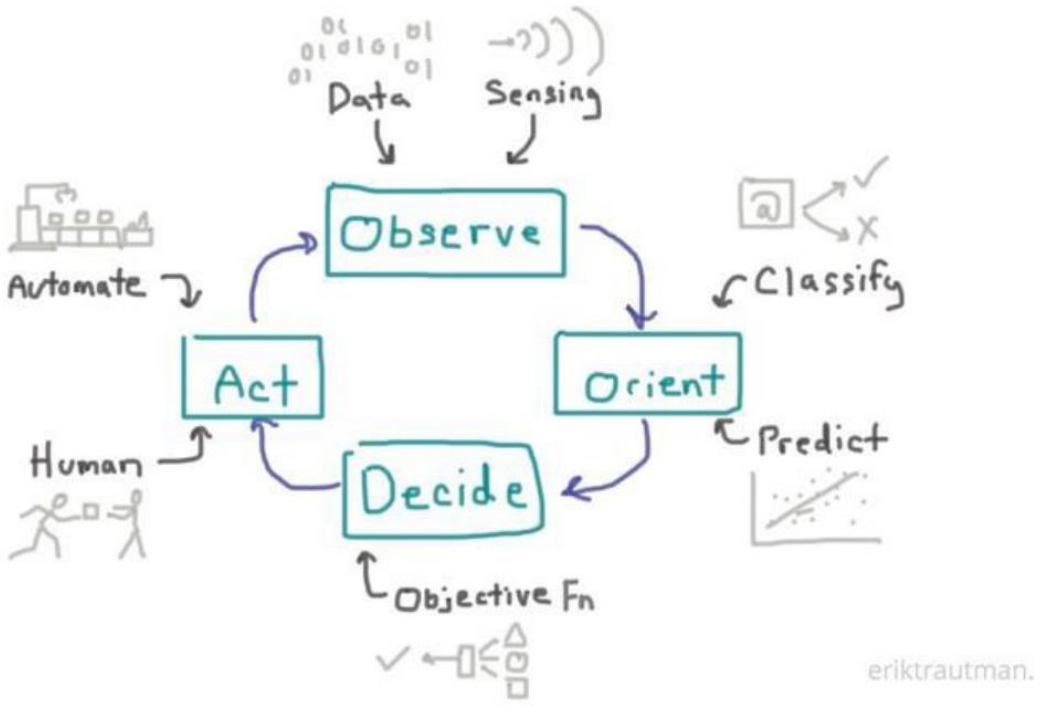


Figure 6 – The intelligence loop[11]

Humans without senses wouldn't be able to do much of anything, let alone produce work. It is only after retrieving data that our brains can process information about the world and decide on an outcome for our bodies.

Recalling the productivity equation, an intelligent actor is *necessary* to perform work. When we talk about the proliferation of inorganic life in the form of robots, not only do they need to be powered by energy so that they can perform mechanical interactions with the physical world, but they need to be powered by data so that they know what to do in the first place. Although data is not an energy source per say, it is a necessary input to the work equation.

$$[(DATA + AI + MECH) + E_O * \eta]_{s_0} = W + E_P \qquad \textit{Equation 3}$$

$DATA$ = Information

AI = The ability to process information, compute, and decide

$MECH$ = The ability to interact with the physical world. Not required for software-based systems

Data is the new oil, the expression goes – it will be the fuel of a new automated, machine-based economy. This means that data is just as, if not more, important to the work equation as energy. Robots can perform tasks much more efficiently than humans and the number of work capable robots is only going to keep

[11] Picture from @CryptoOracle's God Protocol Paper v1.0

growing in size. The hypothesis that data will drive more productivity growth than energy appears to make sense in this context. Regardless, it is clear that data is as fundamental a resource as energy.

4.2 Foundational Technologies

4.2.1 The Internet of Things

Robots are no different than organic life – machines rely on data to make decisions and act. Whether that data is manually inputted by a human or automatically retrieved from a sensor, it is a necessary part of the intelligence feedback loop. Sensor technology has progressed substantially throughout the years, and can measure nearly every physical, chemical, electrical, magnetic, or optical interaction necessary to understanding our environment.

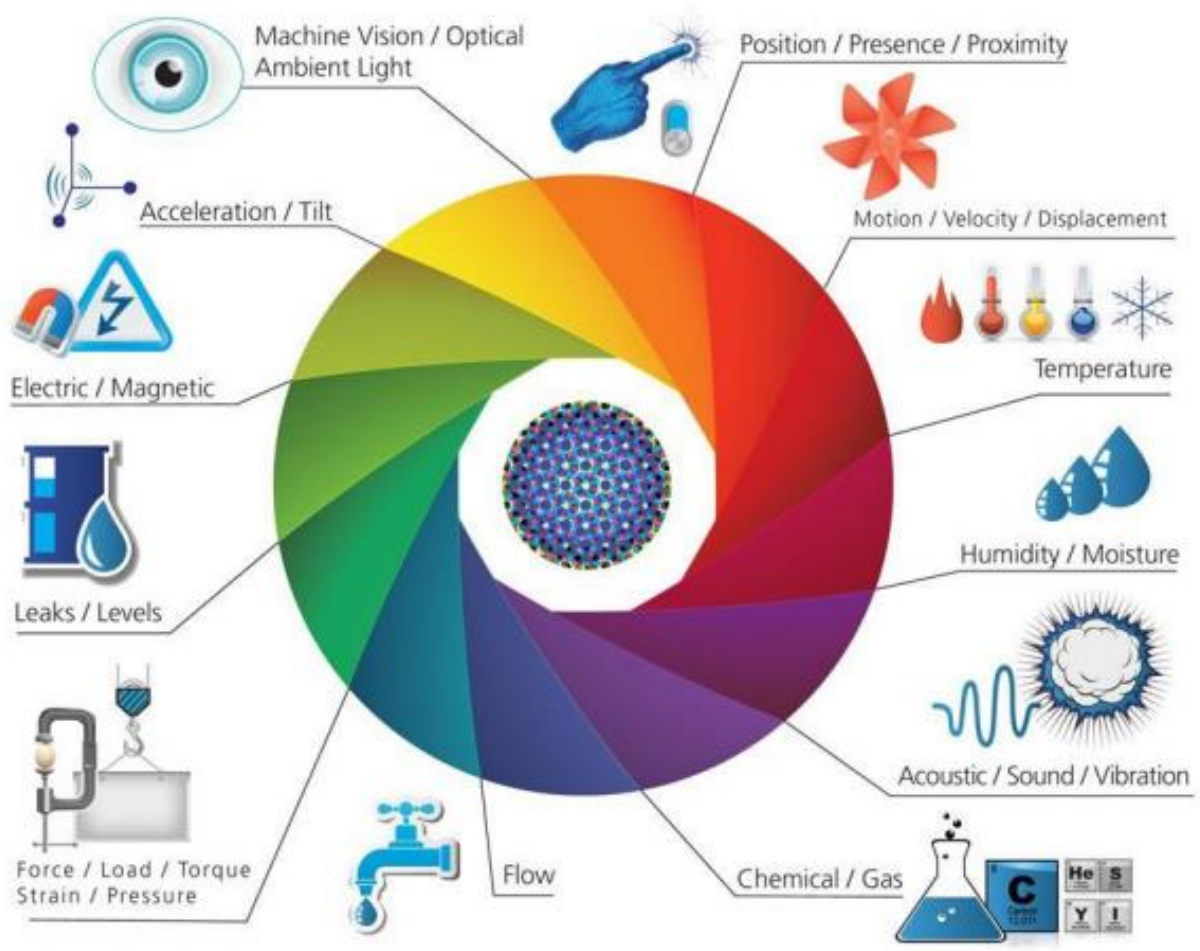


Figure 7 – Various types of sensors

These sensors will be embedded into everything around us, from our phones, laptops, clothing, bed, house, cars, cities, and factories. Together, they will form the Internet of Things (IoT). This collection of eventually trillions of sensors will compose the base layer of the 4IR stack – where information about the world will be observed and converted into a string of bits, where it can now be processed in the digital world.

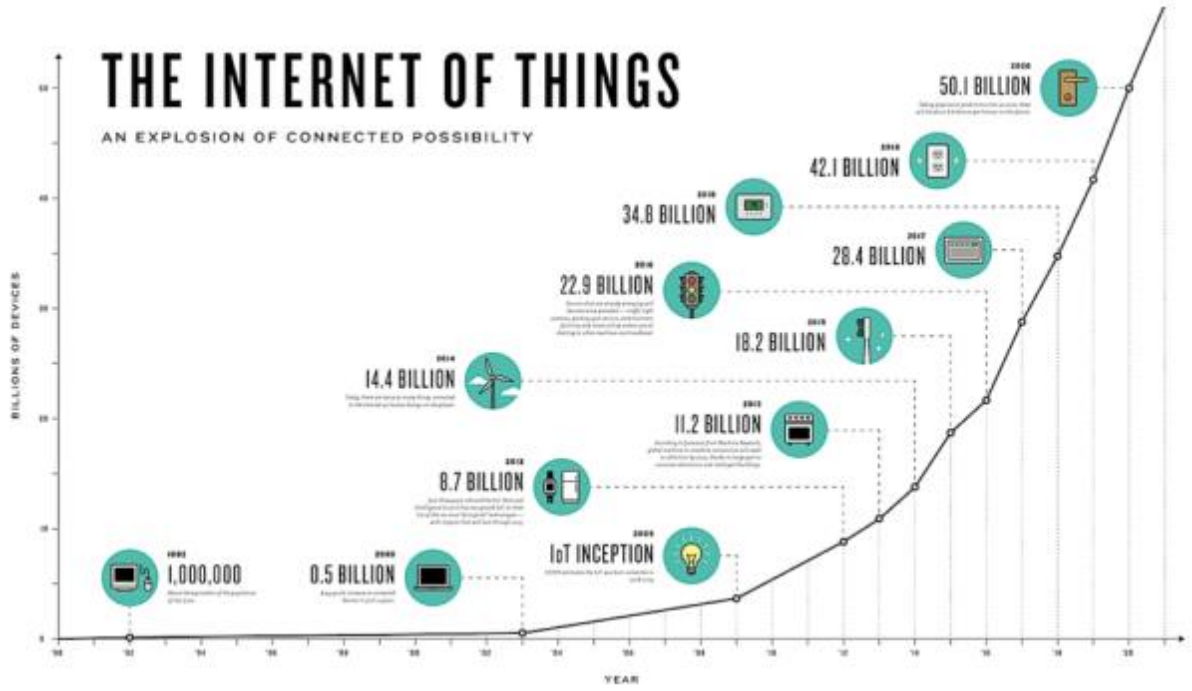


Figure 8 – Over 50 billion edge devices exist as of 2020, and the exponential trend is not slowing

At the base level, data must be gathered from observation, i.e. a sensor. Through edge-computing and cloud computing, this data can then be processed, filtered, and stored efficiently in a company's data center, where it can then be distributed through the use of APIs. An application program interface (API) is a set of routines, protocols, and tools for building software applications. It is effectively a standardized connection point to query data from in a specific format. The API economy is growing rapidly and will be the basis for data transfer in the 4IR.

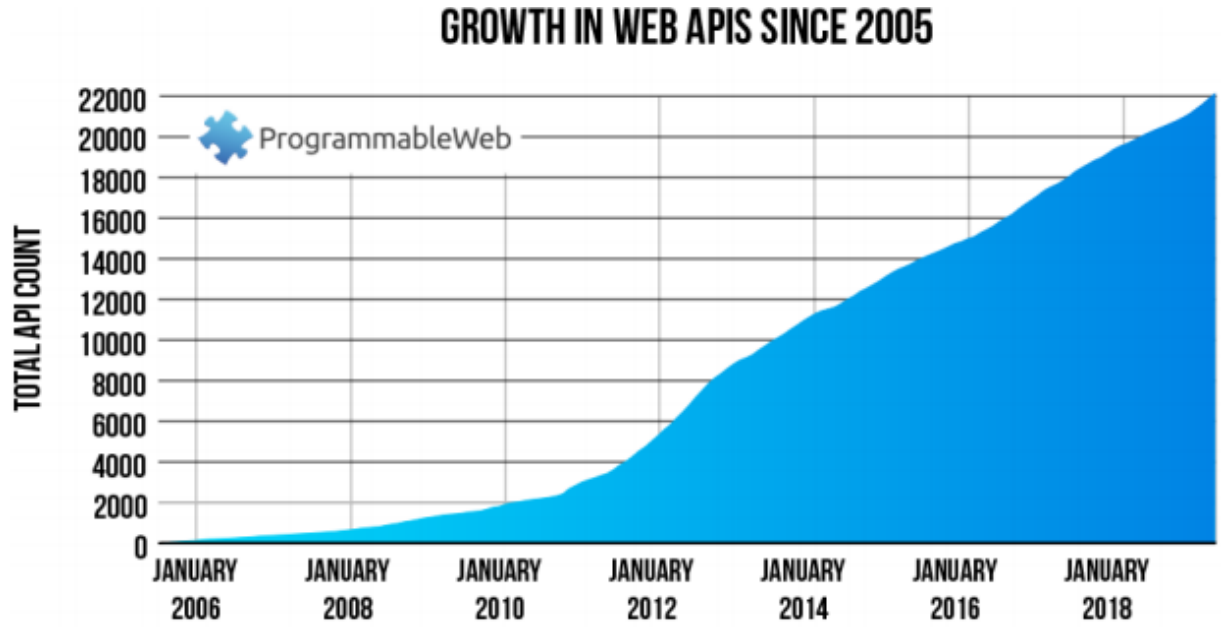


Figure 9 – The API economy has grown exponentially

4.2.2 Artificial Intelligence & Machine Learning

if the sensory nervous system is IoT, then the brain is AI. Today companies collect data on almost every process they perform, building up large data sets of what used to be throwaway data. With AI and machine learning, though, trends and insights can be seen in these data which could not have been retrieved before. This is what makes data so valuable – it enables AI to extend human intelligence and productivity to a place previously unachievable. Today the AI engine (in most cases) is basically a number cruncher that can drastically outperform people. Typically this is referred to as machine learning, a category of artificial intelligence. The 4IR will be defined by AI which is capable of much more.

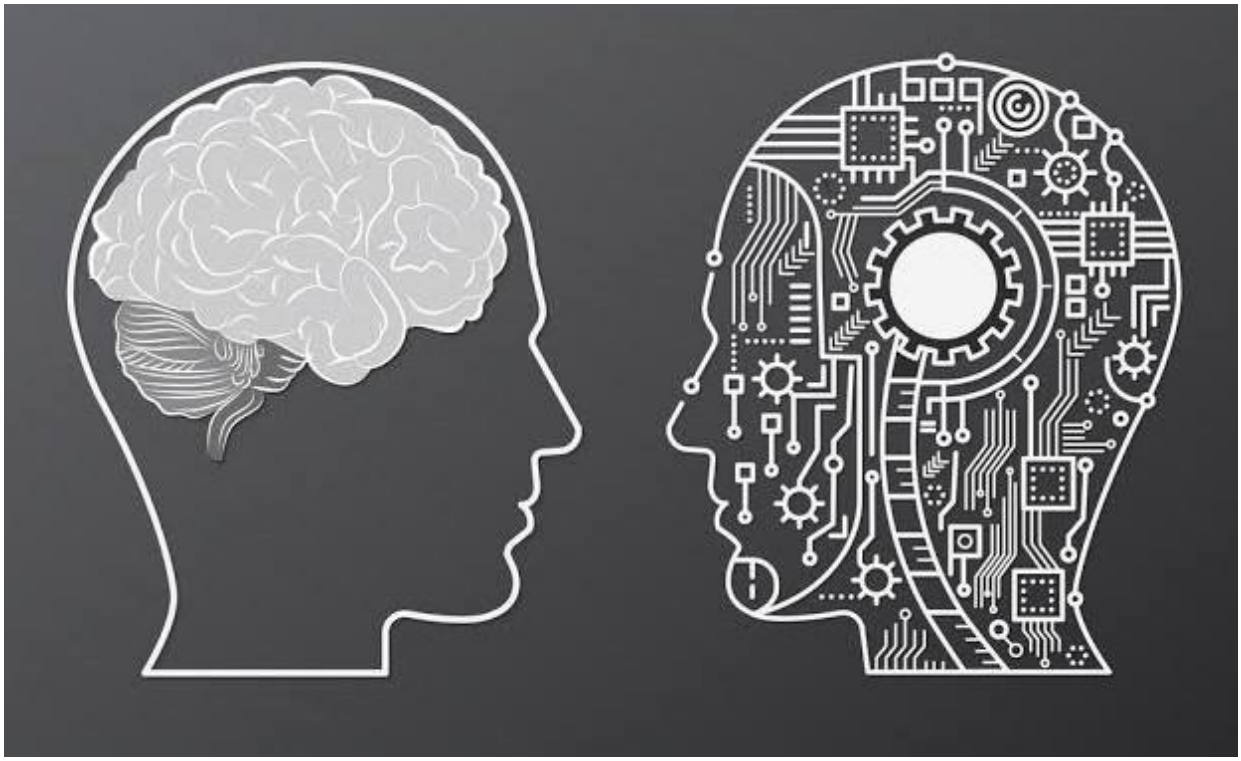


Figure 10 – AI is the brain

Advances in deep learning, a class of AI algorithms which utilize neural networks and aim to complete tasks previously only capable by humans, will determine how impactful AI eventually becomes. Neural networks have already solved complex problems and have become "intelligent" enough to beat humans at games like Chess, Go, and StarCraft. AI exists at the 2nd layer of the stack because AI is only as useful as the data it receives. For example, a marginally simple image recognition neural network will outperform an advanced one if it has access to more images to learn from. The key takeaway here is that the productivity of AI is directly proportional to the amount of data it receives.

As neural networks require incredible amounts of data to "train" on. The proliferation of IoT devices will open up new neural network-based AI systems which previously weren't possible. When we talk about an autonomous machine-based economy beyond the scope of a factory or assembly line, robots will have to predict and react to unexpected events in the outside world. Over time as more data is fed into these deep learning algorithms, machines will get better at predicting all potential outcomes, until they become better than humans at reacting to new situations.

Figure 11 – A self-driving car detecting objects in it's environment

4.2.3 Distributed Ledger Technology

It is important to acknowledge that use of automation and machine learning/AI is widespread today. As such, these topics have clear crossover within the realm of the 3rd Industrial Revolution. Specifically, automation is used extensively in factories and assembly lines. For example, Amazon uses self-controlled robots to move boxes around its distribution centers.

Figure 12 – Amazon robot which moves around boxes in their distriubtion centers

AI is also used today in many software-based applications, such as eCommerce, workplace communication, HR management, Cybersecurity, forecasting, supply chain, and retail [10]. Gartner estimated that approximately 30% of companies used AI in 2020 [10]. It begs the question, how will automation in the 4IR be any different?

The key is interoperability. What if competing businesses with confidential information could automate processes with each other without giving away any critical information? What if you could have a sensor in your car measuring your speed which could trigger an insurance policy in a tamperproof manner? What if companies could develop supply chains together to save costs? 3IR automation is almost entirely confined to single actors because trust plays a major role in fully automating processes.

Another major factor is security. A cyber-physical system means it is most likely interacting with humans. Large scale robotic systems, such as self-driving cars, have the potential to harm human life. If these systems are hacked by malicious actors, especially if they have widespread use, the damage can be significant[12].

[12] E.g. crashing an autonomous car network

The final key factor is privacy. If you have sensors throughout your home that help automate different processes to improve your quality of life, who is collecting this data[13]? Even if a company has no intent to use that data against you, if it exists in a centralized silo it is extremely vulnerable to hackers. In the wrong hands it could be used to harm people.

Interoperability, trust, security, and privacy are key words to the 4IR. When you start to expand automation between multiple companies or entities, you run into the issue of settling automated transactions as well as exchanging confidential data.

Distributed Ledger Technology (DLT), or Blockchain technology, will exist at the intersection of the 4IR technologies. It will be the medium that ultimately perpetuates and enables the endgame of this technology because it will enable automated systems to interact trustlessly, privately, and securely in real-time by acting as an objective, immutable 3rd party intermediary. Likely a network of blockchains will provide the infrastructure for a single connectivity layer which any system or economic actor can connect to. Due to the properties of blockchain systems, this connectivity layer will be secure, fair, permissionless, while maintaining privacy.

DLT will accomplish this through the proliferation of smart contracts. Smart contracts, or tamperproof digital agreements, are virtually the same as current legal agreements except they are digitized into code and arbitrated by a trustless third party, i.e. the blockchain. They can encode any business logic that is scriptable. As such, they can replace any form of digital agreement today, but also provide deterministic guarantees whose outcomes are recorded on an immutable ledger. By removing 3rd party intermediaries, the cost of goods and services will drop substantially. Smart contracts are the game-changing technology that DLT enables.

Figure 13 – Potential use-cases for smart contracts

Blockchain based smart contracts will move commerce from a slow and indeterministic world, to an automated and deterministic world governed by math instead of corruptible people driven dynamics. Any

[13] Right now, it's Google, Amazon, Facebook, and every app that makes you turn on geographical, microphone, and camera data (which is almost every single one nowadays)

form of business logic which can be represented with code will be automated with a smart contract. This will greatly improve the efficiency, fairness, and accessibility of systems across every industry, and will be necessary for an automated machine-based economy with potentially millions of transactions per second. Smart contracts are the game-changing technology of the 4IR on par with past inventions such as the steam engine and transistor.

4.3 4IR Use-Cases

The 4th Industrial Revolution will come in stages based upon the maturity of the three core underlying technologies: IoT, AI, and DLT. An interesting fact about technological adoption is that the rate of it increases over time.

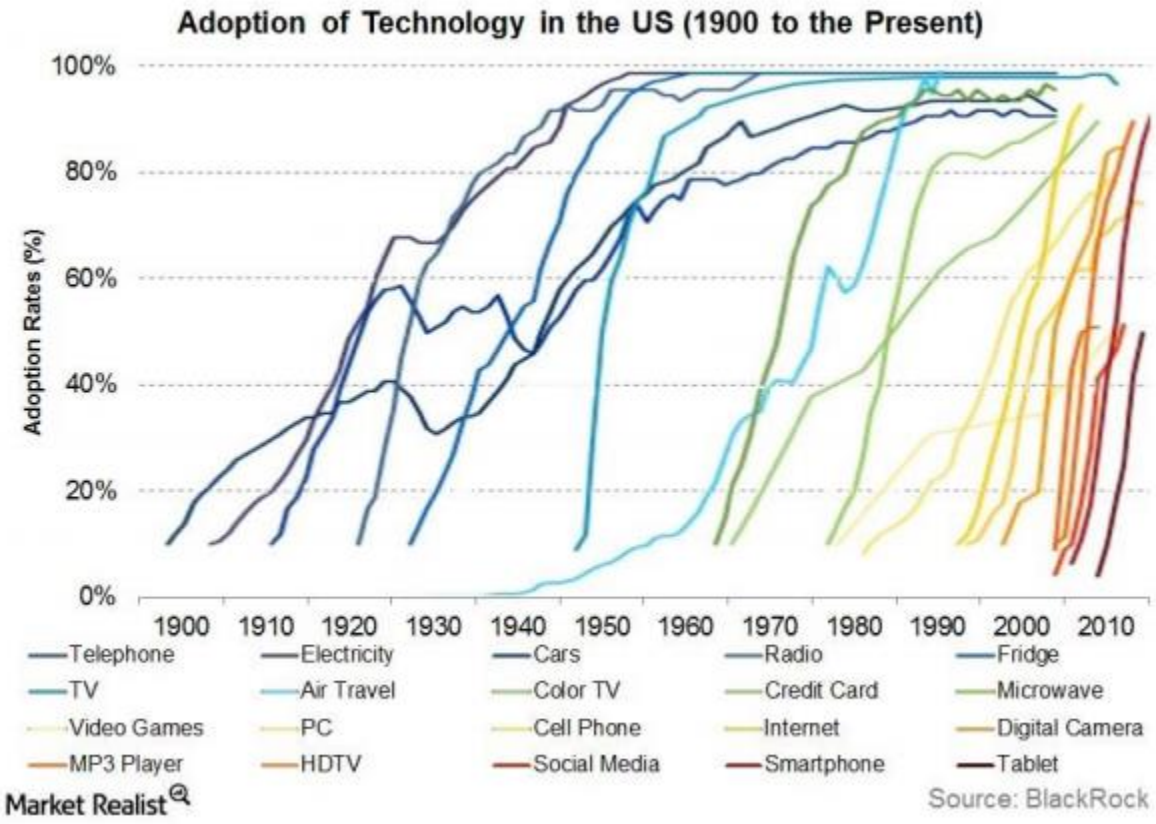


Figure 14 – Rates of technological adoption over time

As previously discussed, due to many modern innovations being in the realm of bits, it makes sense that adoption rates have increased. For a technology like Social Media, for instance, people only need a computer and internet connection to start using it. It is for this reason that software innovations can be adopted incredibly quickly – in a matter of years or less.

If the general theme of the 4th Industrial Revolution is automation, it is clear the first major industries to be automated will be digitally native. These include disruption and innovation in the realms of financial products, insurance, and trade finance. Decentralized protocols as well as enterprise blockchain solutions will compete to innovate in these spaces. We will also see enterprise OEMs begin to automate large parts of their businesses – from accounting, operations, and administrative departments. They will be able to

reduce their workforce, while cutting costs drastically. This automation will be accomplished with hybrid smart contracts and an increase in IoT devices to provide data to trigger said contracts.

As the IoT grows, AI becomes more advanced, and other 4IR technologies converge, cyber-physical systems will be developed which can interact autonomously with their environment and other systems. These interactions between autonomous systems will be data-driven and controlled by hybrid smart contracts. These systems will be developed by OEMs which have been supercharged from increased profits, and who can commit large amounts of workers and capital towards R&D.

The focus of this paper will be on this first wave of technology – specifically blockchain innovations which will lead to the disruption of the modern financial system.

4.3.1 A Revolution in Money & Markets: Decentralized Finance

The legacy financial system has been one of the slowest industries to adopt to modern technology. As of 2019, "Nearly 50% of banks do not upgrade old IT systems as soon as they should, according to a report by the UK's Financial Conduct Authority (FCA). And, 43% of US banks still use COBOL, a programming language dating from 1959, a report shows; and extra layers embedded on top of it are causing outages." Core banking systems also do not run in real-time, making them incredibly slow and outdated [11]. Although banks are beginning to make improvements, the fact that a small FinTech like Venmo created a peer-to-peer payment application before a Wells Fargo or Chase shows you how slow these large players are to innovate.

As bank's lag behind, so does interbank payments technology. The SWIFT (The Society of Worldwide Interbank Financial Telecommunication) system, who has effectively had a monopoly on bank messaging (bank transfers) since 1972, takes multiple days to send cross-border payments. They have recently addressed this with their SWIFT GPI initiative, but none-the-less this was due to pressure from new open-bank regulation (ISO 20022) as well as competition in the form of FinTechs and blockchain technology.

With respect to remittances, rent-seeking 3rd parties often take more than 5% in fees. It is also estimated that 1-5% of GDP is paid to rent seekers for global trade, where local currencies must be traded for dollars, or whatever reserve asset the transaction is denominated in.

Finally, the 2008 financial crisis pulled the curtain back on many flaws that existed in the legacy financial system. The largest ones being the fact that there is no true accountability and transparency, leading to corruption. Before '08 both interest rate swaps and credit default swaps did not need to be cleared by a central counterparty. Trades did not need to be reported to any global repository, either[14]. In conjunction with sub-prime mortgages, these issues led to leverage building up in the system based on assets which didn't actually exist. When the system collapsed, many OTC dealers delayed payments to clients who shorted the housing market in order to establish similar positions to cover these liabilities. Delayed settlement can reduce payouts due to changes in underlying values between the agreed upon settlement and actual settlement date. After main-street bailed themselves out using tax-payer money, it should be increasingly obvious that having players which are "Too big to fail" creates a risk dynamic which underpins the fundamental values of capitalism.

Enter Decentralized Finance (DeFi).

[14] Both of these were addressed by regulatory changes post '08, Dodd-Frank

Pioneered on Ethereum[15], DeFi is a new sector of blockchain development that uses hybrid smart contracts to recreate common financial applications/instruments such as lending, derivatives, exchanges, reserve assets, and more. Instead of the financial system being dominated by private, centralized institutions, DeFi enables trustless end-to end finance using automated protocols that function based on the interplay between user interactions and decentralized backend infrastructure. The DeFi space is being built with a few key advantages not afforded by centralized finance (CeFi):

Accessibility — Anybody around the world can interact with, build on, and monitor the activity of a DeFi protocol. Conversely, traditional finance often restricts access to users based on geography, political controls, sophisticated investor laws, etc.

User-Run and Owned — Users in DeFi can participate on both sides of a financial transaction, as in using the service and providing the service. This comes in contrast to traditional finance where consumers purchase financial services offered by large institutions but often cannot participate in and/or earn profits by providing the service. In this regard, value is mostly captured by the institution, as opposed to spreading equity out through more user-driven participation.

Transparency — The open-source code of DeFi protocols allows anyone to verify the security, rules of engagement, and actual network usage. On the other hand, traditional finance is done on privately owned servers where users cannot always verify how a transaction was processed nor control how their data is being handled. As a result, less sophisticated or capitalized investors oftentimes fall victim to information asymmetry because large institutions, especially institutional derivatives players, have more holistic views regarding the health of markets due to greater access when it comes to private processes and recordkeeping.

Censorship Resistant — Decentralized backend infrastructure means that financial transactions are computed and stored in immutable ledgers backed by a decentralized network of computers running the same open-source software that reaches constant consensus on the state of the network. However, traditional finance uses a centralized infrastructure that is subject to centralized control over if transactions get processed or not.

Automated — DeFi instruments are automated markets governed by software protocols that react to data. Whereas centralized finance has intermediaries and fallback procedures that get in-between the data, processes, and actions. This often leads to multi-day waiting periods from the time a trade is executed to the time a trade is fully settled whereas the user finally has full access to their funds outside of the exchange.

Composability – Because DeFi is permissionless open-source software, the services provided by DeFi protocols can be combined with each other to create exciting new applications. Similar to current Web 2.0 app development which has access to an API economy, this will allow for rapid development of new services which will ultimately benefit consumers. We will dive deeper into composability in the next section, as it is one of the most important features of DeFi.

[15] DeFi applications are expanding to chains beyond Ethereum such as Polkadot, Avalanche, and Binance Smart Chain

Some of the services that have been re-created with these key advantages are lending and borrowing, synthetic assets and derivatives, asset management, insurance, tokenized securities and NFTs, and Reserve Assets.

4.3.1.1 Money Legos: DeFi Composability and the Future of Finance

The size of DeFi is only around $85 billion, and the entire crypto market cap is hovering around $2 trillion. Only a small percentage of people in crypto actually use DeFi.

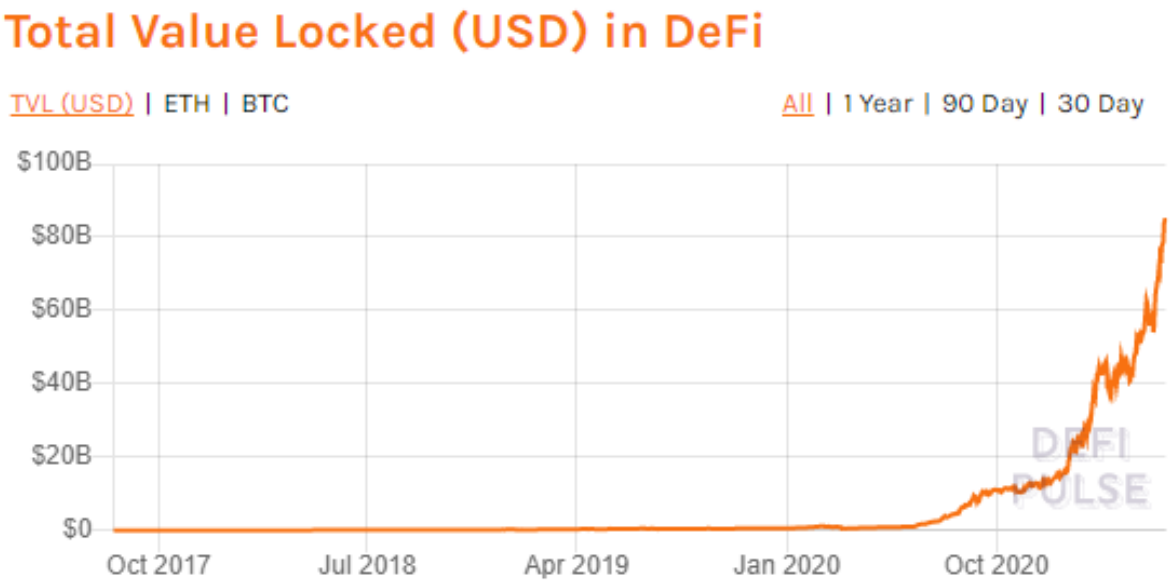


Figure 15 – DeFi Pulse Total Value Locked across all DeFi protocols

DeFi is growing and the core protocols are being built out at a rapid pace. The major applications in this ecosystem – Uniswap, Aave, Synthetix, etc. – can be thought of as primitives. Due to the composability of these applications, these are at the base layer of the DeFi application stack, in which more user-friendly products will be built on top of using the features of these various applications. As with all open-source software, every problem only needs to be solved once. Whereas every bank replicates the same services – custody, borrowing, lending, investing, etc. – in DeFi every application only needs to focus on a singular problem. This will allow for more efficient capital allocation which will result in better services provided. Because DeFi is software based, the overhead to create a DeFi protocol is 100-1000x less than a bank. This means more capital for R&D which will result in better and more creative solutions.

Figure 16 – DeFi money Legos

As a user in the DeFi ecosystem, you could own 3% of an Amazon Distribution Center, 0.03% of a Banksy, a few tokenized insurance cashflows for drought insurance for farmers in India[16], a Bitcoin, and maybe some USD stablecoins. You can toss all of these into a meta-aggregator like yEarn, where thousands of developers have competed to create the best investment strategy. Once in a strategy, your assets will algorithmically be deployed across various asset classes to earn yield, from fixed income financial products, to venture investments, or to hedge fund strategies utilizing derivative instruments, and be adjusted over-time based on performance. All while the system is overcollateralized, transparent, and fair – if any investments lose value to where the total collateral drops below a specified target, you will automatically be liquidated so that the system remains solvent and operational. There are solutions popping up to manage liquidation risk, such as DeFi Saver, which have smart wallets which can automatically monitor market conditions and protect your wallet from liquidation events.

In the traditional web 2.0 tech world, composability is what led to some of the most popular apps today. Take Uber for instance – in 2010 it could not have been built. For GPS data, Uber relies on the Core Location Framework and the Google Location API for iOS and Android devices respectively. For map data,

[16] This will be discussed in the following section

it relies on the MapKit API and Google Maps Android API for iOS and Android devices respectively. Uber text messages are powered by the Twilio telecommunications provider, and to implement push notifications Uber has integrated the Apple Push Notification Service and Google Cloud Messaging for iOS and Android devices respectively. Finally, Uber integrated the Braintree API to integrate payments into the application, as well as the card.io API so that users can input credit card info by simply scanning a card. As one can see, the composability of these different systems enabled an app like Uber to be successful. The same thing is beginning to happen in DeFi right now.

We are starting to see apps get released that utilize this composability to create simple products for retail users, that have powerful features enabled by these high APY DeFi fixed income products. Currently to earn stable interest on Aave, one would have to make a wallet, send some Ethereum to it, swap that Ethereum to Dai on Uniswap, and then move that Dai into Aave to start earning interest. An easier way to get access to stable interest like this would be through an app you can download on your iPhone or Android. Currently Aave stablecoin depositors average 10% APY. If an app is created which integrates with Aave and can abstract away the complexity of depositing funds but still provide 8+% APY, people will absolutely use it. It is products like these which will onboard millions of retail users into DeFi. Due to their simplicity, these users won't even know they are using DeFi protocols. They will just know they are getting better yield than what the legacy financial system offers.

There are unlimited possibilities of composability. Today two kids in their garage could think of an interesting way to combine Aave lending and yield farming. They could turn this into a winning investment strategy which shoots up the ranks of an aggregator like yEarn. This strategy could then get composed into 10 different applications, and they did not need to worry about building any infrastructure for their product because the base layer DeFi primitives already handled that. The rate of innovation will be exponential – never before have we see open-source permissionless software like this that is built on a deterministically reliable system which can be automated.

4.3.2 Insurance

Insurance plays a vital role in any market, and historically has enabled great achievements as it has allowed economic actors to take risk. One great example is that the Columbus voyage was actually insured, and likely never would have happened if it was not.

Today, insurance products typically only exist in geographies where a local legal system exists to support them, leaving many people without access. Also, due to the slow process to gather data on an insurance event (such as a car crash, a family member passing, or a natural disaster), payouts can take an unnecessarily long time. This is also because insurance companies must perform significant due diligence because of fraud. This leads to higher premiums for end users because fraud must be accounted for in their cost models. Finally, because the industry is dominated by a few large players, consumers suffer from higher prices.

Many InsureTechs are popping up that are competing with traditional insurance companies, and they are not going away. To compete they have to rely on the best technology possible, and that is leading them directly to blockchain and hybrid smart contracts. Parametric insurance, defined as data driven insurance contracts that pay out based on preset conditions[17], works perfectly in the smart contract format. Smart contracts are actually the only format where parametric insurance payouts can be guaranteed to policy

[17] If you're flight is delayed by x minutes, you will be paid out $\$20x$ in real-time

holders, and where claims management can be automated. Hyper-reliable, automated hybrid smart contracts will open up a path for incredibly sophisticated and unique insurance policies that can compete with traditional financial companies. This will also lower the cost of premiums for end users, and reward customers who act favorably with respect to a specific type of contract (such as safe driving).

Not only will they compete in developed markets, but they will create new markets in undeveloped markets where insurance products don't exist. Anyone with a smart phone can gain access to hyper reliable insurance products so that they can hedge risk and ensure the security of their life. One such example is crop insurance.

For instance, farmers can purchase insurance which protects against excess rain insufficient rain, snow, exceedingly hot temperatures, yield, and fertilizer coverage. For farmers in developed nations, this is nothing new. For farmers in countries where their local legal infrastructure does not support these types of contracts, this is groundbreaking.

There are over 500 million farmers without access to crop insurance. For a farmer in India, for instance, one or two bad seasons of crop yield could cause their business to fail and for them to have to become a migrant worker. The ability to access insurance from a smart phone with internet access will give millions of individuals the ability to mitigate this risk and to secure their work and future livelihood.

Because these smart contracts based parametric insurance products are hyper-reliable and effectively collateralized by end users (users must pay up front to receive insurance), a modern asset class will emerge where these insurance cashflows are securitized. This new asset class, called a Securitized Insurance Cashflow, will be superior to an asset backed security. These securities can be sold to the global marketplace where sophisticated investors are constantly seeking diversification and cash flow generating assets.

4.3.3 Government & Enterprise Blockchain

The value of DeFi is a mere fraction of the total value of capital markets. It is not going unnoticed by enterprises, though. Blockchain technology can be utilized to gain massive efficiency improvements in a variety of different industries, including but not limited to: Finance, Digital Identity, Records, Securities, Financial Data Recording, Mortgages, Land Title Recording, Clinical Trials, Cancer Research, Gambling, Sports Contracts, Automotive, Charity, Cloud Storage, Commercial Vehicles and Transportation, Credit History, Cybersecurity, Donation, Education, Energy, Forecasting, Government and Voting, Gun Safety, Human Resources, Law Enforcement, Legal, Marketing, Media, Music Streaming, Ride Sharing/Public Transit, Real Estate, Travel, Wills & Inheritance, Event Tickets, etc. Although many enterprises will end up using protocols built on the public Ethereum main net (or a web of public blockchains), in many cases private blockchains could be utilized for very specific applications. Enterprises are going to have to adopt blockchain technology or else they will likely be disrupted by it.

This section will focus on a few high value enterprise use-cases, including payments, derivatives, and enterprise business automation and interoperability.

4.3.3.1 Payments

Payments are a primary and obvious use-case of blockchain technology. The largest enterprise player in this space is SWIFT, The Society for Worldwide Interbank Financial Telecommunication. Founded in 1973 provides a network that enables financial institutions worldwide to send and receive information about

financial transactions in a secure, standardized and reliable environment. As of 2018, around half all high-value cross-border payments worldwide used the SWIFT network. As of 2015, SWIFT linked more than 11,000 financial institutions in more than 200 countries and territories, who were exchanging an average of over 32 million messages per day. They account for nearly $600 billion of bank transfers every day.

SWIFT has run into a few problems in the past 5 years, though. SWIFT has been criticized for its inefficiency, with the Financial Times observing in 2018 that transfers frequently "pass through multiple banks before reaching their final destination, making them time-consuming, costly and lacking transparency on how much money will arrive at the other end." At the time its market dominance was described as being challenged by blockchain technology, although SWIFT argued that the 90 scalability issues of blockchain solutions remained unsolved, confining them to bilateral and intra-bank applications. Not only are they facing competition from fin-tech startups, but legislators are attempting to break up the monopoly as well in the form of a directive titled PSD2. PSD2 is the second Payment Services Directive, designed by the countries of the European Union. It could revolutionize the payments industry, affecting everything from the way we pay online, to what information we see when making a payment. PSD2 will break down the bank's monopoly on their user's data. It will allow 'merchants', businesses like Amazon, to retrieve your account data from your bank - with your permission.

SWIFT has acted in an attempt to evolve and maintain market share. SWIFT started a proof of concept on January 30th, 2019, in collaboration with R3 to bring GPI payments to DLT and blockchain based platforms. "To support the growing demand amongst trade ecosystems for secure and reliable settlement, SWIFT has launched a proof of concept to trial a new gateway to interlink trade and e-commerce platforms with GPI – the new standard in cross-border payments." GPI is currently used by hundreds of banks across the globe, and it settles over $300 billion in payments every single day. The goal of this PoC was to bring GPI payments to DLT, this is what they call GPI Link. It still has a way to before it can integrate fully into their existing systems, but so far their PoC has been successful.

Although there has been incredible pushback, we do think it is worth mentioning Facebook. They want to create a stablecoin, Diem, which is tied to a basket of various currencies, mainly the USD, to ensure it is not volatile. Stablecoins built on a fast blockchain can be sent anywhere with nearly instant finality and incredibly low cost – we are talking fractions of a cent. Although there are many regulatory hurdles here, the upside of a project like this is massive. Facebook has over 2 billion users which could lead to rapid adoption.

4.3.3.2 Derivatives

Derivatives are integral to today's society, as companies need innovative ways to hedge against uncertain market conditions to remain competitive. It ultimately benefits consumers when companies are able to prevent unnecessary risk. With their yearly notional value estimated to be somewhere between $500 trillion and $1.4 quadrillion, the derivatives market is a high stakes and deeply interconnected environment that requires substantial overhead to establish trust between counterparties. However, there is a clear line between hedging individual risks and creating systemic risk through overleveraging and market manipulation, that can lead to systemic risk for the global financial system. Only 15% of the derivatives market are traded over exchanges, where there are standardized, regulated products. The other 85% or so are negotiated directly (OTC) between two parties. They are usually not digitized, and

technically not regulated[18], leaving room for systemic risk. As we mentioned earlier, interest rate and credit default swaps are a large part of the OTC market and contributed to the 2008 financial crisis.

While the OTC market is technically not regulated, most major OTC participants are members of the International Swaps and Derivatives Association (ISDA), a trade organization that created a standard contract called the ISDA Master Agreement. The ISDA Master Agreement is used by 925 members in 74 countries as "the standard contract used to govern all over-the-counter (OTC) derivatives transactions entered into between the parties." we believe enterprises will look to create a blockchain based system to settle these transactions in a trustless and more efficient manner.

In May of 2020 the Depository Trust & Clearing Corporation (DTCC) completed a PoC called project Whitney to address this problem. For reference, in 2019 the DTCC settled $2.15 quadrillion worth of securities – they are the largest securities processor in the world. Project Whitney is a collaborative effort between the Enterprise Ethereum Alliance, Digital Asset Group, and the DTCC.

Figure 17 – IC3 Partners

"The DTCC selected the public Ethereum network and it's ERC20 standard for minting tokens, as well as an off-chain compliance oracle…While the DTCC chose to work with the public Ethereum network, an alternative approach used by many clients to date would be to create a private instance of Ethereum. A private network enables users to achieve far higher performance on dimensions such as throughput and avoid the need for gas payments. Technologies such as Hyperledger Besu and Quorum have emerged as default choices for enterprise friendly Ethereum clients" [20].

[18] OTC participants are typically members of the International Swaps and Derivatives Association (ISDA)

Abstraction Capital believes that either on a public or private blockchain (which would be between all ISDA members, for instance) a system will be created for institutional OTC derivatives. Any system which can capture some of this value would have massive upside.

4.2.3.3 Enterprise Business Automation and Interoperability

Moving on from financial use-cases, it is incredibly interesting to see how blockchain technology can begin to impact Original Equipment Manufacturers (OEMs) and other businesses. When looking at the capability of smart contracts, one realizes that they represent a way to automate companies in the collective sense. They are especially well-suited for handling operations, bidding, finance, accounting, contract enforcement, and program management tasks. In other words, the back-end nuts-and-bolts that hold any company together. From Fast Company:

"What Ethereum proposes, in effect, is a global computer that could not only handle those transactions but also eventually emulate many of the functions of companies like Uber, Airbnb, Dropbox, Amazon, and Kickstarter — but without the inefficient bureaucracies and the other intermediaries who take a slice of the pie…….Where bitcoin aims to disrupt banks, Buterin's Switzerland-based company, Ethereum, aims to become what he calls "the foundational platform for everything"…….If the blockchain is a giant ledger, Buterin's goal is to build the army of robot accountants working on top — what are sometimes known as smart contracts" [25]. Smart contracts allow entire accounting, operations, and administrative departments to be outright eliminated. The robot accountants can provide huge savings. To quote Nick Allen, Product Director at Zap:

"Businesses spend countless hours and immeasurable amounts of money on administrative costs, including: escrow, legal fees, time spent negotiating, etc. Smart contracts automate payments, making the entire process much more streamlined" [26].

Per Roger Feng: "The promise of "virtual companies" is by no means limited to OEMs. Smart contracts can be applied to countless industries. In fact, the majority of both the Fortune 500 and Fortune Global 500 are susceptible to automation. To what degree can OEMs become "virtualized"? About 70–75%. OEMs already have a high percentage of personnel dedicated to new product development (NPD), usually in the form of engineers and program managers. In particular, OEMs with shorter product life cycles (such as automotive, which releases new models each year) have a particularly high number of NPD engineers (as a % of their total company personnel). Many business models and industries can be automated over 95%, but OEMs are not one of them. Automating away nearly all operations, bidding, materials procurement, risk management, finance, accounting, contract enforcement, and (non-NPD) program management positions only results in 70–75%. Nonetheless, this is still more than enough."

Let's look at an example of how smart contracts could be utilized for trade finance. Here is an overview of what the automated process flow from a supplier to a customer would look like:

"Self-driving trucks deliver shipments of supplier components to the OEM's assembly plant. A 3D CMM scanner, such as a FARO 8-Axis Quantum ScanArm with FAROBlu Laser Line Probe, evaluates all the incoming mechanical parts for noncompliance. These are no dumb 3D scanners. They are equipped with IoT (Internet of Things) capability and can harness the full connectivity of the digital manufacturing ecosystem. So when a noncompliance is detected, it can feed this information into a smart contract that automatically bills the supplier for noncompliance. If multiple non-compliances are detected within the same shipment batch, then the smart contract will automatically pay to return all the noncompliant parts

to the supplier for firsthand study (instead of just trashing the part). Multiple non-compliances indicate likelihood for an inherent manufacturing *process* defect, not an isolated incident, and therefore warrant further study. The smart contract keeps tallies of each supplier's noncompliance rates and uses that to calculate PPM scores in real time (a convenient tool that the suppliers can also check to see how they're doing). On a quarterly basis, noncompliant suppliers are issued an email warning (via the blockchain2email.com API, EmailMesh API for Ethereum smart contracts, or this novel solution: http://jonathanpatrick.me/blog/ethereum-smtp) by the smart contract to step up their game or risk having the smart contract automatically start requesting competitive bids from alternate suppliers" [27].

It is very easy to see how shipping/receiving can be completely automated in a business. An issue still exists here though, specifically in the exchange of data or information between two companies that might be shipping goods to one another, or performing any other type of collaborative activities. This is where trustless interoperability between companies becomes critical. The most promising solution to this currently is the Baseline Protocol.

Figure 18 – The Baseline Protocol aims to solve inter-company collaboration

"The Baseline Protocol is an open-source initiative that combines advanced cryptography (Zero Knowledge Proofs [ZKP][19]), messaging, and blockchain to secure and private business processes at low cost using the public Mainnet for event ordering, data consistency and workflow integrity. The protocol will enable confidential and complex collaboration between enterprises without moving any sensitive data from traditional systems of record. The work is governed by the Ethereum-Oasis Project, which is managed by OASIS." [28] The Baseline Protocol operates of the Ethereum Mainnet, and allows companies to link their ERP, CRM, or other backend systems to each other so that they can 'baseline', or synchronize, information with one another.

"Businesses spend hundreds of millions of dollars on ERP, CRM and other internal systems of record. Failure to properly synchronize these systems between organizations causes considerable disruption and waste: disputes, lost inventory, inflated capital costs, regulatory actions, and other value leakage. To avoid these problems, systems require a common frame of reference. But only the largest high-volume

[19] Zero Knowledge Proofs allow two parties to prove things to each other without actually revealing any information

partnerships can afford the capital expense involved in setting up such integrations. The baseline approach employs the public Ethereum Mainnet as that common frame of reference, because it's always on, companies can't be locked out or restricted from using it, and they only need to pay for what they use." [28] Through this technique, one company could trigger an ERP event in another companies' software. This opens the door for even more complex automation. Let's look at an aerospace OEM supply chain, for instance.

Let's say Boeing has a sensor which detects engine health. When the health value drops below a certain threshold, this would automatically trigger a smart contract which purchases engine components from GE. This will trigger another smart contract from GE's partner companies to purchase the sub-components necessary for the repair, which will trigger more smart contracts for those companies to purchase the raw materials necessary to build those parts, etc. At each level, these smart contracts will trigger the operation of a smart supply chain to create these parts. Quality systems from 3rd party companies operating on verifiably tamperproof hardware will validate the components were built properly at each step of the design and manufacturing process before they ship. GPS sensors or RFID tags in shipping containers will trigger trade contracts when parts reach their destination. The entire process can be automated so that the new engine part shows up at the door of Boeing with every element of it verified and paid for.

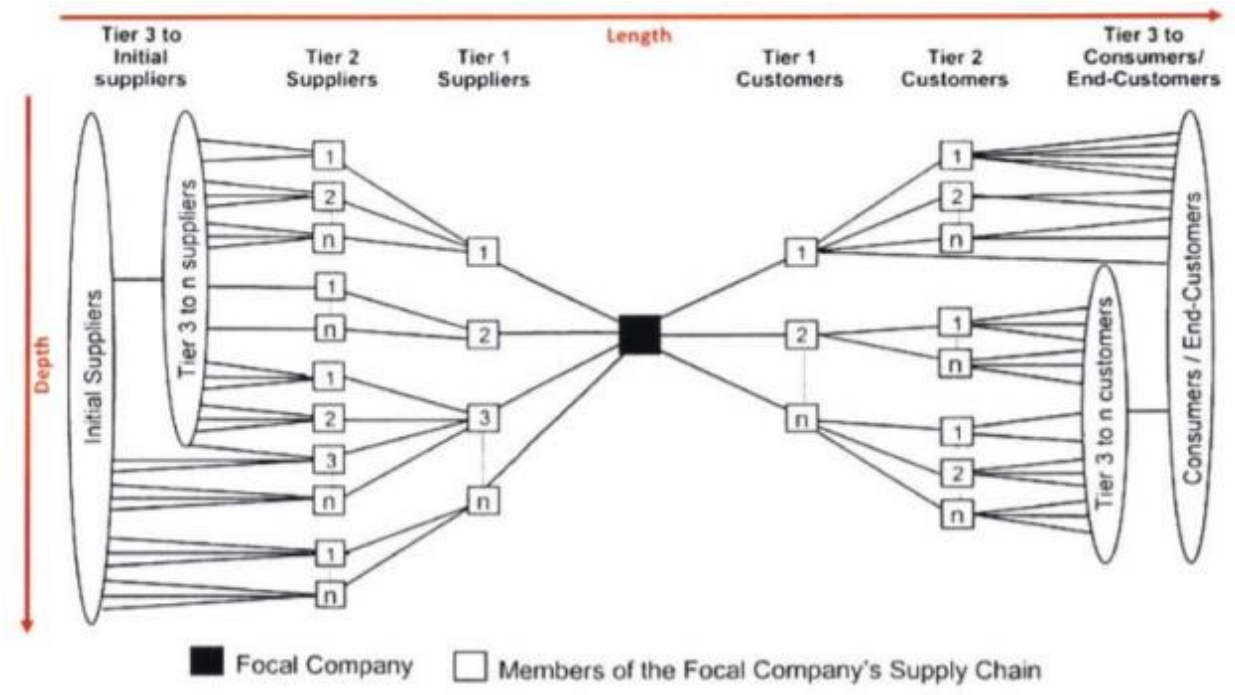


Figure 19

Airplanes can be composed of up to a million parts from hundreds, if not thousands, of companies. The ability to 'baseline' supply chains like these together will result in vast efficiency increases.

As more and more processes become automated, AI becomes increasingly useful. An AI powered business could extract data from these automated processes to create hyper-accurate sales forecasts. It could also simultaneously scan various supply chains to automatically trigger smart contracts which will purchase

the cheapest materials, or purchase from locations with the shortest lead times. More automation means more areas of a business which AI can optimize.

Automation will affect every fortune 500 and OEM company. Combining hybrid smart contracts, IoT sensors, and AI with privacy preserving cross-company workflows will allow for multi-company autonomous workflows. Hybrid smart contracts are going to fundamentally change the way companies operate.

4.3.4 Rise of the Machines: The Autonomous Economy

The end game of technological progress in the 4IR will be highly advanced cyber-physical systems which are capable of interacting with the world and each other. This automated machine-machine based economy will grow until it is fully integrated into our daily lives. We could reach a point where most companies are entirely automated. Through the use of robotics and AI, these autonomous companies could simulate the functions of any current real-life company while having few to no human employees.

One such example would be an autonomous shipping company. As opposed to Amazon acting as a marketplace for retailers and handling all operations and logistics, it is possible for an autonomous distribution company to be created which is owned by nobody, but maintained by the ecosystem of all possible retailers. Instead of Amazon siphoning value from these companies, they could all engage with a trustless 3rd party company governed by a DAO. This company would be composed of a self-driving delivery trucks and drones which can ship products directly from a retailer to the customer, effectively replacing Amazon as the middleman. Hybrid smart contracts would control every necessary type of business logic. Robots would perform the physical activity necessary to transfer goods, and an AI brain would decide and optimize all processes[20]. Although a use-case like this could be decades away, it is completely in the realm of possibility. We would argue it is inevitable, considering the exponential increase in the power of AI.

Wrapping up this section from a high level, this parallel machine-based will continue to grow and evolve over time, due to the property of neural networks becoming smarter as more and more data is fed into them. We believe it will actually grow at an exponential rate. When trying to predict the adoption rate of this technology, it is important to look at the types of jobs which AI is capable of automating. Generally speaking, there is a loose correlation between IQ and career path. By looking at the integral of the IQ bell curve, (also modeled by an S-Curve), the rate at which jobs will be automated will accelerate as we approach the center of the bell curve.

[20] Software engineering would be handled by a group of independent engineers which are economically incentivized to maintain and develop the AI system. These engineers would get paid via a smart contract, in amounts voted on by participants in the DAO.

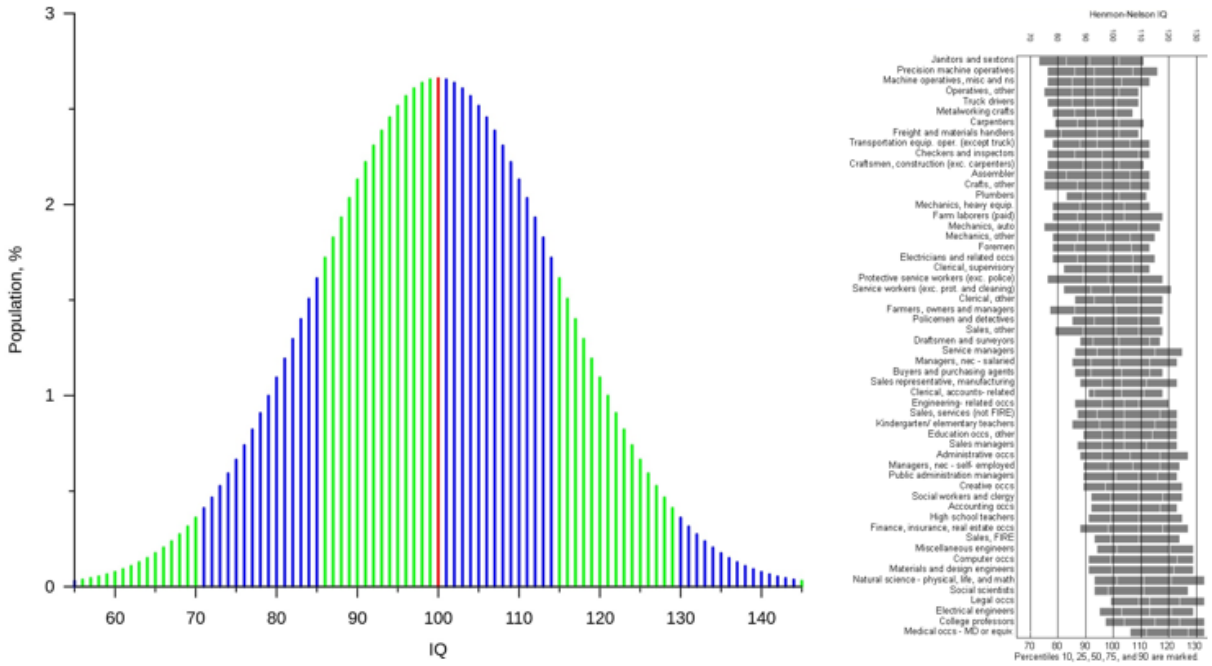


Figure 20 – IQ distribution and Job-IQ correlation

There will be a turning around the mean of the IQ distribution where a large percentage of the population will likely lose jobs to automation.

As the World Economic Forum points out, "According to calculations by Carl Benedict Frey from the Oxford Martin Programme on Technology and Employment, only 0.5% of the US workforce is employed today in industries that did not exist at the turn of the 21st century, a far lower percentage than the approximately 8.2% of new jobs created in new industries during the 1980s and the 4.4% of new jobs created during the 1990s…Furthermore, the type of jobs being created in these industries tend to require higher levels of education and specialized study, while those being destroyed involve physical or routine tasks." Although this trend is likely to continue, there are reasons to remain optimistic that in this new world humans will be able to focus on more fulfilling jobs. Job positions that interface with technology innovation, product development, and/or the customer experience will become exponentially more in-demand. They will be the vital lifeblood of any company (OEM or otherwise). We could enter into a golden age of content creation, where rent seeking platforms becomes disintermediated by 3rd party protocols. Content creators and artists could finally sell their product directly to consumers. This is already being seen with NFTs.

Regardless, automation is going to accelerate rapidly and will be the story of the next century and beyond. Not only is distributed computing necessary to facilitate trustless interaction between independently owned autonomous systems, but decentralization will be critical if we are to achieve a favorable outcome for greater society. Due to natural game-theoretic dynamics, systems controlled by people will always be susceptible to corrupt people driven dynamics. The vast majority of humans will opt towards moving towards open source, auditable, and immutable systems defined by algorithms and owned by all.

4.4 Productivity Analysis

With the use-cases described above, it is important to bring things full circle and see how and why they have the potential to spur a spike in productivity growth.

Starting with the first wave of technologies, the future of DeFi is exciting because every asset or income producing product will become tokenized on the blockchain. Once tokenized, these assets can be utilized in decentralized financial products where they can provide liquidity and earn yield for their user. They will be able to choose the level of risk they are willing to take and because this entire system is completely transparent and overcollateralized, systemic risk will be drastically reduced[21]. Another interesting thing to note is that these assets can be traded into any other asset instantly for nearly free (once scalability is live), and each of these tokens are divisible to 18 decimal places[22]. The divisibility, composability, and granularity of money is about to take an exponential leap forward. All of these assets will exist on a system composed of multiple blockchains, but due to interoperability solutions they will be able to interact with each other *as if* they were all on a single server. This will become the biggest, most accessible, pool of liquidity in human history.

This will result in a fundamental change in E_P in Equation 1.

With Bitcoin, potential energy can now be stored across time with almost no decay factor. Cryptocurrencies will allow potential energy to be sent anywhere through space at light speed and with almost zero cost. With an internet connection, any person in the world, regardless of their country's political or financial infrastructure, has access to this entire ecosystem. It will be permissionless, user-run and owned, transparent, censorship resistant, automated, and fair. This is a revolution in money, or potential energy, the likes of which we have never seen. All people of the world will be able to combat inflation, earn interest, purchase insurance, receive loans, and ultimately pursue their economic destiny.

It is important to remember that much of the world population is unbanked. Approximately 2 billion people have access to traditional banking systems. Not only is this revolution going to greatly increase the efficiency of developed countries, but it is going to bring billions of people into the market. Currently 4.5 billion people have smart phones, so at the very least 2.5 billion more people have some way to enter this space quickly. Because most people only have access to cash, it will still be incredibly hard for these people to access DeFi. The important takeaway, though, is that it is far easier for people to get access to smartphones and the internet than it is for local financial/legal infrastructure to be built in their respective geographies, which could take decades.

By giving the unbanked access to sound money and the ability to earn interest and get loans through decentralized networks, there is going to be an incredible amount of value creation in these unbanked communities and give intelligent, hard-working people the ability to save and take risk. Their successes will lead to more investment into products and services for their communities. As these communities grow in size and wealth, they will be able to direct that wealth into social services and infrastructure. Education will improve rapidly, and this will create a positive feedback loop of global productivity growth.

[21] It is never possible to completely eliminate risk, but insurers from the legacy world + decentralized insurers will create a system many more orders of magnitude safer than the legacy system

[22] The standard of ERC-20 tokens

In developed markets, enterprises will begin to automate as advances in DLT, IoT, and AI enable companies to utilize deterministic smart contracts. Through interoperability techniques, companies will be able to connect with each other in ways never before possible. Utilizing open-source protocols as a standard connectivity layer, groups of companies will develop infrastructure which helps their entire ecosystem become more efficient. Companies will be able to divert human capital to things such as engineering, R&D, and creative tasks – things that actually result in productivity growth. This raises the bar of competition for all. It is these companies which will develop the ground-breaking cyber-physical systems of tomorrow.

As the creation of non-organic intelligence accelerates, the amount of intellectual capital, INT, will increase as well. This means more productivity growth will necessarily occur. Due to blockchain acting as an immutable trustless interoperability layer, this inorganic intelligence will be able to interact with each other autonomously. As the IoT expands and AI becomes more sophisticated, humans will be able to create more advanced robots capable of performing more types of work. No longer will machines act just as a lever on human intelligence. They will be able to act independently with each other. This will lead to an exponential increase in the number of work-generating actions that can take place on Earth.

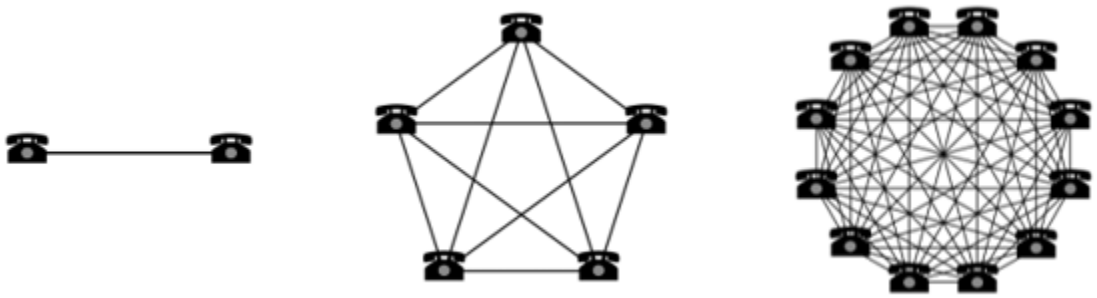


Figure 21 – Number of connections between an increasingly number of nodes

To be specific, this increase in number of interactions will be defined by Metcalf's Law, where the number of interactions is proportional to the square of connected users of the system (n^2). As such, there is a tidal wave of self-reinforcing effects at play here as more data, robots, and potential connections increase. This parallel machine to machine economy is going to grow exponentially, and will eventually become larger than the current one.

5 Roadblocks Towards a Fully Operational Blockchain Layer

As a critical piece of infrastructure for the 4IR, there are a few problems that must be solved with blockchain technology before mass adoption can begin taking place. These include the Oracle Problem (or data connectivity problem), scalability, and privacy. Today in 2021, the areas of growth we see within the space (specifically DeFi) have been made possible as these problems are solved. There is still a ways to go before these problems are fully solved, however, but we predict much progress to occur within the next year.

5.1 Connectivity: The Oracle Problem

Blockchains cannot interact with off-chain data without interfering with the consensus protocol (the process by which a distributed system forms a single state of truth). Interacting with off-chain data can lead to multiple states of the blockchain ledger. This is why Bitcoin was the first blockchain – the only information the protocol needs to function is: What is the list of all wallet addresses on the ledger, and how much BTC is in each wallet. This information is native to the bitcoin blockchain and hence stored in every node. Most of the world's data exists off-chain. The current lack of connectivity between off-chain and on-chain systems means the new and existing worlds cannot interact with each other.

So, how does one get data on chain? One must use an Oracle – a third party agent with the sole function of supplying data to blockchains which permits for the creation of smart contracts. Through the use of external adapters, an Oracle can process data so that a blockchain can interop with it. Although this solves the connectivity problem, it creates a much greater problem.

The moment a smart contract receives data from a single source, the advantages of smart contracts and blockchain, such as trustlessness, immutability, and censorship resistance, are completely lost.

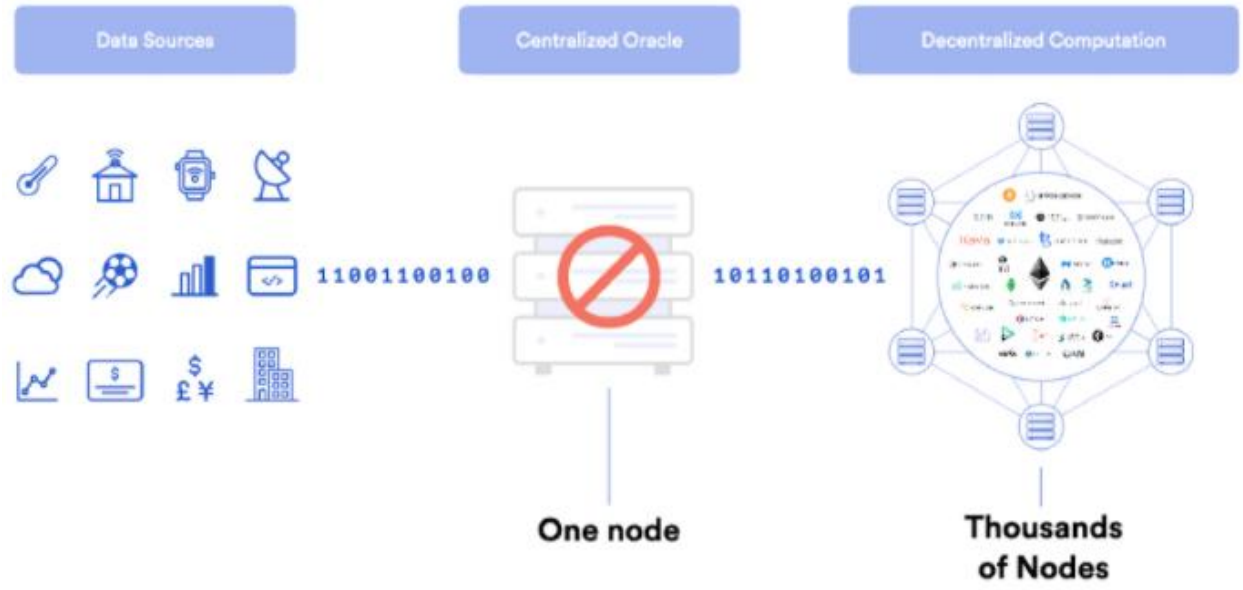


Figure 22 – The unique properties of smart contracts are lost when connected to data sources by a single entity

As such, centralized oracle schemes are worthless. The reason being is that this single point of connection can influence the contract (through bribery, malicious intent, system failure, or simply user error). If a betting smart contract with $10 million in escrow will pay out a party who correctly predicts the presidential election, if the data source is controlled by either party or a known third party, it would be very easy to bribe that individual to game the contract.

The second challenge facing today's smart contracts with respect to connectivity is that smart contracts cannot push outputs onto external systems. For example, smart contracts cannot execute payments in fiat currencies on traditional payment systems. Cryptocurrencies are simply too volatile for traditional companies to use and hold on their balance sheet. While that could change in the future, most businesses are not willing to adopt smart contracts that are limited to cryptocurrency-only transactions.

5.2 Scalability

Because trustless blockchains (public chains) are decentralized, every node in the network needs to process and confirm every transaction. This means that as a blockchain becomes more decentralized, it's throughput must slow down. Ethereum, for instance, can only handle 15 transactions for second. In order for it to reach its full potential, it will need to process hundreds of thousands of transactions per second. This is known as the Blockchain Scalability Trilemma. Lack of scalability has led to exorbitantly high gas costs on Ethereum, pricing out many retail investors from DeFi.

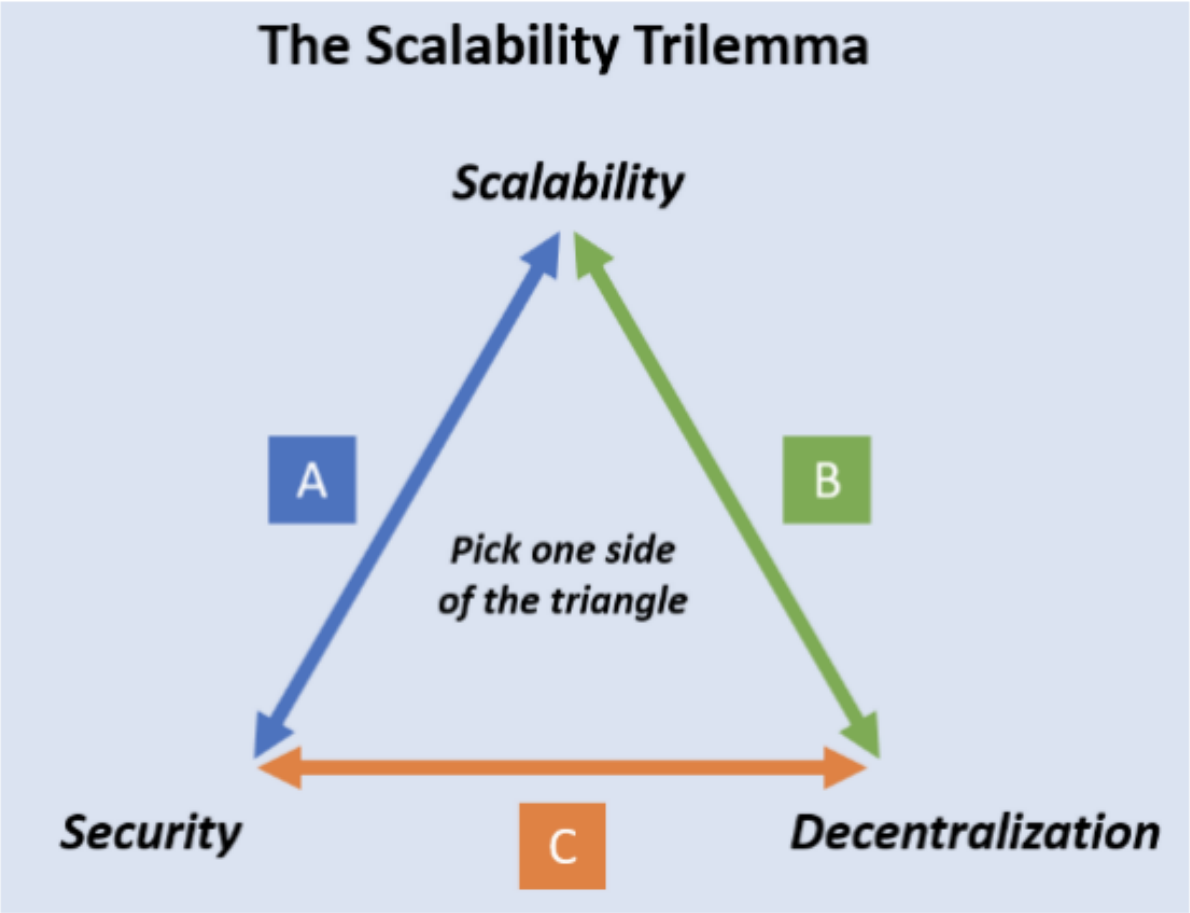


Figure 23 – The Blockchain Scalability Trilemma

For Blockchains to gain widespread adoption, they will have to solve this problem. 2020 has been a year of great development in the base layer protocol space. Ethereum has successfully launched phase 0 of Ethereum 2.0, and many new chains such as Tezos, Algorand, Avalanche, Polkadot, and Solana are extremely promising projects which will attempt to provide scalability orders of magnitude beyond what Ethereum currently provides while maintaining security. Similarly, there are other layer 2 off-chain scalability solutions which are in the works or have recently released which are extremely promising. Two important ones are Arbitrum[23] and Optimism. They are set to go live in the summer of 2021, pending no setbacks. Layer 2 scalability solutions have the potential for Ethereum to "have it's cake and eat it to" – effectively breaking the blockchain trilemma by moving to modular blockchain structure[24].

There has also been significant development of private, or permissioned blockchains for enterprise use. Although these chains lack decentralization, constituent members can enter into traditional legal agreements regarding the terms of membership. This can allow a group of a few dozen to hundreds enterprises to gain access to blockchain technology, and not sacrifice scalability or have to pay gas costs. Due to the additional legal costs, however, if public blockchains can make good on their promise of scalability, long-term picture for private blockchains is uncertain.

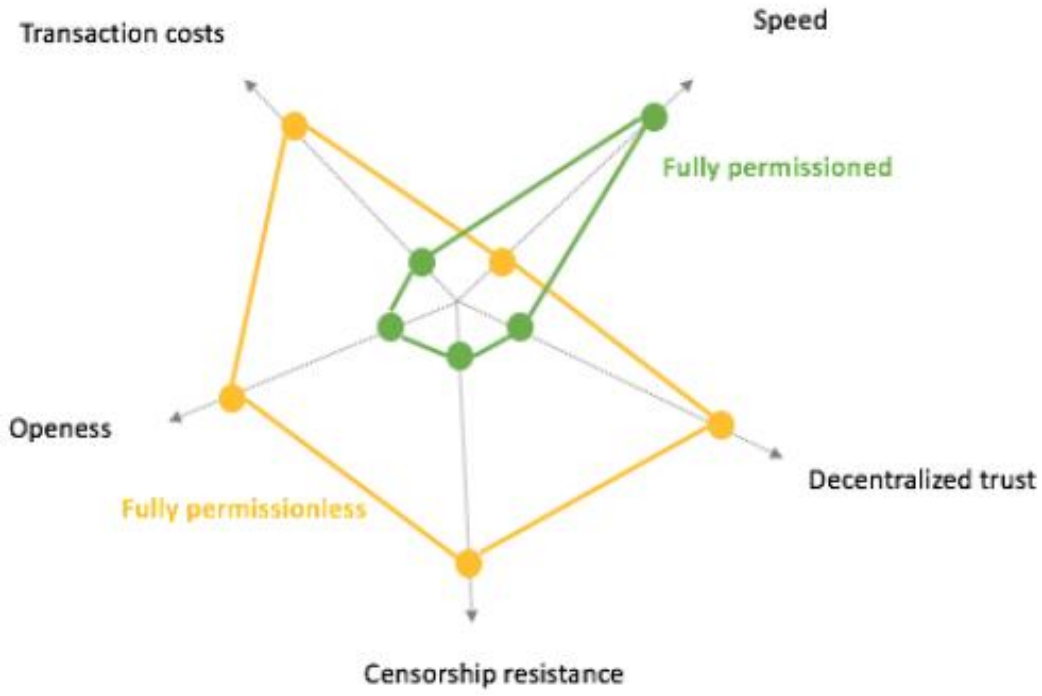


Figure 24 – Comparison of permissioned (IBM Hyperledger) vs permissionless (Ethereum) Blockchains

5.3 Privacy

Trustless blockchains are inherently open source and public, and they lack true privacy. All wallets are pseudonymous, but every transaction for a wallet ID can be traced with complete transparency. If a sophisticated party (a government, hacker, corporation, etc.) can link a wallet ID to an individual or

[23] Arbitrum has announced they are going live May 28th

[24] https://www.youtube.com/watch?v=xjxyjgWiqLE&t=3276s

collective, there is now no anonymity. This is of grave concern that enterprises must consider when using public blockchains, as most businesses possess sensitive data that they do not want compromised or seen by their competitors.

Unless smart contracts can be auditable, but simultaneously maintain privacy for every party involved, for all high value enterprise use cases they will be worthless. For this reason, permissioned chains have emerged to fill the void, but again it remains to be seen whether they will last as public blockchains develop more functionality. This is very similar to the argument of intranets vs. the Internet, which ultimately saw the Internet win out as the main highway of exchange when privacy protocols were implemented.

6 Chainlink

The one project which has made great strides on the aforementioned problems is Chainlink. Chainlink is a blockchain agnostic[25] middleware protocol for building decentralized oracle networks. In simple terms, it has the core functional objective of bridging two environments, on-chain and off-chain, through the use of APIs. It does this by taking on-chain resources from a blockchain, and connecting them via APIs to off-chain resources, such as market data, bank payments, retail payments, backend systems, events data, other blockchains, and any web API that exists. These tasks are performed by *node operators*[26] – individuals or collectives who run the Chainlink software and take on jobs over the network.

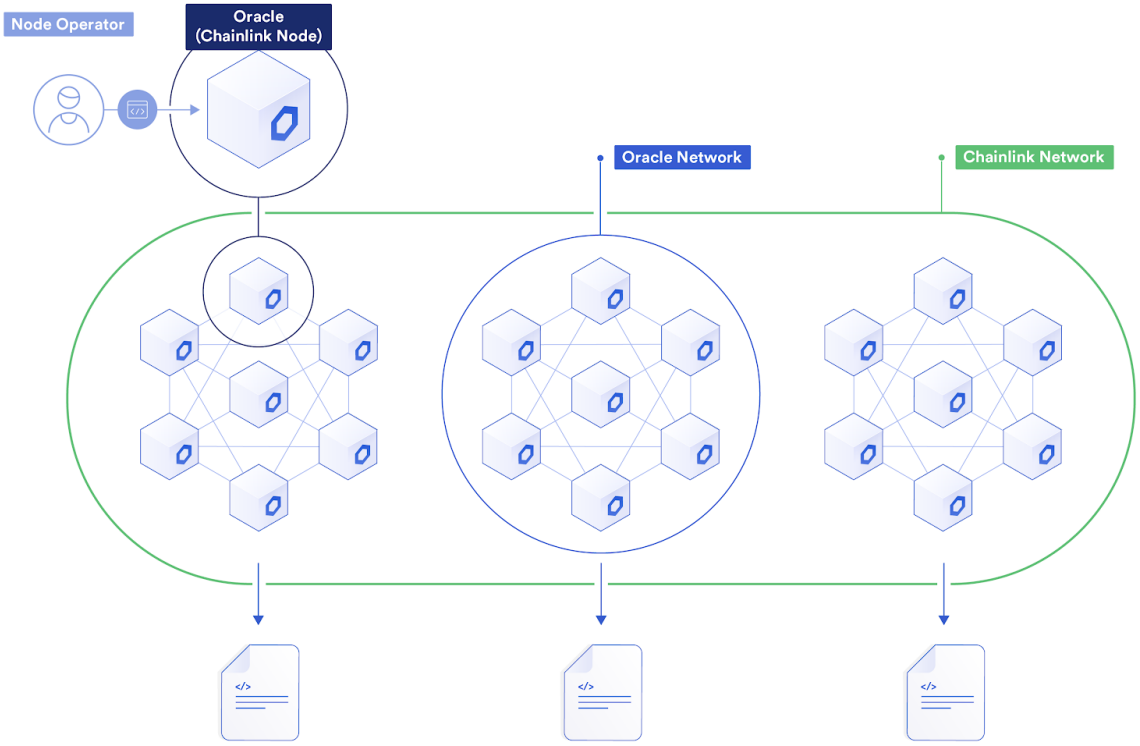


Figure 25 – The architecture of the Chainlink Network

6.1 Solving the Oracle Problem

Chainlink applies the same theories of decentralization from the computation layer to the data delivery layer. By having multiple oracles retrieve data from multiple data sources, a single aggregated data point can be delivered to a smart contract which is resilient to manipulation. Chainlink uses various other mechanisms as well to ensure that oracles supply good data. They have a reputation system where oracles are rewarded if they perform jobs correctly and lose reputation if they fail. Once staking is live, nodes will have to deposit LINK tokens as collateral against their jobs. If they fail to send good data, their stake will be slashed. This creates an economic incentive to provide good data. Chainlink also owns Town Crier, a technology for Trusted Execution Environments (TEEs). An oracle running TEE software can provide

[25] Chainlink can work with any blockchain
[26] The equivalent of a Bitcoin Miner

cryptographic proof that it performed a task correctly, such as delivering signed API data to a hybrid smart contract.

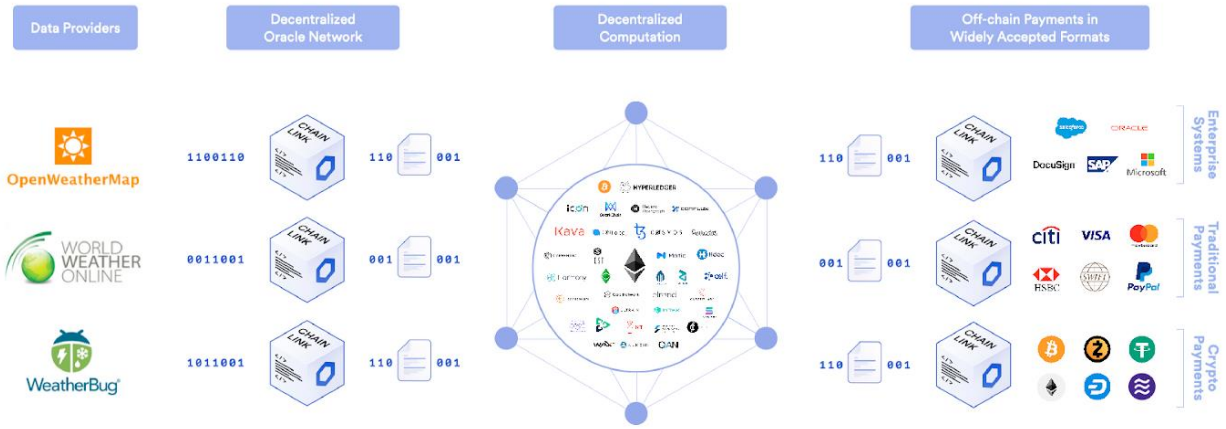


Figure 26 – Example of inputs and outputs Chainlink provides for smart contracts

6.2 A Piece of the Puzzle to Solving Scalability

Node operators can do more than just deliver data. A committee of independent node operators can be thought of like a build-your-own blockchain, where users can select the number of nodes in that committee based upon the level of decentralization they need for a specific task. As a result, these nodes are capable of also performing "off-chain" decentralized computation, and then relaying those results to a main chain such as Ethereum. This vastly increases the scope of what a decentralized oracle network is capable of, allowing use cases such as: off-chain-computation, verifiable randomness generation, blockchain interoperability, fair transaction ordering, proof of reserve audits, on-chain automation, and more.

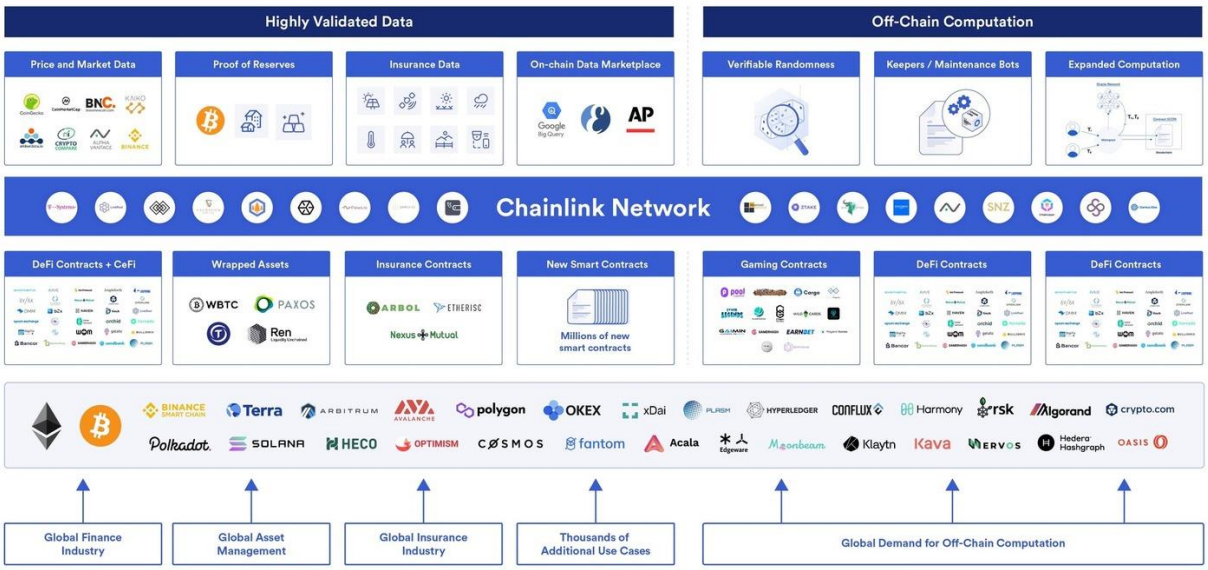


Figure 27 - Chainlink decentralized services

Although Ethereum is upgrading to Eth 2.0 in Q1 or Q2 of 2022, , it will not natively be fast enough to handle the number of transactions produced by the global economy. As such, there is a growing consensus that layer 2 scalability networks, such as optimistic rollup and ZK rollup protocols[27], will ultimately be the way that Ethereum achieves full scalability. These protocols perform computation off-chain, and then rely on validators to relay the results of the computation to the Ethereum main chain. This way the heavy lifting doesn't have to be replicated by every node in the entire Ethereum network. These solutions can and will use Chainlink oracles to perform this computation as well as validation. Optimism and Arbitrum are two of the first, and most popular, layer 2 scalability solutions set to go live, and they will both utilize Chainlink's growing set of node operators to act as validators on these networks. Although there are new layer 1 protocols (Avalanche, Tezos, Solana, Polkadot, etc.[28]) that offer scalability, and hence do not require off-chain computation, it is still unclear if any of them can unroot Ethereum after it upgrades. Although it is not the main part of the solution (like it is for connectivity), Chainlink will have a part to play in the scalability problem.

Even if the computation layer doesn't present scalability options in the short term, Chainlink has developed a technique called Threshold Signatures, or off-chain reporting (OCR)[29], to help with oracle scalability. This is a technique where nodes can aggregate their response off-chain, such that there is only a single interaction with the Ethereum main chain. OCR 2.0 is now live, and gas costs have dropped over 90% for node operators.

6.3 Solving Privacy

The first product Chainlink offers so users can maintain privacy is Mixicles. All oracle-enabled smart contracts use data inputs to trigger contract execution (state change) that produces settlement outputs. For example, a derivatives contract takes in market data (input) about the price of an asset and pays out (output) the winners based on the terms (coded logic) of the contract. Chainlink offers a marketplace of oracles that mine inputs and outputs for smart contracts. Most smart contracts today produce state changes on-chain, which makes it easy for public observers to see and correlate the input and output of a contract. However, Mixicles redefine smart contracts by splitting them into two parts where the state change is separated from the payment output. These two components are divided into off-chain and on-chain components and are not connected in any way the public can correlate together. The interlinking components that bring the two together, while maintaining privacy, are the oracles. Mixicles can be applied to most on-chain smart contracts. This means that almost all DeFi products can be used by enterprises on public blockchains, because their privacy can now be preserved.

The next product Chainlink offers is called DECO, a novel privacy preserving oracle protocol that can retrieve data privately from any TLS web session. Note that any website that utilizes the HTTPS protocol[30] likely utilizes TLS to establish a secure, encrypted channel for data transfer. With DECO, Chainlink oracles can prove facts about a user's TLS session while hiding privacy-sensitive data. It works with modern TLS

[27] Vitalik Buterin on Rollups: https://vitalik.ca/general/2021/01/05/rollup.html
[28] Note all of these protocols have integrated Chainlink as their native oracle solution
[29] https://blog.chain.link/off-chain-reporting-live-on-mainnet/
[30] 99.999% of public websites, so essentially the entire internet

versions, requires no trusted hardware, and requires no server-side modifications. Some applications include decentralized identity[31], DeFi, relaying electronic health records, etc.

Finally, one of the major areas of development for Chainlink are oracles that run in a trusted execution environment (TEE) using some type of trusted hardware, such as Intel SGX. The major advantage of an oracle running in a TEE is that the node operator cannot see the details of the query: inputs, outputs, and requestors. TEEs are appealing because closed private information, such as passwords, private keys and closed source APIs, can be handled by a TEE without revealing any of the information to the node operator or the public. Essentially, a TEE oracle could be programmed to access a private account to get data or trigger an action if sent the login details. Chainlink, through the acquisition of Town Crier, has access to working TEEs, and recently joined the HyperLedger Avalon Project to further develop TEE technology.

6.4 Overview

This enhanced level of connectivity brings a whole new level of functionality to smart contracts. Just like a computer with no Internet connection has limited capabilities, so too do smart contract platforms that cannot connect to outside functions. Chainlink acts as the Internet for smart contracts, allowing connectivity between almost everything[32].

This was a very brief description of how the Chainlink network works. For an in-depth analysis of the network, team, and partnerships, please refer to this article[33].

[31] https://initc3org.medium.com/making-decentralized-identity-possible-with-candid-231d9ffe3154
[32] Chainlink for Blockchain Interoperability and Real-World Connectivity
[33] https://smartcontentpublication.medium.com/completing-the-god-protocols-a-comprehensive-overview-of-chainlink-in-2021-746220a0e45

7 Chainlink and the 4IR Stack

The technologies that will enable the disruptive products and applications of the 4IR will now be referred to as the 4IR stack. Chainlink will exist as fundamental infrastructure in this stack. Every hybrid smart contract will utilize Chainlink in some way, shape, or form. As hybrid smart contracts underpin all of DeFi, decentralized insurance, trade finance, enterprise interoperability, and future data-driven autonomous system interaction, it is fair to say that Chainlink will power the 4IR.

7.1 All the Worlds' Data: The Sensory Input Layer

The base layer of the 4IR stack is the Internet of Things, which includes any and all edge devices and sensors. As such it will be composed of trillions of sensors from disparate economic actors. This presents no problem for centralized systems initially. Enterprises will deploy sensors and collect data internally for self-use.

When it comes to interoperability, though, this presents a problem. Recall the use case of trade finance, where GPS sensors or RFID tags can be installed in shipping crates to automate payments upon shipping of goods. If one enterprise is selling material to another, which company's sensor gets to be in the shipping crate? Can one enterprise trust that the other will execute the payment on time if the sensor is under full control of the counterparty? What if both companies put a sensor in the crate? One counterparty could still modify their sensor, undermining an agreement where both sensors need to detect the same data for the smart contract to execute. Using a 3rd party sensor could work, but that presents further problems. That company could be bribed, charge high costs, or create non-ideal legal dependencies. Data is simply not enough in use-cases such as these.

Chainlink provides a solution to these problems, acting as the sensory input layer for the 4th Industrial Revolution. It is an objective 3rd party intermediary of truth, that is trustless and tamperproof. Chainlink was designed from the ground up to be modular and upgradeable. Through the use of external adapters, it can connect to any API, any enterprise backend software system, or any micro-processor via RFID/etc. It is system and blockchain agnostic, and thus presents a single endpoint which any system can connect with to consume any type of data. The end user can individually select what oracles they want to retrieve the data they need. Based on the end user's needs they can pay for higher levels of decentralization, which will in turn increase the probability the data they are consuming is truthful. One can never reach 100% certainty, but one can asymptotically approach it[34].

Chainlink offers a means for any entity to monetize their data. It also incentivizes node operators through payments to deliver this data to smart contracts. This is why it is the sensory input layer – end users can access any type of data from trillions of sensors through a single interface which removes the complexity of interacting with multiple parties. All of the world's data will be sold into the Chainlink network, effectively acting as the Amazon Marketplace for data[35]. It will be the one-stop-shop for not just data, but trustworthy data. And as discussed, data is and will likely continue to be the most valuable resource on the planet.

[34] If the cost to hack/game an oracle mechanism is greater than the smart contract payout, there is no reason to hack/game the oracle mechanism

[35] https://market.link/

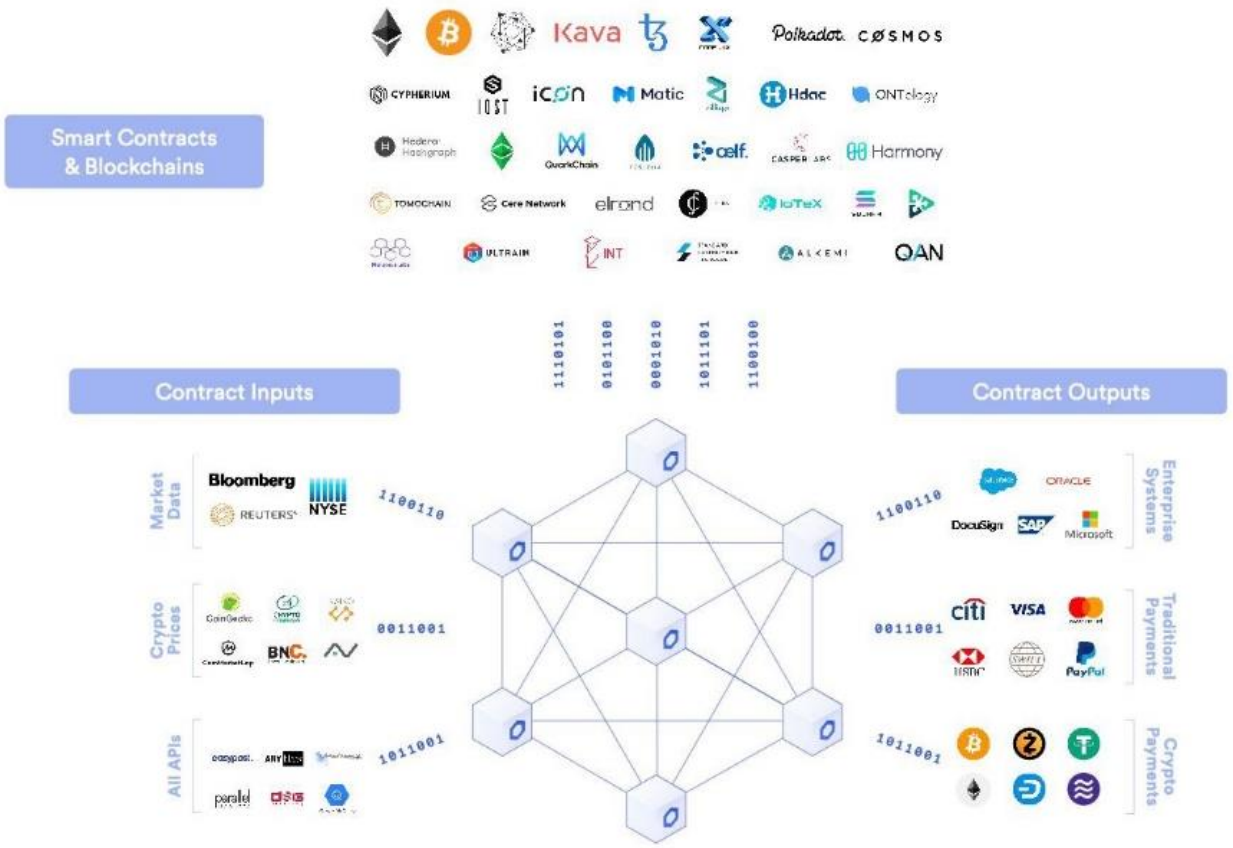


Figure 28 – Any type of data can be consumed by the Chainlink network, where it can trigger any smart contract on any blockchain

As a network for building decentralized oracle networks, both public and private oracle networks can be created. Currently, the Chainlink team has constructed public networks for price reference data[36], acting as a public good [37] for the crypto ecosystem. These price feeds are continually becoming more decentralized as node operators join them. Because staking is not yet live, the Chainlink team has self-audited every company which is running a node in these networks, to ensure they are sybil-attack resistant[38]. As more users consume these feeds, fees are split between all users of the network. For instance, the ETH-USD price feed is sponsored by 27 different applications that consume the feed. This lowers the cost for every user when someone joins. This creates a network effect dynamic, where users are incentivized to choose Chainlink because the fees are the cheapest, and with each actor that joins the utility of the network increases for all (better security, cheaper costs).

[36] https://feeds.chain.link/

[37] In economics, a public good is a good that is both non-excludable and non-rivalrous. For such utilities, users cannot be barred from accessing and/or using them for failing to pay for them. Also, use by one person neither prevents access of other people nor does it reduce availability to others.

[38] https://bitcoin.stackexchange.com/questions/50922/whats-a-sybil-attack#:~:text=A%20Sybil%20attack%20is%20an,virtual%20machines%2C%20and%20IP%20addresses.

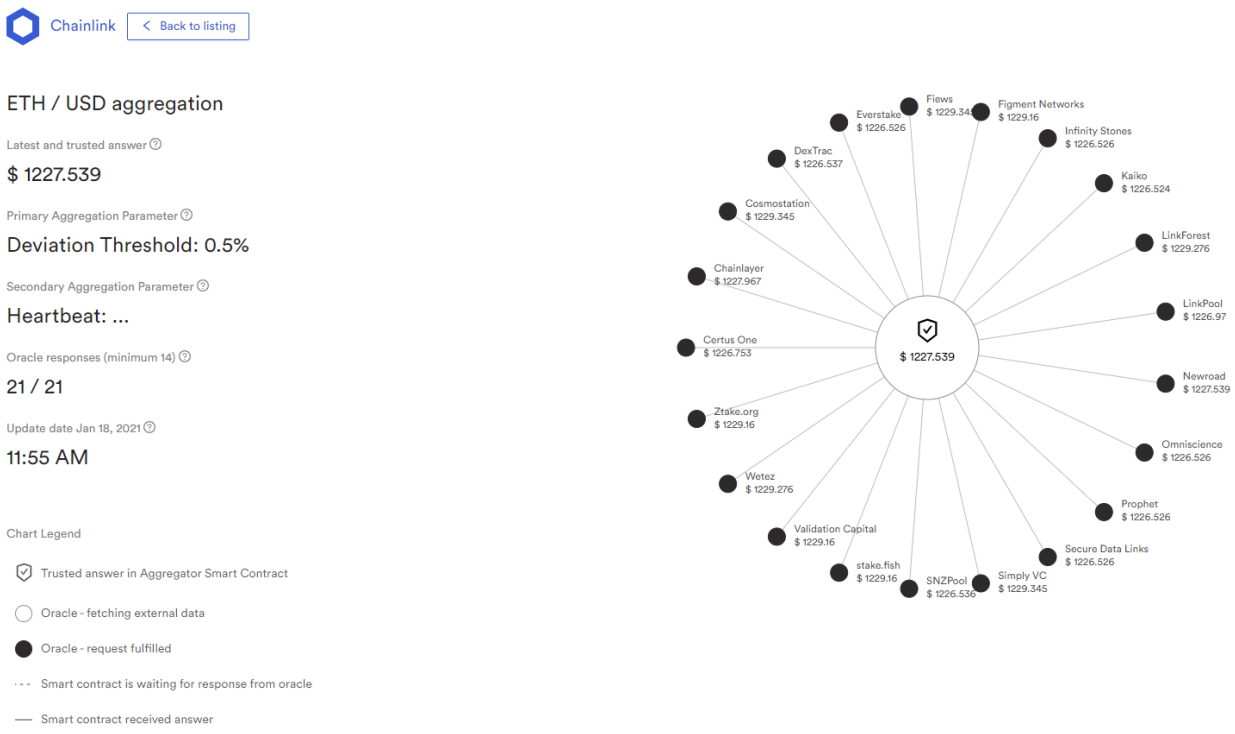


Figure 29 – The Eth/USD Chainlink Oracle Network

For enterprise derivatives contracts which would likely need larger amounts of decentralization, it Is possible for two counterparties to compose a public price feed like this to act as a single oracle in an even more decentralized oracle network. Navigating to the Chainlink Oracle Marketplace[39], any contract creator can individually compose an oracle network to meet their specific needs. They can filter nodes by reputation score[40], collateralization requirements, or total jobs run to ensure that the nodes they are choosing are trustworthy and capable of collateralizing a specific contract. Due to the architecture of the Chainlink network, every oracle or oracle network can be composed into larger networks. Oracles and oracle networks will compete to provide the best service possible so that they collect the most fees. This dynamic increase security, gives the lowest possible costs to end users, and incentivizes everyone to use the Chainlink Network. These are the benefits of a heterogeneous oracle network that is fully upgradeable and customizable to act as the single sensory input layer for the 4th Industrial Revolution.

[39] https://market.link/
[40] https://reputation.link/

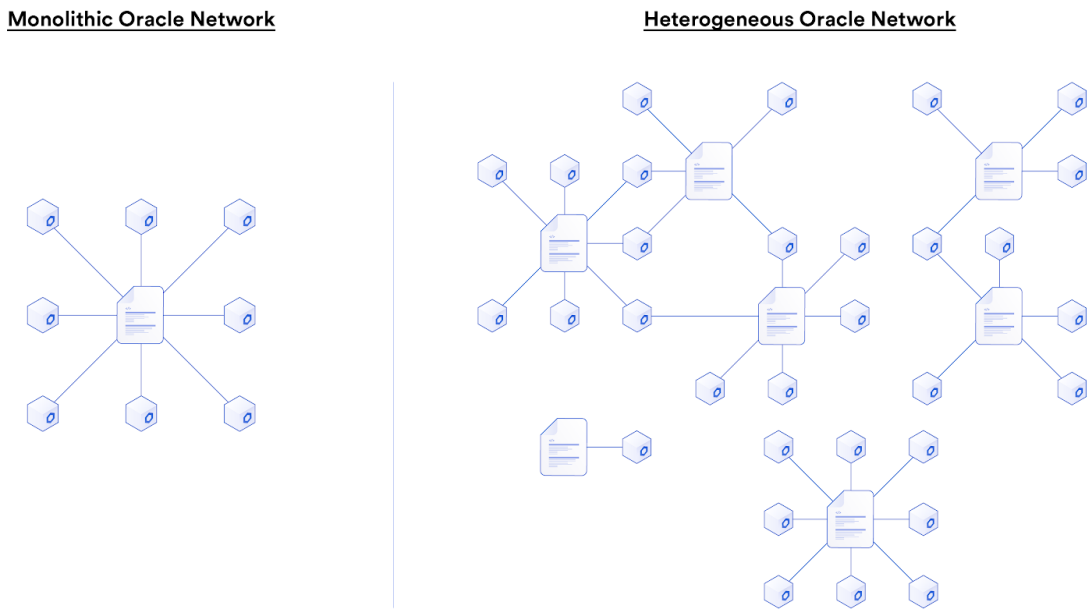


Figure 30 – A heterogeneous oracle network enables networks of networks

7.2 Enterprise Interoperability: The Blockchain Abstraction Layer

Although connectivity, scalability, and privacy are the major three issues to even begin talking about smart contract adoption, there are a few of others when it comes to enterprise or government smart contract adoption.

Per SmartContent: "The current fragmentation of both permissioned and permissionless blockchain environments is quite extensive. Even with some consolidation over time, it's likely to see various counterparties, industries, and entire geographic regions using a diverse set of blockchains with different trade-offs over the years to come. As such, large enterprises or government entities dealing with globally distributed or even locally distributed counterparties will be expected to eventually operate on dozens or more blockchain environments simultaneously." [17] It is already known that China will have its own blockchain network, the BSN, and hence will not be on Ethereum for instance. Because of this, it would be prohibitively expensive for governments and multi-national enterprises to hire multiple blockchain teams with specialized skillsets to create service integrations with every blockchain environment. Especially as the number of relevant blockchain environments continues to increase over time.

The other large problem is that it is extremely costly to upgrade enterprise backend infrastructure. There is a large ecosystem of companies which consult enterprises on planning their enterprise software upgrades as well as executing the upgrade. Not only is it expensive with respect to capital, but it is time intensive as well. The DLT space is developing rapidly, and even if an enterprise were able to upgrade their enterprise software, it would likely become outdated fast.

The World Economic Forum has identified these problems in an official white paper co-authored by the Chainlink team:

“A sensible approach that helps to mitigate technology risk and switching costs is to adopt an open-source secure blockchain middleware, wherever the use of blockchain is relevant, that provides legacy systems with universal access to current and future blockchain environments without needing to restructure or rebuild any mission-critical internal backend infrastructure. In addition to universal connection, blockchain middleware might provide some legacy systems with an “in-house” method of developing higher security and reliability standards onto their existing systems using various validation and filtering techniques such as decentralization (redundant confirmation of the same data point in a trust-less manner), reputation systems (filter oracles based on performance quality) and technologically enforced financial incentives/penalties (stake capital to back the quality of oracle services).

Enterprise systems can support the development of new or innovative services in an ecosystem if those systems can interact with other platforms and networks. This stands true for legacy-to-DLT interoperability as well. However, enterprises and governments may innovate with DLT-related services at a slower pace if they are unable to connect legacy and DLT systems securely and effectively. The ability to easily integrate with any existing and/or future blockchain network and maintain strong guarantees of integrity and determinism will provide governments and enterprises with the ability to build across and interact with counterparties operating in any blockchain environment. Furthermore, organizations or regions may use different blockchain networks, and integration and interoperability among them will be valuable.” [18]

As stated before, Chainlink is much more than a data delivery network. It has been designed specifically to be able to bi-directionally interact with any legacy enterprise software system. By serving as a universal interoperability layer, Chainlink is and will further cement its place as the standard, permissionless medium for on-chain and off-chain interoperability. It will also allow developers to coalesce around a single repository for all resources such as documentation, technical walkthroughs, and information regarding interacting with a specific system (external adapters). All users will be able to contribute to a large open-source community building on a common interoperability framework, much like the internet. This removes any enterprise specific incentives which could cause larger companies to gain control over this layer at the detriment of others. Per the WEF:

“A closed network may also be subject to political stand-offs whereby certain enterprises will not join consortium networks operated by competitors or will refuse to write documentation for certain competitors, thereby limiting access or causing delays. Such an approach will likely result in a fragmented, unscalable system of many different intranets, instead of the one global internet we all enjoy today.” [18]

Similar to price feed oracle networks, the singular use of a standard middleware by all users, enterprises, and governments reduces the costs for every party involved. The shared financial support of the node operators running the interoperability services will be split amongst all parties. This does not only benefit the blockchain ecosystems by providing dApps with the largest set of users providing services and data, but benefits legacy systems that can provide their services and data across all DLT networks.

The collective use of a common middleware by users from different blockchains, enterprises, and governments reduce the costs of providing and accessing data and services for everyone. This benefits blockchains through the cultivation of more data-rich environments for developing applications that interface with legacy infrastructure, while equally benefiting legacy systems that can now provide data and services to users across all kinds of DLT networks.

The Chainlink network, just like the internet, is a public good which acts as The Blockchain Abstraction Layer for any legacy system to conduct economic activity on the blockchain without changing any existing infrastructure.

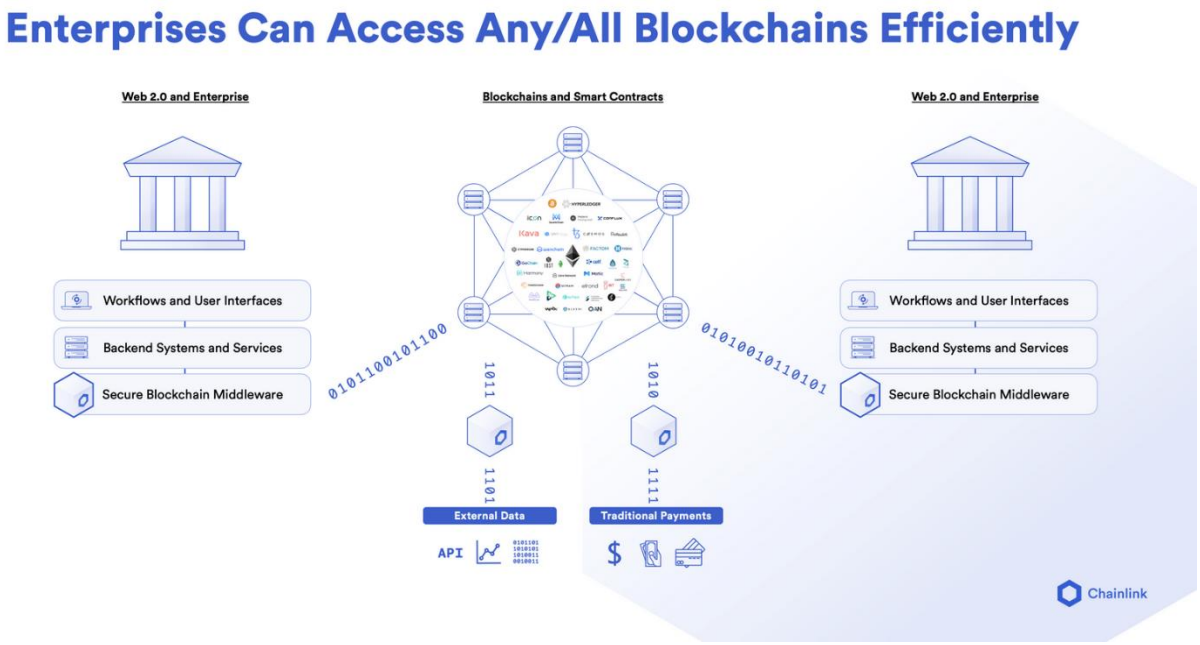


Figure 31 – Chainlink is the Blockchain Abstraction Layer

As stated before, the game-changing technology here is hybrid smart contracts. Not only will Chainlink enable enterprises and governments to leverage the power of smart contracts, but they will also be providing all smart contract services needed by said smart contracts (data, off-chain computation, privacy, etc.).

7.3 Blockchain Interoperability: Cross Chain Interoperability Protocol

Not only can Chainlink connect any legacy system to the blockchain layer, but it can connect every blockchain to each other through a new communication protocol: the Cross Chain Interoperability Protocol (CCIP). CCIP enables decentralized inter-chain messaging and token movements.

Per Chainlink, "CCIP provides smart contract developers a generalized, compute-enabled infrastructure for transferring data and smart contract commands across blockchain networks. CCIP will underpin a variety of cross-chain services, such as the Chainlink Programmable Token Bridge, which will empower users to move their tokens across any blockchain network in a highly secure, scalable, and cost-efficient manner."

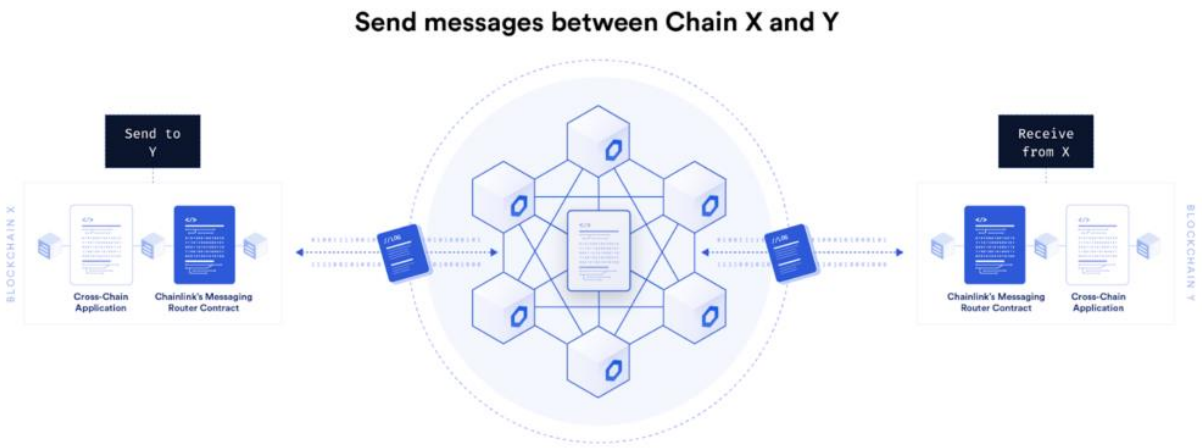


Figure 32 - Chainlink CCIP

Chainlink CCIP allows developers to create applications which utilize multiple blockchains. The core code sits on the chain of the developers choosing, which opens up the possibility of using their desirable coding language (as different blockchains utilize different languages). The Chainlink Programmable Token Bridge allows smart contracts to not only send tokens to other chains, but to also execute commands on other chains once those tokens have been sent. This enables cross-chain applications which blur the lines between various L1 and L2 blockchain protocols. Developers will pick and choose what services they want from each blockchain and combine them all into a CCIP enabled application. One example of this is a cross-chain yield service. Celsius, the leading CeFi platform with over $16 billion in digital asset holdings, plans to leverage CCIP.

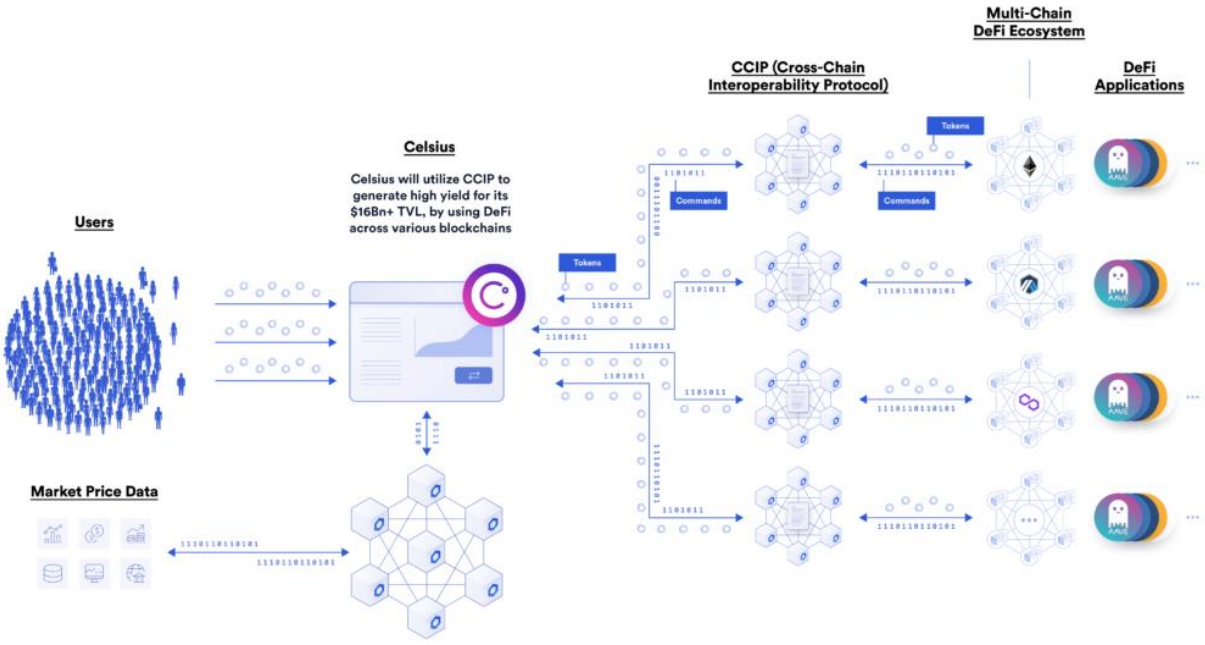


Figure 33 - Celsius CCIP based cross-chain yield architecture

The Chainlink team also plans to implement the Anti-Fraud Network – a separate set of nodes which monitors all cross-chain interactions for faulty behavior.

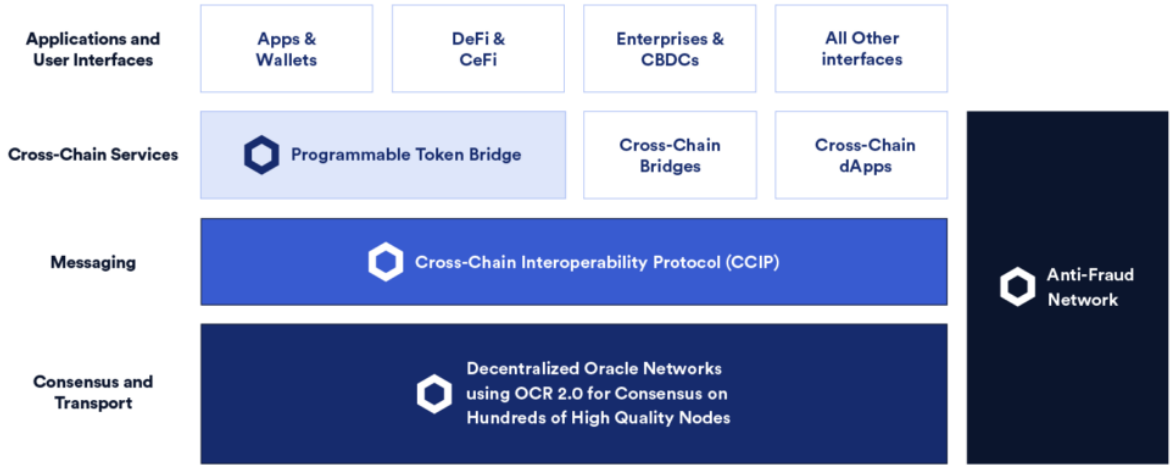


Figure 34 - CCIP enabled cross-chain stack

7.4 A Bi-Directional Compute Enabled Network for the 4th Industrial Revolution

All the worlds' data will pass through Chainlink as it is used to trigger every digital contract which opts for deterministic, data driven math-based guarantees over brand-based guarantees. Every enterprise system will utilize Chainlink to become blockchain enabled. All applications which enterprises or users interact with will be built on CCIP enabled cross-chain infrastructure to gain the benefit that each chain has to offer. Chainlink is at the heart of for the 4IR stack. It connects the physical domain to the digital domain and is necessary for every smart contract – whether it is public, private, permissionless, or permissioned. Eventually Chainlink will become a decentralized metalayer which will abstract away all complexity of interacting with the blockchain layer by providing a single input for all services across all blockchains.

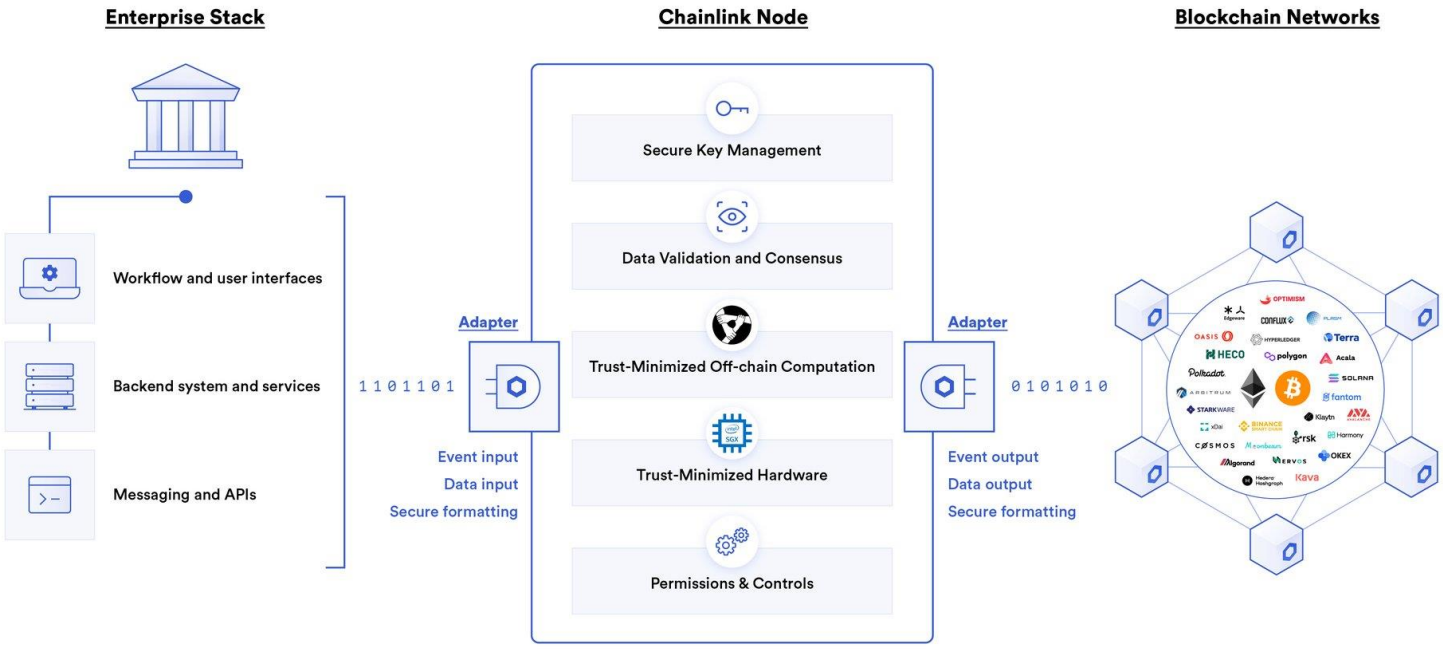


Figure 35 - Chainlink acts as a decentralized metalayer for accessing the blockchain layer

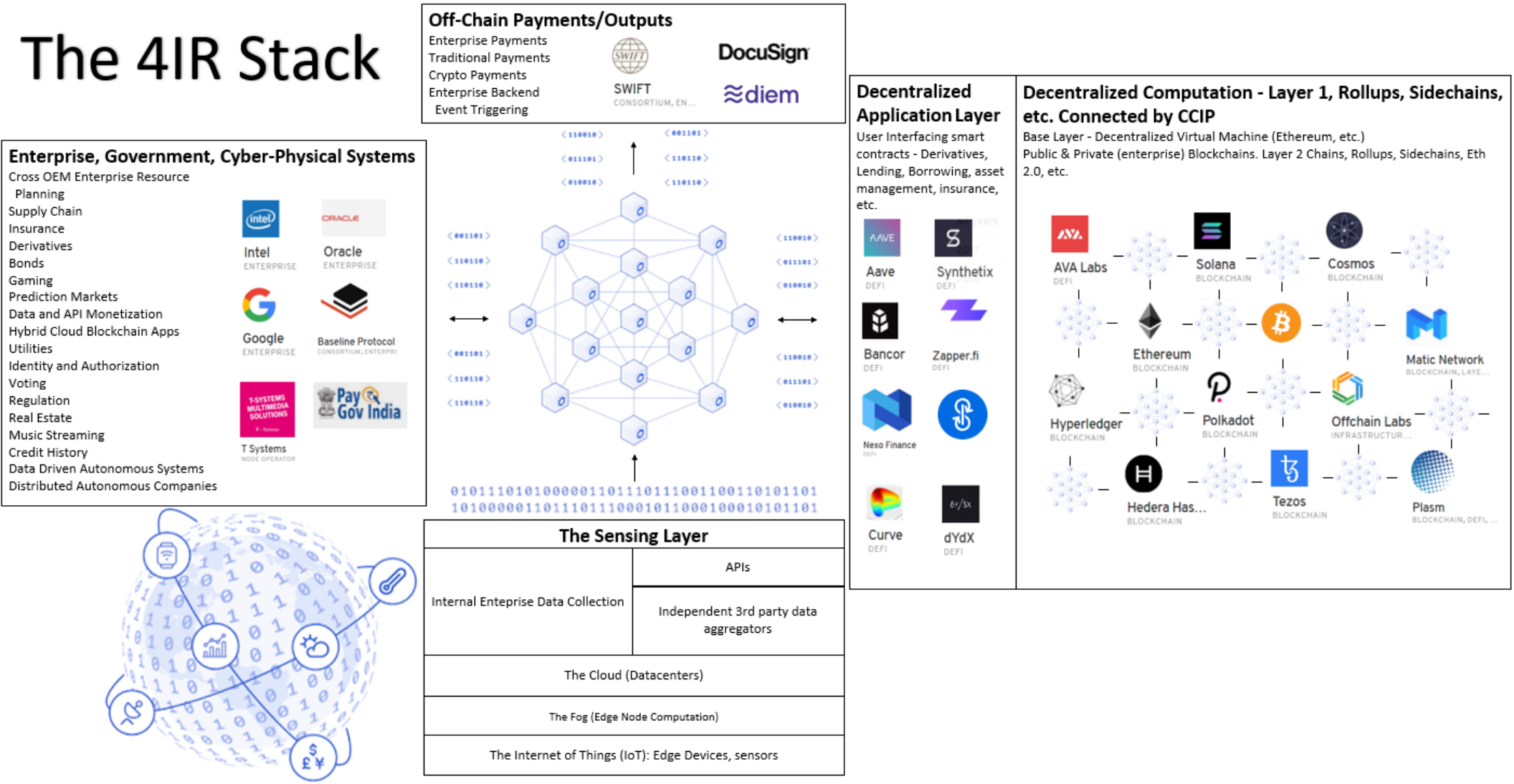


Figure 36 – The 4IR stack. Chainlink has a larger addressable market than any other piece of infrastructure

8 Value Proposition

Tamper-proof contractual execution via hybrid smart contracts is the future of both high-value financial agreements (derivatives, insurance, trade finance, etc.) and micro-transactions (IoT payments, Ad payments, Mobile payments, etc.). This shift will massively reduce non-performance risk, eliminate certain insurance/legal costs, and create valuable trust, which leads to superior deal terms for all categories of contracts. In many cases, costs can be reduced by 90%. Chainlink provides the necessary infrastructure for all hybrid smart contracts to function.

The Chainlink team, led by Sergey Nazarov and Steve Ellis, began as Smartcontract LLC in 2013. They were initially working on what would become Ethereum before they pivoted to instead create a decentralized oracle network. This manifested itself as the creation of Chainlink, which held its ICO in 2017. Smartcontract has now morphed into Chainlink Labs[41], a research team part of Chainlink dedicated to solving the fundamental problems holding blockchain adoption back. Chainlink Labs is led by Chief Scientist Ari Juels, the Weill Family Foundation and Joan and Sanford I. Weill Professor in the Jacobs Technion-Cornell Institute at Cornell Tech and Co-Director of the Initiative for CryptoCurrencies and Contracts (IC3), as well as co-writer of the Chainlink whitepaper and Chainlink whitepaper v2.0[42]. Juels, along with Nazarov and Ellis, uniquely identified the oracle problem before anybody else. Ari Juels formalized and coined the term Proof of Work in a seminal 1999 thesis[43]. Vitalik Buterin, co-creator of Ethereum, was 5 years old in 199. This gives one an idea of the length of time Ari has been researching cryptography, even though the space is relatively young. The Proof of Work consensus protocol would be the choice protocol for both the Bitcoin and Ethereum blockchains, the two largest blockchain protocols today. With an h-index[44] of 84, Ari Juels is the most cited security and cryptography researcher on the planet.

Chainlink has already secured the largest network effect of any decentralized oracle network within the ecosystem. Chainlink secures 100% of all DeFi derivative contracts, and 85% of total DeFi Total Value Locked (TVL). On 12 November 2021, Chainlink secured over $83 billion in value. Note users depositing tokens in DeFi protocols is referred to as TVL, whereas the total TVL across DeFi protocols which Chainlink secures is denoted by Total Value Secured (TVS).

Figure 37 - Chainlink TVS surpassed $80 billion as of 12 November 2021

With a rapidly growing team soon to be over 200 employees, a 5+ year advantage over any other decentralized oracle protocol, integrations with leading dApps, and partnerships with large enterprises (Google, IBM, Oracle, SWIFT, WEF, etc.), Chainlink is the clear standard in the Decentralized Oracle space.

[41] https://chainlinklabs.com/
[42] Refer to further resources for whitepaper links
[43] http://www.arijuels.com/wp-content/uploads/2013/09/PoW.pdf
[44] https://paperpile.com/g/what-is-a-good-h-index/

8.1 Macro Forces will Drive Crypto Inflows

Amidst a global pandemic the US has experienced the most widespread racial unrest protests since the Civil Rights Movement. We just concluded one of the most divisive presidential elections in recent history, if not of all time. Finally, rioters stormed the capitol in objection of what they believed to be a rigged election. These are not idiosyncratic phenomena specific to the US – civil unrest exists throughout the world[45] as well. Economic metrics have bounced back in 2021, but in 2020 they were the worst since the Great Depression. The US experienced the fastest crash ever, and from a % standpoint was almost as bad as the Great Depression crash. Since March-April of 2020, the stock market has rallied to new all-time highs. This has investors confused - per Druckenmiller, "I actually believe we are in the most unique set of economic circumstances that I have seen in my career and certainly in the post-war period" [32]. Why is this all occurring? To tell this story one must begin in 1945.

8.1.1 How We Got Here

World War 2 made the US incredibly strong. The US had amassed almost half the gold in the world by selling equipment to Europe for the war. The war also made the US incredibly technologically capable, and the combination of these two factors led to an era of prosperity post-war. This technologically led productivity growth was consistent and very well distributed amongst each socio-economic class. That is, up until 1971.

As referenced earlier, the Great Stagnation is defined by this sudden collapse in technologically led growth. It is not that scientific discoveries stopped happening, it is that scientific discovers had less application in technology which could impact people's lives. As stated before, the digital revolution was an outlier here, but even considering the boost it gave to productivity growth the US was still way below the period of 1945-1971. Other monetary, political, and technological factors contributed to this strange decline in productivity growth as well.

Many imply that this decline was from moving off the Bretton Woods Standard (a pseudo gold standard) which led to this stagnation. Although this had an impact, it is not the only factor which contributed to it. One can argue Nixon went off the Bretton Woods standard *because* growth had slowed, and the economy and business structures which were created post '45 would have collapsed if he stayed on it. The thought at the time was The Fed and fiat money would allow the control of interest rates and the supply of money as to soften economic crashes and promote positive economic growth. The problem is by deploying a fiat system it enables the issuer of that fiat currency asymmetrical power. People are corruptible and placing the power of the printing press in the hands of the Federal Reserve has no doubt contributed to income inequality in some form. Look no further than where the bailouts went in 2008, where the vast majority of Corona Virus stimulus went to, and refer to the Chapwood Index[46] to get an unbiased look at the true cost-of-living increases in each state in America. Successive rounds of QE have continued to widen the income gap since '08 as well.

As Eric Weinstein says, "The idealism of an age is usually the cover story for the theft". In the Early 1990s post fall of the Iron Curtain, the Davos idealism of "We are the world" and the globalization that came

[45] Brexit, France Yellow Vest Protests. Sudan, Algeria, Egypt, Hong Kong, Catalonia, Iran, and Iraq are experiencing massive instability as well. Columbian protests, Venezuela hyper-inflation + protests, Santiago, Chile subway burning/riots

[46] https://chapwoodindex.com/

next have also led to the gutting of America's middle class. Manufacturing jobs have been pushed overseas where wages are near zero, and universities and companies have imported internationals on student and work visas to flood the STEM market with labor to reduce pay for US scientists [29]. This has contributed to a steady flattening out in median income since 1971.

One last reason for stagnation is due to the nature of the digital revolution. Although it can be considered a savior for productivity growth in the post 1971 world, it can be argued the technologies that it created have been deflationary. Wealth isn't highly distributed when it takes a team of 10 software engineers to make a billion-dollar company, where the only people investing in that company are Silicon Valley venture funds. This has led to an extreme concentration of wealth from the productivity growth experienced during the 3IR. The tech giants of today who at this point have monopolies in their respective domains can buy out and destroy competing startups, as well as offer too-good-to-turn-down compensation packages to hoard the best talent. Chamath Palihapitiya of Social Capital has pointed this out, and notes the similarities of today to the Gilded Age [19].

These factors have led to the largest wealth gap since the Great Depression. Wealth distribution follows a power law distribution, where the richest people in a society hoard a disproportionate amount of the total wealth. This number is reflected in a statistic called the Gini coefficient. In a zero-sum game, naturally the people with the most wealth and assets will be able to capture more wealth/assets than the poor.

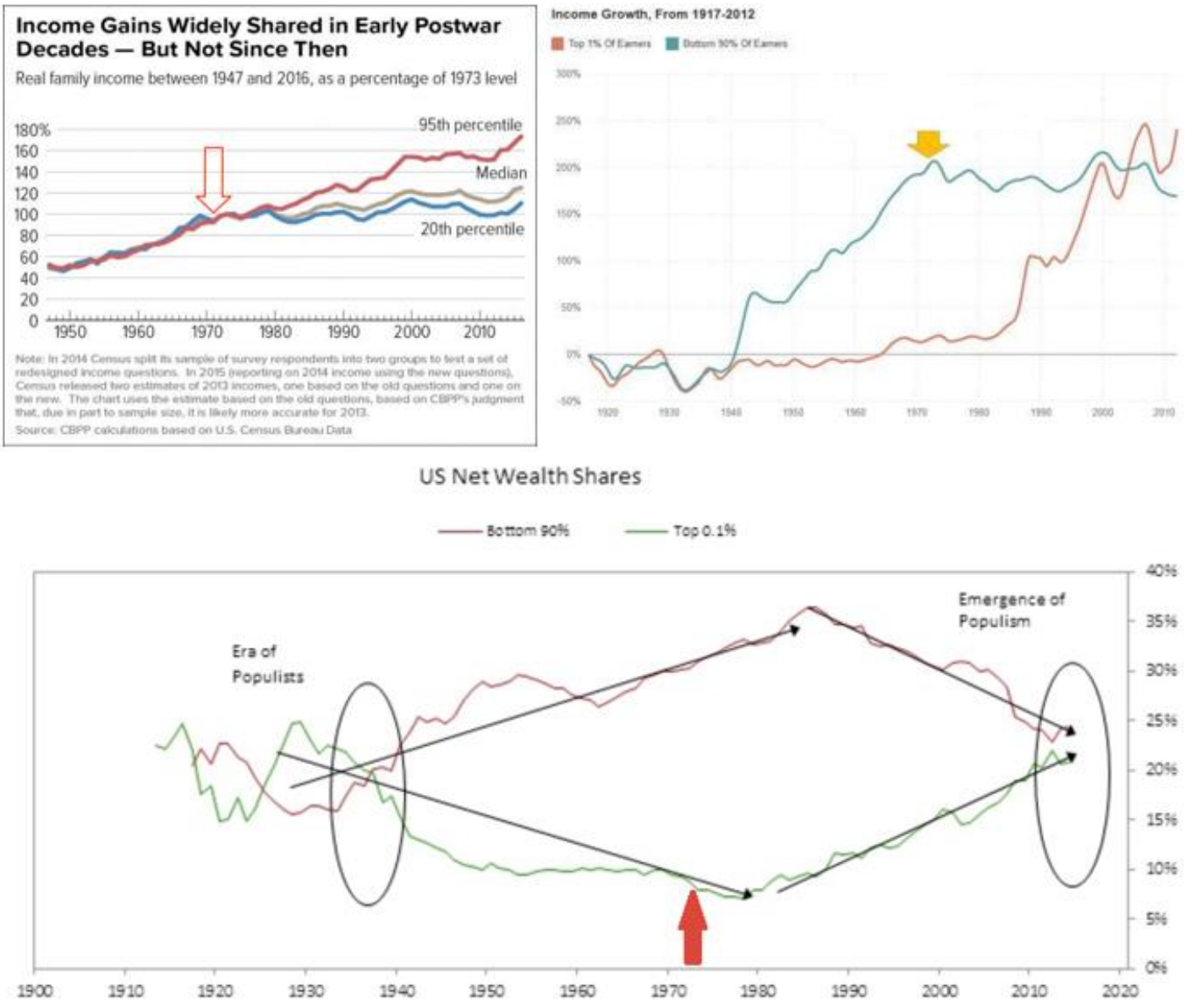


Figure 38 – The Rise of Income Inequality

Can the kleptocrats be at blame for their wrong doings? Both yes and no. Considering that more and more institutions look like Ponzi schemes, where necessary retirement was done away with in the '80s, people at the top are simply capitalizing on their situation[47]. If one paid their dues for a lengthy career and either through hard work or luck rose to the top in their institution, it would be considerably hard to pass up on the outsized gains for oneself and one's family. As compensation packages are stock heavy, executives can morally justify outsized stock buybacks in reference to their fiduciary duty of shareholder value while

[47] Our top 5 presidential candidates all would have been the oldest president ever. 49/50 top colleges have Boomer presidents

getting rich in the process. More stock buybacks mean less R&D and ultimately productivity growth for all, though.

Charlie Munger said, “Show me the incentive, and I will show you the outcome”. This is why growth is so important. It is the fuel that can get the US back on track so that the pie is growing for everyone, not just a small number of people that take it at the expense of the majority. Without well-distributed, technologically led productivity growth, the nation will keep incurring debt as politicians spend more money. This will lead to a vicious cycle of more money printing, and a further deteriorating economy and financial system.

So, why does this all matter? The current state of the economy, which exists today as a result of these forces listed above, will most likely lead to either inflation or a deflationary crash. These produce the slow and fast cases of crypto and DeFi adoption.

8.1.2 The Slow Case

Without real productivity growth, the economy is not working for most people. The stock market continues to rise, though, and the Fed has seemed to prevent any sustained crash from occurring. This has been through the reduction of interest rates, as well as Quantitative Easing (QE). In many countries around the world, interest rates are actually negative – implying large financial institutions actually have to spend money to store their capital.

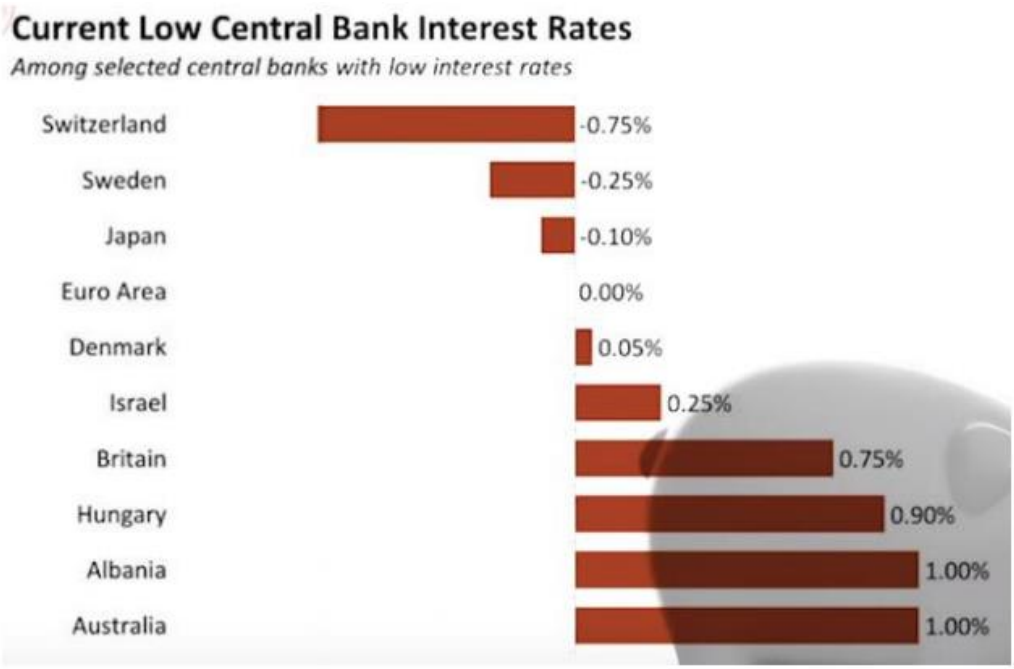


Figure 39 – Interest rates are near 0 or negative for many countries

Unless the Fed wants to go to negative interest rates, their only tool left is to perform increasing amounts of QE. As of Q2 of 2021, hilariously the Fed doesn’t even update the M2 money stock chart anymore. There was a 24% increase in M2 in 2020. The Fed did more QE in a 3-month period last spring than the entire 2008 to 2020 period.

Figure 40 - USD M2

Does this matter, though? When people argued runaway inflation would occur after QE 1, 2, and 3, it simply has not been so, although true CPI inflation is higher than the department of labor lets it out to be[48]. Because of this, a branch of economists called Modern Monetary Theorists have risen in popularity, led by Stephanie Kelton. Although most of their fundamental beliefs are flawed, they believe that CPI inflation is not directly correlated to the printing of money, and they are right in some respect - it depends on where the QE goes. Looking at other baskets of goods rather than the CPI basket: luxury items, real-estate, college tuition, or asset prices for example, it is clear inflation is very real. So the question becomes, is *CPI* inflation on the horizon?

This is the core issue in our opinion. As wealth inequality continues to further increase from the secular trends detailed in the previous section[49], there will always be populist figures that rise with a promise to save the proletariat. Their goal is, simply, to get elected and then re-elected. Therefore, there is no incentive for the current, or next, politician to address the debt, regardless of the side of the aisle they sit on. Currently the national debt is at 28 trillion and the debt to GDP ratio is at record highs.

[48] They can change the way CPI is calculated, continue to "move the goalposts" so it stays low
[49] Corona Virus accelerated it as well

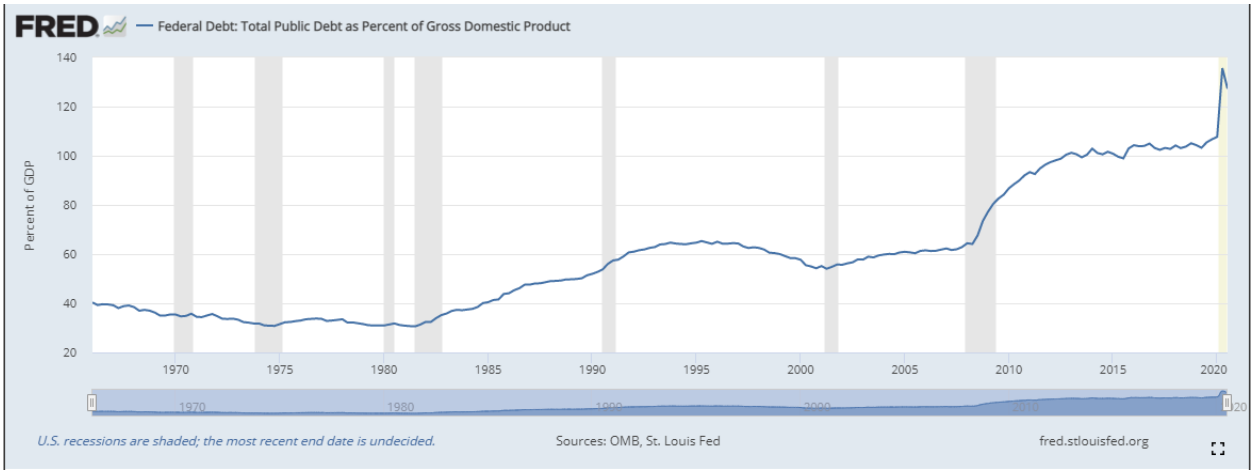


Figure 41 – US Debt to GDP ratio

Politicians will continue to promise to save the people, and will increasingly use money printing to do so under the influence of MMT economists.

Figure 42 – Populist political figures

This begs the question, is it possible for this cycle to reverse? We would argue strongly that there is not. The problem is that increasing asset inflation has led to the continuous decrease in treasury yields. For instance, the 10-year T-bill is effectively at all-time lows. If you measure inflation by the decrease in yield of the 10-year, it would be at 22% over the last decade.

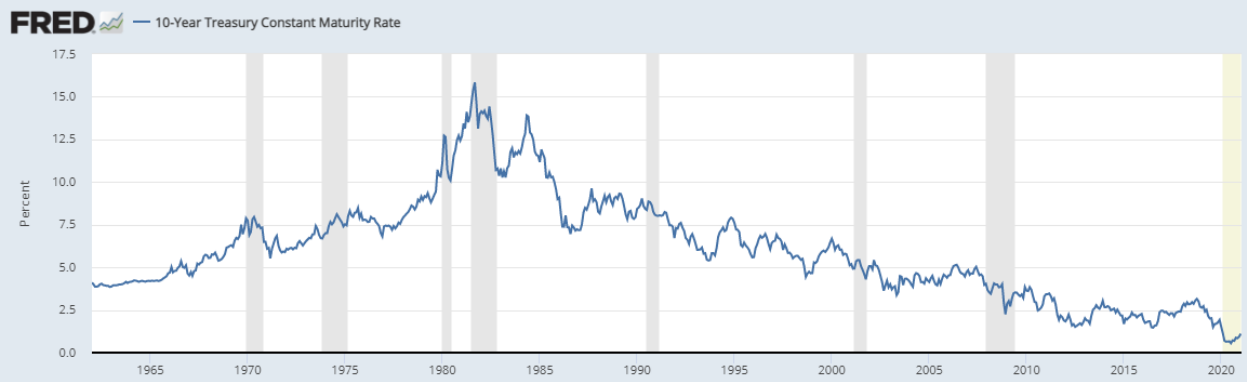


Figure 43 – 10-year treasury bond yield

As the risk-free rate of returns have decreased over time, institutions starving for yield have had to allocate more capital to risk-assets, specifically equities. In particular, pension funds have ventured out into the risk curve to satisfy their *legal* obligations. In 2020 pensions managed over $32 trillion.

The Fed cannot let pensions and social security fail, there is simply too much money and too many people's lives depending on these reserves. The Fed has ventured down the path of backstopping almost every type of asset now directly, and they can't go back. They have locked themselves into this direction and we believe they are going to be committed to the point that they will go down with the ship.

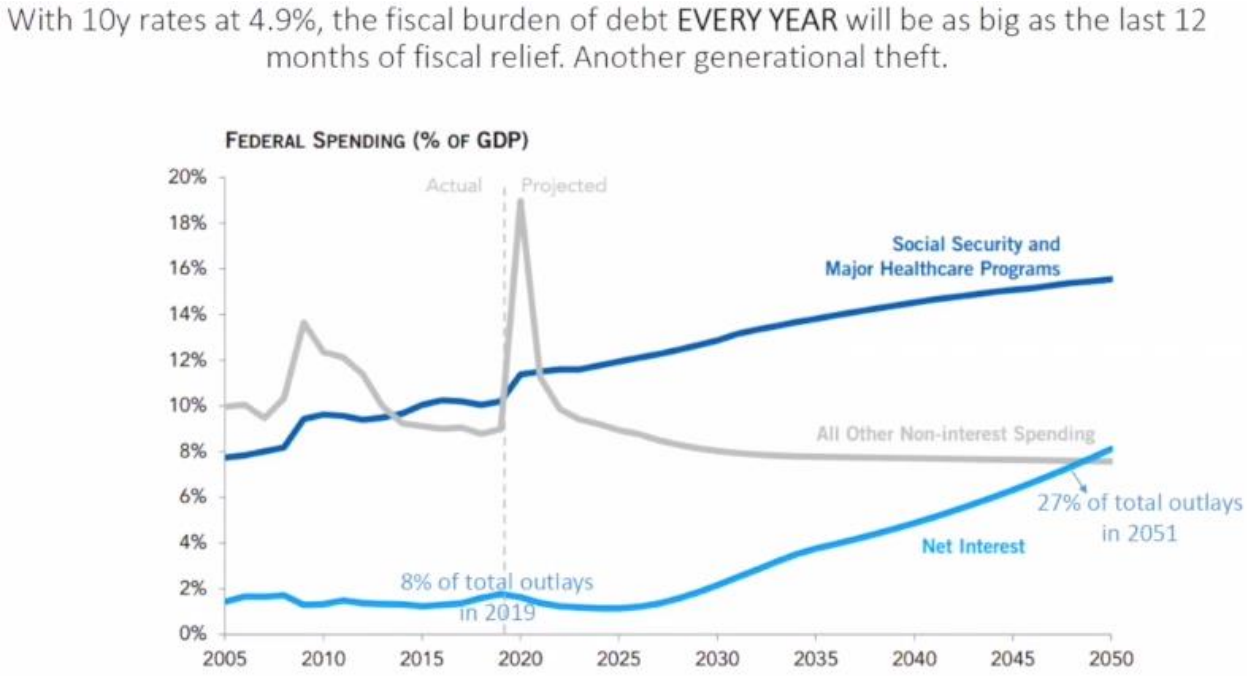


Figure 44 - Interest rate payments on social security and major healthcare programs

Per Druckenmiller, "The CBO projects that the new debt levels, despite drastic cuts in non-entitlement spending, will result in interest expense of 27 percent per year if the 10-year rate was to normalize at 4.9 percent simply put the system cannot handle it so the FED will be forced to monetize it. Think about that, 27 percent of GDP just in interest costs alone. That is basically all the money we spent in covid relief in

the last 12 months. Like many post war periods, this will inevitably lead to inflation and financial repression by central banks despite not having had to finance a major war. I believe we have crossed the Rubicon, and this Is the only solution to this unnecessary and self-inflicted situation from this radical monetary and fiscal policy I have outlined." Figure 44 is scary because the implication is that mathematically the numbers simply don't work out. The Fed *will have* to print.

As only 50% of individuals have any money in the stock market, and 90% of the stock market is owned by the top 10% of individuals, as the Fed relentlessly keeps the market afloat they are further driving income inequality. Wealth inequality combined with inflation lowers the quality of the vast majority of people's lives. This further increases populism, influences political elections, and eventually increases the chances for massive social program spending. The US has already printed over 4 trillion dollars for Corona Virus stimulus, and now Biden wants to have another 2 trillion stimulus in conjunction with a 4 trillion-dollar infrastructure plan. This is the cycle that will continue until devastating amounts of inflation eventually occurs.

Hugh Hendry, on what matters more than the Fed:

"Circumstances, my dear fellow. circumstances. And so, I want to warn you that it's the febrile world of psychology and shifting expectations that matters more than the Fed and its reserve printing: that it's the mood of society that ultimately unleashes the inflationary genie from the bottle, not these huge inert central - banking reserves".

As the masses slowly lose their assets to inflation, social programs will increase, not decrease. By the time inflation pops up, it will already be too late.

For a system to be disrupted, a new product has to have 10x the improvement, or the system must fail. Already, DeFi offers a significantly large improvement over the traditional financial system with respect to yield. People don't care about privacy, they don't care about decentralization, and they will always choose a big brand over a small one. One thing is certain, though, is that if one savings account offers 2.5% APY and the other offers 0.25%, they will chose the 2.5% every time. If we enter into an environment where inflation begins to pick up, Sergey Nazarov, co-founder of Chainlink, believes this will create the setup for a DeFi boom.

"Do you know where your bank account gets your savings rate from? Your APR? Do you know if it does commercial or residential loans? Do you know the risk profile of your bank? Do you know why? Did you know that they actually reduced your rate of return? I think a lot of people don't know their rate of return. They don't know where it comes from. Many of them probably don't even know it was reduced. But once inflation kicks in, everyone's going to know real, real quick. Then there is going to be a mad dash for yield. And I think that's where you really have the equivalent of the e-commerce boom. If DeFi can provide that yield, the boom will be the mainstream using blockchains not to own a crypto asset, but because cash in the form of a stablecoin that gets two percent yield is obviously superior to cash in a bank account that gets point one percent yield."

In the world today, the traditional financial system offers low yield financial products, and inflation exists on the horizon. These two factors will bring institutions with fiduciary obligations to seek out yield – leading them to DeFi. It's not that financial institutions will buy crypto expecting it to appreciate over time. They will buy crypto assets so that they can participate in DeFi yield generating products. This is the slow

case of adoption, which will unfold over the next couple years. Assets such as Bitcoin can be used to fight inflation, while DeFi products such as Aave are returning 10% APY on stablecoins. DeFi will become a blackhole of liquidity as the legacy financial system continues to crack.

8.1.3 The Fast Case

One might ask that if the Corona Virus pandemic couldn't crash the market, then what could? The answer to that lies in demographics. Over the next 10 years the largest demographic cohort, the Baby Boomers, will exit the market in what will be the largest wealth transfer in modern history.

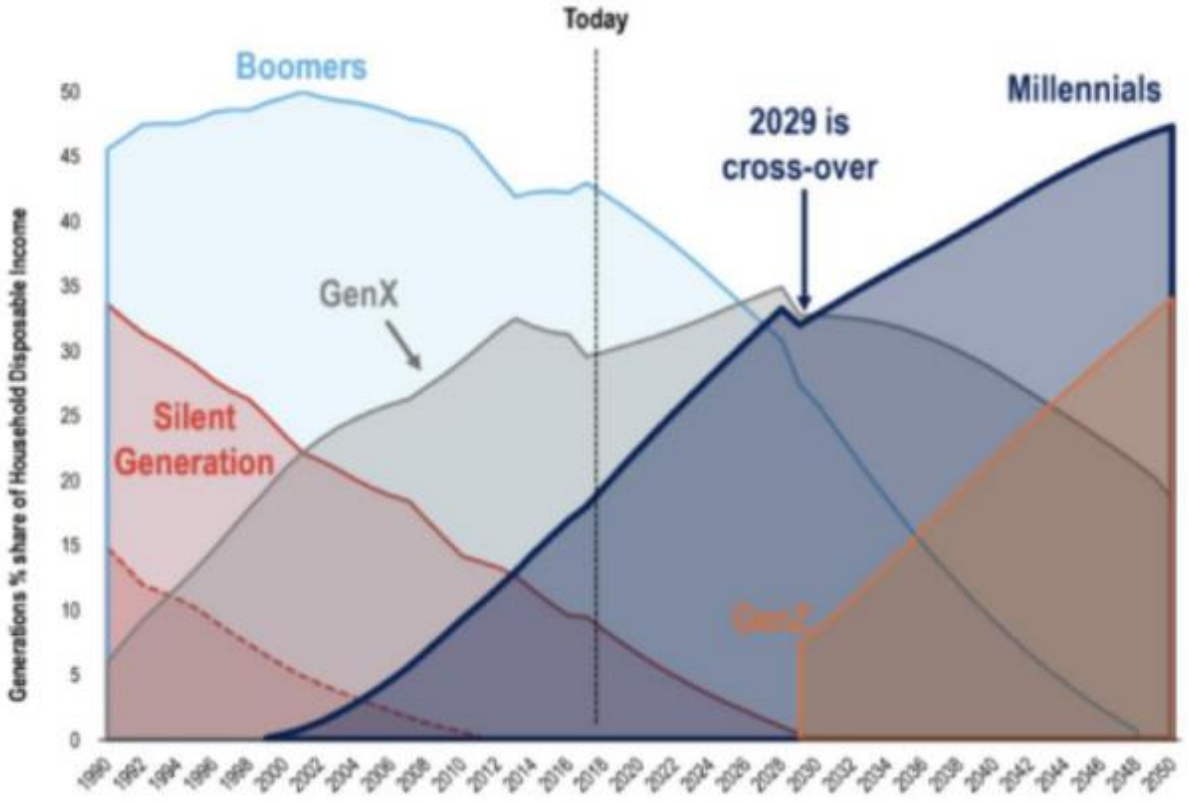


Figure 45 – By 2029 Millennials will control the most wealth

Currently more than 40% of all money is in passive vehicles. In 2017, the share of equity assets invested each year in passive funds was 44.6%. Similarly, 58% of all money going into retirement savings in 2017 (higher now) went directly into target date funds. Vanguard expects 80% of their investors will be in a target date fund by 2023. People think they are diversified, but they are not. The vast amount of money is in ETFs, which are highly concentrated among the most liquid assets. This extreme concentration, which has broken the pricing mechanism in markets, could lead to a systematic crash when the passive flows stop.

The equation is simple: inflows vs. outflows. If outflows start to outsize inflows – well, we all know the market goes up on an escalator, and down on an elevator. Baby boomers are set to turn 65 in the next few years and debt to GDP is about to cross 100% in the next decade.

"Are these extreme valuations "good"? Do they create more "wealth"? In order for this presumptive "wealth" to be spent, the overvalued securities have to be sold, but at that moment – Iron Law of Equilibrium – someone else has to buy them. The seller effectively receives a transfer of spending power from the buyer, and the buyer is left holding the bag of poor long-term returns. No – the true "wealth" is in the stream of future cash flows and value-added production that generates those future cash flows. All rich valuations do is provide a window of opportunity for current holders to obtain a wealth transfer from buyers, but the only way to realize that is by selling. The moment enough holders attempt to do so, the presumptive "wealth" vanishes, because all of this "wealth" reflects nothing other than the relative eagerness of the marginal buyer and the marginal seller. Put simply, the true wealth is in the cash flows, not in the overvalued prices. Policy makers at the Fed seem to be thinking about this issue so loosely that they don't recognize that security markets operate under the constraints of equilibrium. This failure of systematic thinking is why they've responded to the devastating consequences of a yield-seeking mortgage bubble by encouraging yet another yield-seeking bubble, but this time in virtually every class of risky assets. All of this will end badly"

– John P. Hussman, Ph.D., Blowing Bubbles: QE and the Iron Laws, 5/16/15

The worst periods in economic history have occurred after the bursting of asset bubbles, and currently the stock market to GDP ratio is the greatest it's been in over a century. Although he is betting on inflation, per Druckenmiller a deflationary crash is his close 2nd base-case,

"How does this thing end? To me, the asset bubble, which [Powell] is blowing up to unbelievable proportions busts before the inflation ever really manifests itself. That's what happened with the housing thing in '08, '09. We never really got to the inflation because the asset bubble burst. None of this is similar to what happened in '29. That is not my central case, but let me just say we have never had a deflationary bust because inflation was too close to 0%, or 1.5% or 2%, we have had them because we have had these tremendous asset bubbled, it happened here in '29, it happened in Japan in '90, and obviously it happened in the Great Financial Crisis."

When the system is working nobody looks at the fine print of their contractual agreement with their bank or financial advisor. People are fine trusting a big brand; it makes them feel safe. When things turn south, however, many will begin to realize that their relationship with their bank, for instance, is not what it seems. If the entire system fails similar to as it did in '08, the curtain will be pulled back rapidly on how flawed it is. As Nassim Taleb argues, the financial juggernauts in America conveniently ignore the tail risk that is so blatantly obvious in markets. They know the Fed has their back, so they are comfortable privatizing gains and socializing losses. With each crash, more and more people recognize this fact.

I believe a significant amount of people will choose a math-based guarantee (smart contract) over a brand-based guarantee when systems continually operate irregularly (Robinhood shutting down trading for users, for instance). A new consensus will develop such that brand-based contracts will no longer be able to compete with math-based contracts. It will be required to provide math-based guarantees if a business is not to fail. A crash would expose many of these lopsided relationships between consumers and institutions, and in our opinion create a fast case for DeFi adoption.

8.2 Addressable Markets

Although hybrid smart contracts will be used in nearly every industry, similar to the internet, we will focus on a few prominent use-cases that Chainlink addresses.

"There are very important technologies being built: Blockchain, Machine Learning, IoT, amazing technology around it that can be very disruptive. But in their own right, they are just technologies. What you really need to invest in is a company that has an idea to take some of that technology and apply it in a unique way against very large markets: Banking, insurance, financial services, and what they are doing is they are taking this new technology and applying it in a way that they for some reason saw earlier than somebody else to create a new business model… If they can build something that is 10x better than what is there, or 10x faster, or 10x cheaper, they can fundamentally disrupt that market."

-Tom Gonser, founder of DocuSign and Advisor to Chainlink

8.2.1 DeFi

Chainlink secures over $80 billion worth of DeFi financial projects and this number is increasing exponentially. It is not a coincidence that DeFi exploded once Chainlink went live. Almost every category of DeFi application requires data inputs and other off-chain services.

Chainlink's market share in DeFi has grown over time. Per Sergey Nazarov on the Ground Floor Consensus Podcast in January of 2021, Chainlink secures over 70% of all DeFi protocols. This number has risen to 85% as Aave's market share has increased[50]. The reason their market share is not 100% is because there are large protocols, such as Maker and Compound, which have created and rely upon their own oracles/price feeds. Both have experienced successful Oracle attacks.

"The massive crypto sell-off on 12 March saw the price of ETH fall 43% from $194 to $111 - its largest ever loss in a single day. This sell-off triggered unintended consequences for the MakerDAO ecosystem. Dubbed "Black Thursday", this sent the Maker system into chaos as $4.5 million worth of DAI was left unbacked by any collateral, and users lost millions…Due to uncharacteristically high gas prices, price oracles including the Maker 'Medianizer' failed to update their feeds…" [23]

"Lenders on decentralized finance (defi) protocol Compound on Thursday got liquidated for a massive $103 million, according to analytics provider Loanscan. This happened after what appears to be an oracle exploit on the Dai stablecoin. An apparent error or malicious attack to the Dai-dollar-peg data supplied by the Coinbase oracle pushed the price of the stablecoin to about $1.30 – a premium of 30% – leaving some users on Compound under-collateralized." [24]

Note that Compound now uses Chainlink price feeds in conjunction with their own, and Maker has begun the discussion to begin using Chainlink price feeds. Sergey predicted[51] that the big DeFi hacks would be oracle exploits, and he was absolutely correct. Note that these are just two attacks, there have been countless more where users have exploited protocols which rely on single or minimally decentralized price oracles. The Chainlink network has never gone down and has never failed in any moments of extreme price changes, such on Black Thursday in March of 2020 (Corona Virus crash). Teams like Aave and Synthetix do not need to worry about maintaining their own oracles, giving them more safety as well as more time to develop other products that customers want. This trend will continue of Chainlink secured protocols growing compared to protocols which use their own oracles. The cost of price feeds is only going down as more users choose them, and it is clear that customers are starting to steer away from protocols

[50] As Calculated by Abstraction Capital

[51] https://thedefiant.substack.com/p/a-faulty-oracle-will-be-behind-the

that don't have secure price feeds. These hacks will only get worse as the value locked in DeFi continues to grow.

Chainlink is the critical piece of infrastructure which has enabled DeFi adoption. Chainlink and DeFi have a synergistic relationship which will only strengthen moving forward. Protocols will not be able to scale beyond a few billion in TVL unless they use a competent oracle solution.

We expect Chainlink to eventually secure over 99.9% of DeFi value. The World Economic Forum estimates that $866.9 trillion could eventually move into DeFi [31]. DeFi is a superior solution to CeFi, as it provides more yield, transparency, and ownership to it's users.

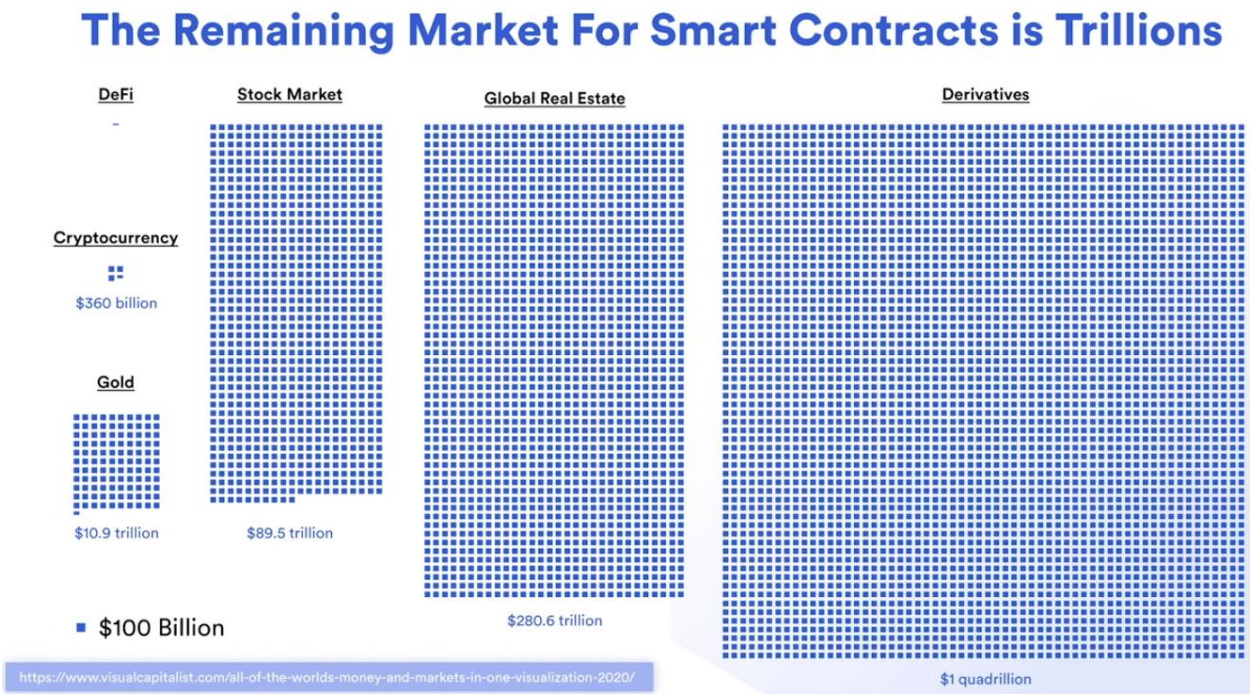


Figure 46 – potential markets which can be tokenized and used in DeFi

8.2.2 Insurance

Insurance is a multi-trillion-dollar global industry driven by the need for businesses and individuals to manage risk. Chainlink powered hybrid smart contracts will provide insurers greater transparency of the customer and shift the industry to a higher-trust-based relationship.

For both developed and undeveloped markets, parametric insurance which utilizes hybrid smart contracts will both disrupt current markets and create new ones. As previously discussed, crop insurance for over 500 million farmers in 3rd world countries is a massive market that is completely untapped. Every class of insurance contract will *require* Chainlink DONs to supply data or event triggers. For instance, Chainlink data feeds will determine if a crop insurance contract should be paid out based on data gathered from weather APIs.

An example for developed markets is parametric car insurance. A car could house a tamper-proof accelerometer running in a Trusted Enclave. This sensor will send position and velocity information to a hybrid smart contract which also connects to a GPS DON which supplies speed limit data based on

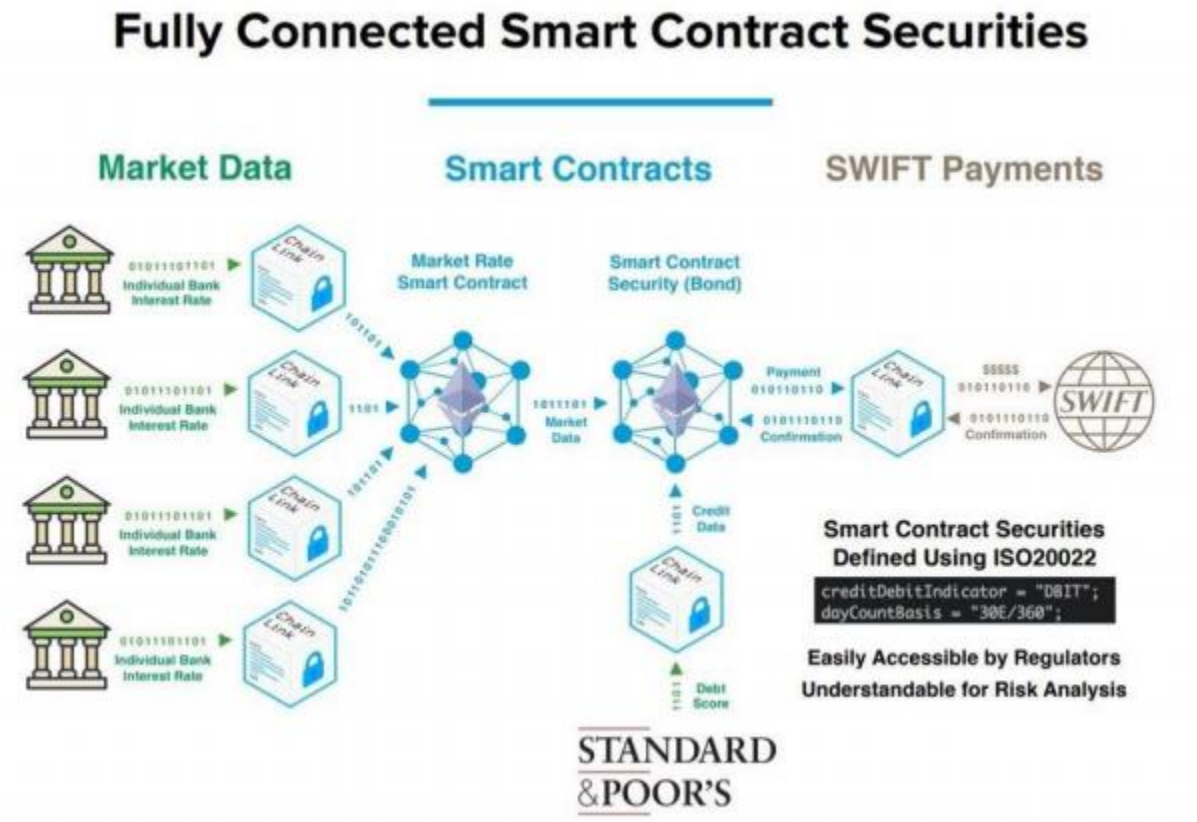
location. In real-time, a hybrid smart contract could pay or penalize you for driving safe or dangerous. This will drastically reduce the cost of car insurance, and actually provide direct incentive for people to drive safely.

These are but two examples of how parametric insurance will change the lives of millions, and eventually billions of people around the world. Chainlink has an excellent blogpost on how the insurance industry will be revolutionized with hybrid smart contracts[52].

8.2.3 Enterprise Blockchain

8.2.3.1 Payments

With respect to payments, Chainlink is partnered with SWIFT. Although the partnership has been confirmed, there has not been an announcement of how SWIFT uses Chainlink. What is known, though, is that their new product GPI Link requires a blockchain based oracle solution, and that it will be used to execute payments by connecting any bank account to the SWIFT API.



[52] https://blog.chain.link/how-smart-contracts-can-decrease-information-asymmetry-build-trust-and-revolutionize-the-insurance-industry/

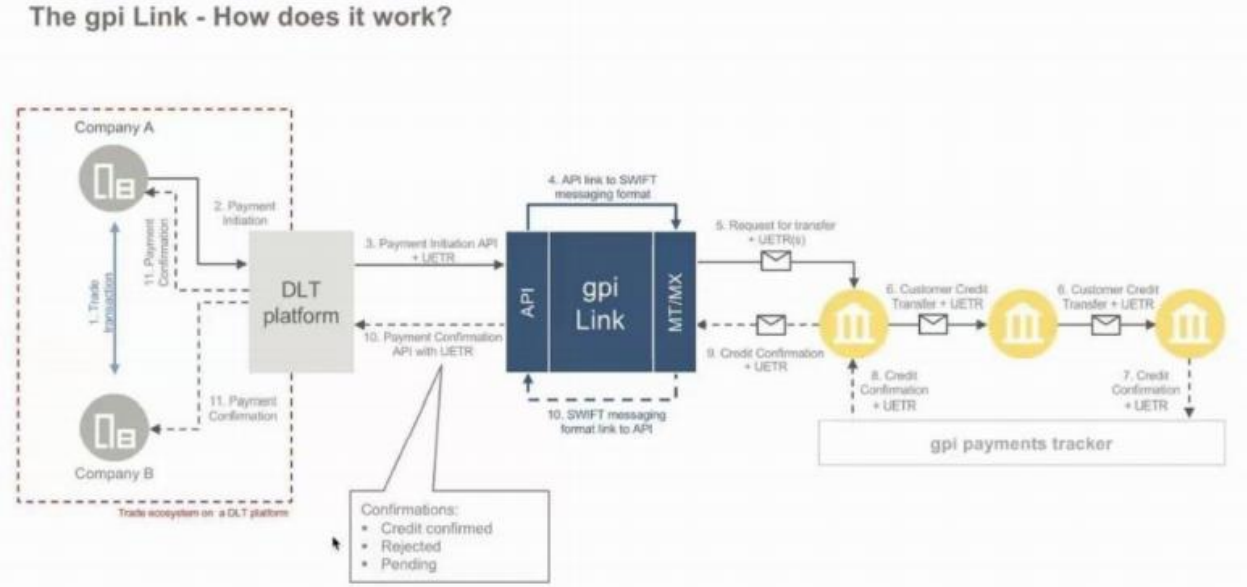


Figure 47 – SWIFT and Chainlink. SWIFT GPI Link mechanism utlilizes APIs

SWIFT is the largest payment processor in the world and as previously discussed settle over $600 billion worth of transactions per day.

The other large payment system that will likely use Chainlink is Facebook's Diem. Evan Cheng is a Director of Engineering at Facebook, as well as Director of Blockchain at Facebook. He is a co-writer of the Facebook Diem whitepaper, and he is also an advisor to Chainlink. Diem would require price feeds if it were to be tied to a basket of various currencies, so the connection to Chainlink is obvious.

8.2.3.2 CeFi Derivatives

With respect to derivatives, there is significant evidence project Whitney utilizes Chainlink. In a recent article written by the Chainlink team, the author says the following:

"An example of a Compliance Oracle was outlined in the Project Whitney Case Study initiated by the Depository and Trust Clearing Corporation (DTCC)" [21]. Navigating to the project Whitney case study whitepaper, they clearly show that the platform requires an oracle.

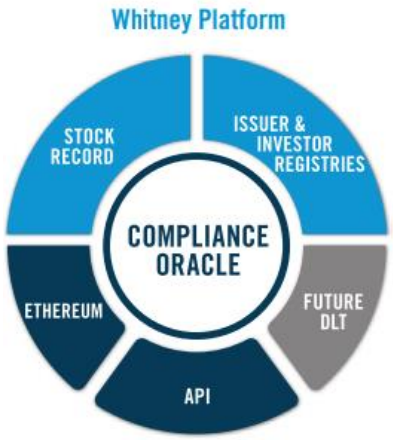


Figure 48 – Prototype build from Whitney case study paper[53]. The oracle connects Off-chain services to on-chain services

Whether the legacy derivatives market moves to Ethereum (on dApps such as Synthetix), or private blockchains are constructed to service ISDA members, this is a massive market which Chainlink will play a vital role in. Every group involved in the project has ties to Chainlink as well. Chainlink is a part of the Enterprise Ethereum Alliance, and the Digital Asset Group is part of IC3, whom Ari is the co-director. Both Besu and Quorum are part of the Hyperledger Avalon projects – where Chainlink is their oracle of choice. The outstanding notional value of the derivatives market is over $1 quadrillion. Obviously DeFi will eat into this market share, but the point being is that whether derivatives are settled on a private consortium chain or the public Ethereum mainchain, Chainlink will be required.

8.2.3.3 Enterprise Interoperability & Automation

As discussed in section 7.2, it is both time and cost prohibitive for enterprise companies to access smart contracts. The World Economic Forum details how Chainlink will be utilized as a single, open-source, global abstraction layer for all companies to interoperate with the blockchain layer. Not only do 95+% of all blockchain protocols require Chainlink for off-chain services, but close to 100% of companies will also require Chainlink to simply access the benefits of Smart Contracts.

In order for any enterprises to interoperate with each other, they will require the use of Chainlink and Baseline protocol. The Baseline protocol has integrated Chainlink to be its native oracle.

Figure 49 – Baseline and Chainlink partnership

As previously discussed, Baseline allows companies to transfer and share data in a privacy preserving way, which is critical for interoperability, and hence automation.

[53] https://www.dtcc.com/~/media/Files/Downloads/settlement-asset-services/user-documentation/Project-Whitney-Paper.pdf

Diving one layer deeper into the IoT, sensors must have a means of being private and tamperproof as well. This is why Chainlink's investment in Town Crier is so important. Sensors running in a TEE are effectively tamperproof[54], and privacy preserving. In this way, one can construct tamperproof sensor networks where end users know the sensor itself has not been meddled with.

8.2.4 Overview

In the short term (1-3 years), Sergey has stated that Derivatives, Insurance, and Trade Finance will be disrupted (simple digital agreements). Below are the nominal estimated values of these 3 industries, respectively:

$1,200,000,000,000,000

$4,000,000,000,000

$20,000,000,000,000

These are massive markets that Chainlink enabled smart contracts aim to disrupt. Not by lowering fees 1, 2, or even 10 percent. Most of it can be lowered 90 % of current business expenses.

Over this time DeFi is going to continue to grow. We saw exponential growth in 2020, ending the year with over $25 billion in TVL. This number is estimated to be somewhere between $100 billion to $1 trillion by the end of 2021. This wouldn't even require new money to come into the space, it would just require more people that hold crypto to put it to work in DeFi. TVL is expected to be well past $1 trillion by the end of 2022. Chainlink will capture *at least* 70% of this value, likely more.

As OEMs and other Fortune 500 companies begin to automate via blockchain based smart contracts, Chainlink is a necessary component for this evolution. In any instance where an off-chain system will need to interact with a smart contract, *Chainlink is necessary*. For a comprehensive list on Chainlink partnerships, please refer to the Chainlink Ecosystem – the website is provided in Section 10. Google, Oracle, IBM, the World Economic Forum, and SWIFT are a few blue-chip partners.

Finally, in the endgame of this technology where cyber-physical systems begin to integrate with our everyday lives, these systems will be *completely data driven*. As such, they will require decentralized, trustless data to function. Chainlink will provide this data.

Recalling Figure 36 (The 4IR Stack), Chainlink's contact area with the stack is greater than any other piece of infrastructure. Other than specific category of decentralized applications that don't require access to off-chain data or computation (Bitcoin, reserve backed stablecoins[55], DEXs[56], etc.), every type of application *requires* said inputs. Similarly, every company regardless of market will utilize Chainlink to access the blockchain layer.

[54] If tamperproof they stop operation and notify every user that they have been tampered with. They are not *physically* tamperproof, and can still be triggered incorrectly

[55] Bitcoin and reserve backed stablecoins like Paxos utilize Chainlink Proof-of-Reserve for wBTC and PAX respectively.

[56] DEX's utilize Chainlink oracles to get time-weighted prices and will utilize Chainlink Fair Sequencing to prevent front-running in the future.

8.3 Price Valuation

In the case of a traditional company, a business valuation might include an analysis of the company's management, its capital structure, its future earnings prospects, or the market value of its assets. The most common approach is to look at the company's present and future cash-flows to predict the market cap of the company. From there one can divide by the number of shares to get the price-per-share.

$$Market\ cap = Price * Shares \qquad \textit{Equation 4}$$

These techniques can be applied to a blockchain protocol generally, but there is one fundamental difference that one has to consider when valuing a protocol. Because a decentralized protocol is maintained and governed in a decentralized fashion, it requires a token to bootstrap the network and to incentivize individuals (miners, node operators, etc.) to secure and run the network software. In the case of Chainlink, it is a network for building decentralized oracle networks. Chainlink, in itself, does not provide a service (data delivery, off-chain computation, etc.). Instead, the Chainlink protocol provides a framework for individual node operators to provide these services, in return for payment in the form of the LINK token. Protocols still rely on a team to develop the protocol, though, and because of this the team will usually keep a portion of the network's tokens. They use these tokens to pay employees, fund further development of the network, and incentivize early network use through token bonuses. One must trust the team's founders to utilize these tokens correctly – this is always a risk when investing in decentralized protocols. If done correctly, though, a team can get a protocol to the point where it is decentralized enough to run independently. Protocols such as Bitcoin and Ethereum have reached this point, and Chainlink is well on its way to becoming fully decentralized. One upgrade to Chainlink that will be required before it can achieve this goal is *staking*.

When two parties create a smart contract that requires external data, they will then create a decentralized oracle network of node operators to provide the data for that contract. Using reputation scores and the Chainlink Marketplace, the parties can hand select the individual nodes that they want providing this data. It is at this point that the nodes and contract creators will come to terms on a binding Service Level Agreement (SLA), where the terms for delivery data, as well as payment if done correctly, are outlined. This is where staking comes into play. In the terms of the SLA, the contract creators can require the node operators to *post collateral* against their terms of the job. The amount of collateral posted is dependent on the number of nodes in the network, and the total amount of value up for transfer in the hybrid smart contract. Collateral will likely be valued in USD terms but must be posted in LINK tokens.

Oracle providers are essentially forced to have "skin in the game" and they are rewarded or punished financially based on their performance as defined in the SLA. The World Economic Forum describes this process in great detail in their co-authored paper with Chainlink:

"Off-chain legacy systems, data providers and oracle node operators need to be held to the same standards as blockchain systems to ensure they are deterministic and reliable enough to be trustworthy to deliver the data that will ultimately be used to execute the smart contract. Through the SLA framework, legacy systems become trusted oracles to smart contracts, as these agreements are binding and technologically enforced with financial and reputational rewards/penalties based on the quality of performance.

Open-source public, permissionless blockchain networks provide crypto-economic security using a native token, which is used to stake as collateral and pay for network services. Bitcoin and Ethereum are both examples of open-source, permissionless blockchains that have found success through having a native token in order to fund the miners who secure the network. Thus, the token's value is tied to the overall security and reliability of the network, creating a positive feedback loop of incentives. By doing so, blockchains become public goods that are collectively secured and maintained by a public community of users and various stakeholders rather than a centrally operated, for-profit entity. Open-source oracle networks follow the same public good model, where secure oracle services are fueled by a native token adopted by both oracle node operators and end users."

The way a native token is used within a protocol defines its cryptoeconomics. To properly value a protocol token, one needs to understand both how it generates revenue (fees paid to node operators/miners), as well as it's cryptoeconomics. The Chainlink network is capped at 1 billion tokens. The team kept 300 million for employee payment and protocol development, 350 million for incentivizing node operators and bootstrapping the network, and then sold 350 million in the ICO. It has a finite supply, and no more tokens will ever be created.

In the Chainlink Whitepaper v2.0, the team released their plan for staking. The staking design has super linear impact, specifically, quadratic. A decentralized oracle network, or DON, is protected against a briber with a budget in accordance with this formula:

$$\$B = \frac{\$dn^2}{2} \qquad \textit{Equation 5}$$

B = Briber's budget in dollars

d = Deposit amount per node in dollars

n = Number of nodes

This means that the amount of security of a network scales exponentially with the number of nodes in the network. The following is an example from the Chainlink Whitepaper v2.0:

> A 100-node network where each node deposits $20,000 would have a total amount deposited of $2 million, but be protected against a briber with budget $100 million. This would mean that this network could secure a derivatives contract worth $100 million, for instance, without a briber being able to game the outcome and make a profit. If the network was expanded to 300 nodes, it would be able to secure $900 million in value.

Because the amount of collateral needed for smart contracts will vary depending on the size of the contract, as well as the number of nodes in the DON, it would be impossible to explicitly calculate how the price of the token should appreciate as the Total Value Locked (TVL)[57] secured by the network increases. With that said, there are a few insights which can be derived from the staking mechanism.

8.3.1 Total Value Secured (TVS) and Price Impact

For each successive dollar of TVS which is added and hence must be collateralized by some amount of LINK deposits, LINK is removed from the circulating supply, decreasing the public float. This creates an

[57] Interchangeable with Total Contract Value (TCV) secured by the network

upward pressure on price as supply decreases. Note that contract creators must pay node operators in the LINK token, which acts as a force maintaining buy pressure as long as there is network usage. Effectively, the price of the token must appreciate in order to account for the collateralization requirements of new contracts.

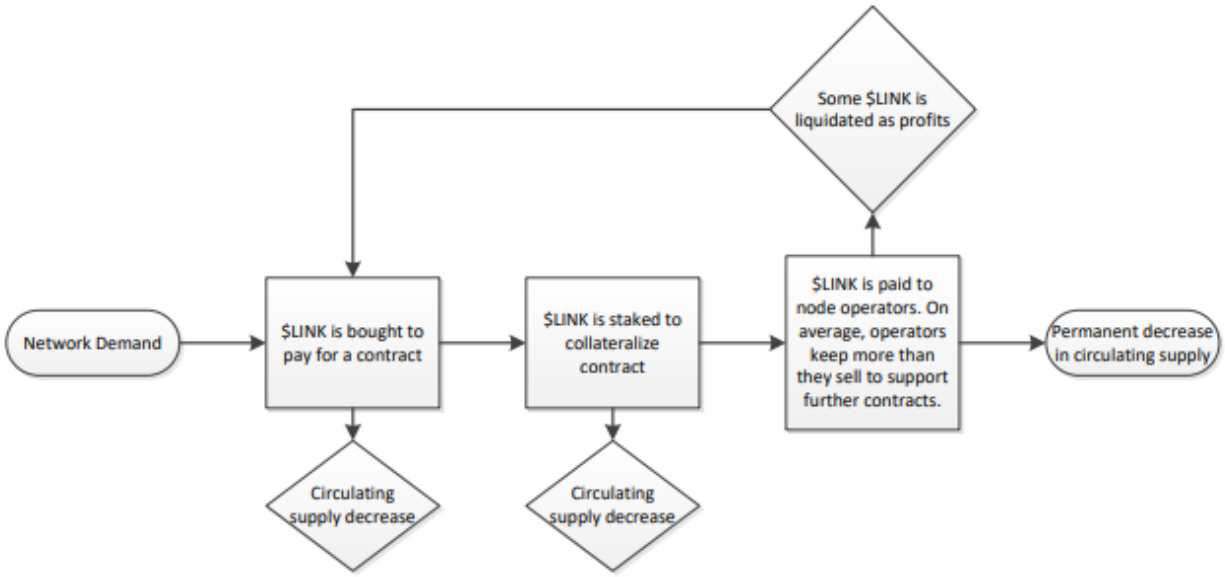


Figure 50 - LINK staking and supply impact

Even if network usage remains static, if node operators do not *net sell LINK* that they earn from fees, then the supply will continually reduce as more LINK is purchased from the market to pay node operators. LINK is divisible to 18 decimal places so there is no technical constraint on the price appreciating indefinitely. There is an economic constraint, however, if network usage remains static. As the LINK token appreciates in price, contract creators will need to purchase less LINK to satisfy the same amount of fees they have to pay to node operators. Also, node operators will likely have to sell LINK tokens to pay taxes. This dynamic leads to an equilibrium point where price stabilizes, assuming constant network usage and node operator selling. If network usage is increasing, necessarily more LINK will need to be collateralized, which will cause a supply reduction and price increase. The following graph is a rough simulation to get an idea of staking's impact on supply:

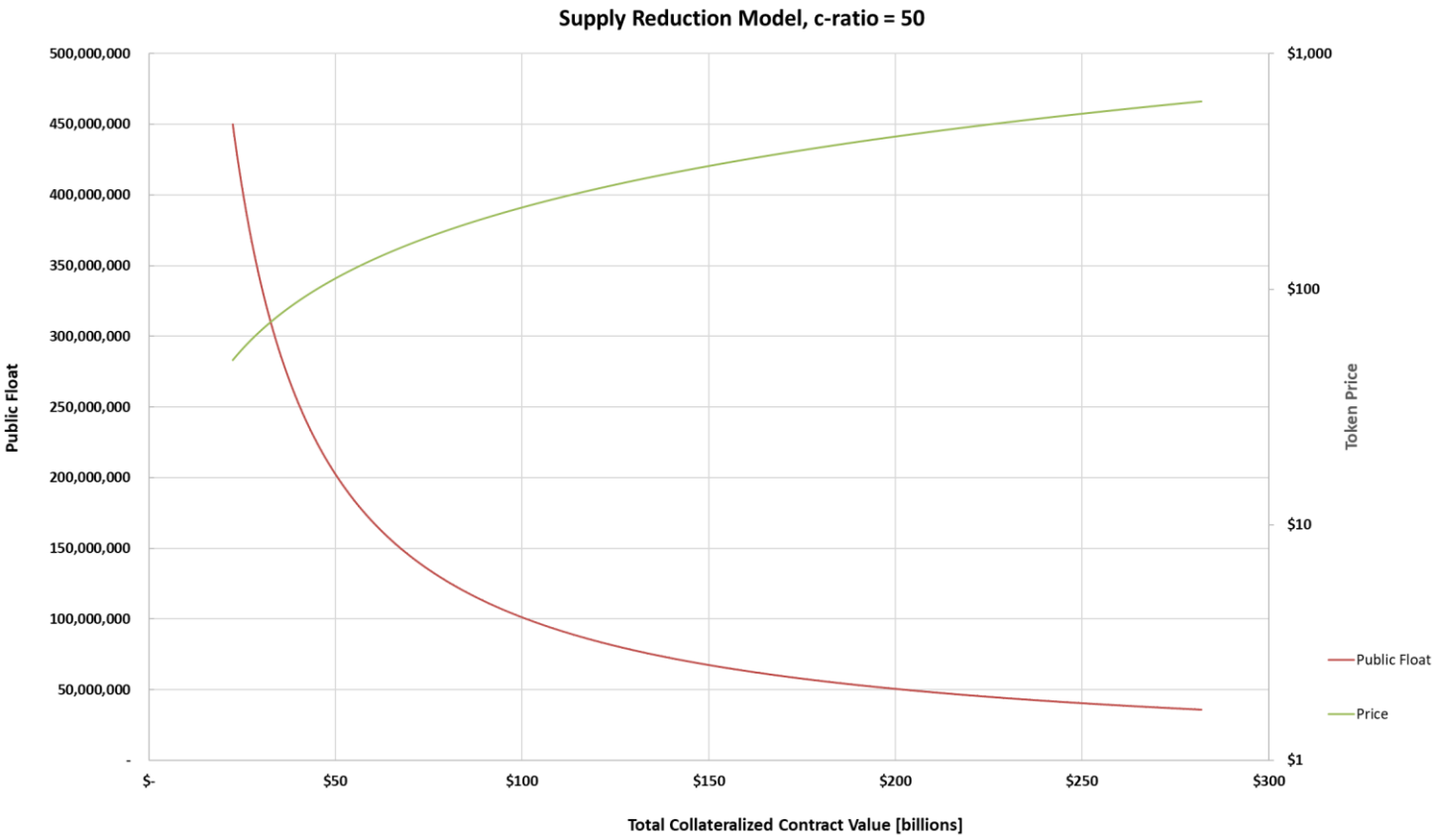


Figure 51 - Supply Reduction Simulation

Once Chainlink implements its staking mechanism, it appears that market cap is not just a function of present and future cash flows of the network. It is also a function of the TVS on the Chainlink network. It appears price is proportional[58] to the total contract value multiplied by a coefficient which accounts for the varying collateralization requirements amongst all DONs. Price will scale with other factors discussed later, but this is an interesting insight because it shows that TVS is an important metric when calculating Chainlink's total network value, or market cap.

$$Price \propto TCV * C$$

The TVS secured by the Chainlink network through staking can realistically reach trillions if the network is used to power even just a small portion of the derivatives, insurance, or trade finance markets. Let's take a look at the derivatives market.

It is estimated up to $1.4 quadrillion of derivatives are settled year to year. This is notional value, though, and not market value. We find it highly unlikely that the notional value of contracts will need to be collateralized. If Chainlink is securing a futures contract, for instance, and let's say the oracle network fails at the point of expiration, both parties would clearly get their initial margin back, as well as any additional value that was added to the buyer/seller's margin position if they had a margin call. There are many different types of derivatives products, and it is clear that various products will need to be collateralized

[58] The relationship is not linear, log, power, 2nd order polynomial, or exponential. Linear looks to be the closest choice

differently. Let's just say if the typical amount of leverage varies from 10x to 20x, then maybe one can assume that the TVS for derivatives would be around 5-10% of the notional value of the contract. Even at 5%, in a quadrillion dollar market we are talking tens of trillions of dollars that must be protected against bribery. As stated earlier, per the World Economic Forum there is $866.9 trillion of *market value* that could be secured in hybrid smart contracts. This will necessarily lead to a large amount of LINK which must be locked as collateral, drastically lowering the circulating supply.

8.3.2 Network Fees DCF Valuation Model

Another way to value the LINK token price is to utilize a model which estimates network value based upon the fees, or revenue, generated by the protocol. Prospective node operators need to purchase LINK to gain access to these cash flows, where their potential to earn is proportional to the amount of LINK they hold. We believe higher value contracts will gain access to larger LINK adjusted returns ($\frac{\$\ earned}{LINK\ staked}$), but due to staking pools[59] even LINK holders with small amounts of Chainlink will get access to some of these opportunities. As such, although the relationship between LINK held and earning power is likely non-linear, for all intents and purposes it can be modeled by a linear relationship. This means that market participants will want to buy and hold LINK to gain access to future cash-flows. The more LINK one holds, the greater one's earning potential.

Because staking is not yet live, all payments to node operators have been mostly subsidized by the Chainlink node incentivization fund. As such, we do not believe that current on-chain payment data is representative of what network payments would look like in the future. In order to get an estimate of how much fees node operators could potentially earn; we will use the derivatives industry as a case study.

Per Deloitte, for centrally cleared OTC derivative transactions, the cost per $1 million of notional value is 0.136 basis points, or $13.60. For non-centrally cleared transactions (which as we know are 85+% of all derivative transactions), the cost is 1.705 basis points, or $170.50 per $1 million of notional value [30]. Note this data is from 2013, so it is very likely that these values have changed.

[59] LINK holders can pool LINK into a community run node to gain access to higher value contracts – fees are split proportionally between all people in the pool by weighting

	Estimated additional cost (per € 1 million notional amount traded, basis points)
Additional costs for centrally cleared OTC derivative transactions	
Initial margin + contribution to the CCP default fund + additional costs arising from requirements for CCPs + clearing fees	€10 (0.10 bps)
Capital charges for centrally cleared OTC derivatives transactions	€3 (0.03 bps)
Trade, valuation and collateral reporting + compliance costs for trade repositories + compliance costs for CCPs	€0.60 (0.006 bps)
Total additional cost	**€13.60 (0.136 bps)**
Additional costs for OTC derivative transactions that will not need to be centrally cleared	
Initial margin for non-centrally cleared OTC derivative transactions	€50 (0.50 bps)
Capital charges for non-centrally cleared OTC derivatives	€120 (1.20 bps)
Trade, valuation and collateral reporting + other compliance costs + compliance costs for trade repositories	€0.50 (0.005 bps)
Total additional costs	**€170.50 (1.705 bps)**

Source: Deloitte calculation based on MAGD (2013), BCBS-IOSCO (2013a), ESMA (2012) and BIS statistics.

Figure 52 – Cost for OTC derivative transactions

For a non-cleared Euro interest-rate derivative, the average notional is €85 million, which implies a cost of €14,492.50, or $17680.85. The cost to settle this over Ethereum (currently) would vary depending on network usage, but it could be anywhere from a few cents to a few hundred dollars. Once layer 2 is live it will be effectively $0. The settlement time for these trades is usually 5-10 business days – hybrid smart contracts can reduce settlement time to seconds. The only cost in this trade (other than the marginal fee paid to Ethereum miners), is the fee paid to the Chainlink node operators for providing the market data which will trigger the contract. Assume the market settles on a fee of around $5,000 (significantly less than $17680.95), which would mean an average cost of $48.22 per million of contract value. Based on the Deloitte Data, there were approximately 2.68 million interest-rate swaps in 2013. This would result in $13.4 billion in fees paid to node operators, *just from swaps*. If one included the entire derivatives industry, this would result in approximately $167.5 billion in fees.

Net revenue of the protocol would be a large percentage of this number because the cost to run a node is not very high. One will need compute architecture (AWS cloud is very cheap) and will need to purchase market data from a premium API provider. Typically, API calls can range anywhere from a few hundred to thousand dollars per month. This is significantly less than fees that a traditional company would have to pay for hundreds or thousands of employees, building rent, legal fees, etc. Add in revenue from other industries, such as bonds, insurance, and trade finance, we could be looking at over $200 billion in net fees, which would put LINK on par with companies like Apple and Amazon.

When valuing the network by fees, a discounted cash flow model can be utilized to estimate the price of the LINK token. The following assumptions were made:

Discounted Cash Flow Analysis

Abstraction Capital
Thursday, May 13, 2021

Assumptions

Model Assumptions		*Chainlink Assumptions*	
Model Start Date	5/31/21	Last 30 Days - Chainlink Fees ($ in billions)	$ 0.014
Valuation Assumptions		# of Nodes	128.0
Discount Rate	25.0%	Monthly Node Growth	20.0%
Shares Outstanding (millions)	1,000.0	API Call Cost per Node per Month	$ 500.0
Circulating Shares Oustanding (millions)	425	Infrastructure Cost per Node per Month	$ 500.0
Public Float	425		
		Market Assumptions	
		Yearly DeFi TVL Market Growth	85.0x
		Implied 2021 Market Growth Rate (monthly)	44.8%
		Decaying Market Growth Rate Post 2021 (monthly)	(8.0%)
		May 2021 Market Size ($ in billions)	$ 85.0

Figure 53 - LINK Token DCF Assumptions

Next, the cash flow for each month from May 2021 until December of 2024 was calculated.

Model

Monthly

Days	31	30	31	31	30	31	30	31	31
BOM	5/1/21	6/1/21	7/1/21	8/1/21	9/1/21	10/1/21	11/1/21	12/1/21	1/1/22
EOM	5/31/21	6/30/21	7/31/21	8/31/21	9/30/21	10/31/21	11/30/21	12/31/21	1/31/22
Quarter	Q2 21	Q2 21	Q3 21	Q3 21	Q3 21	Q4 21	Q4 21	Q4 21	Q1 22
Year	2021	2021	2021	2021	2021	2021	2021	2021	2022
($ in billions)									
Operating Statistics									
# of Nodes	128	154	184	221	265	319	382	459	550
Cash Flow									
Fees Generated by Chainlink Nodes	$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.1	$ 0.1	$ 0.2	$ 0.3
Monthly Growth Rate		*44.8%*	*44.8%*	*44.8%*	*44.8%*	*44.8%*	*44.8%*	*44.8%*	*41.2%*
(-) Cost of API Calls	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
(-) Infrastructure Cost	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Cash Flow	**$ 0.0**	**$ 0.0**	**$ 0.0**	**$ 0.0**	**$ 0.1**	**$ 0.1**	**$ 0.1**	**$ 0.2**	**$ 0.3**

Figure 54 - First 9 months of DCF model

Finally, the annual cash flow was calculated and the network value, and price of LINK token, were calculated. For the base case we assume a public float equal to the circulating supply (a highly conservative approach) as well as a post 2021 DeFi growth decay rate of -8%. This would yield a DeFi TVL of 95.26 trillion on December 31st of 2024. This would also put the total network fees generated in 2024 at $161.5 billion, which is approximately equal to the estimated fees generated if Chainlink powered the derivatives industry.

Annual

($ in billions)	2021	2022	2023	2024
Cash Flow				
Fees Generated by Chainlink Nodes	$ 0.6	$ 17.3	$ 84.2	$ 163.2
Monthly Growth Rate		*2883.7%*	*386.1%*	*93.8%*
(-) Cost of API Calls	(0.001)	(0.011)	(0.097)	(0.866)
(-) Infrastructure Cost	(0.001)	(0.011)	(0.097)	(0.866)
Cash Flow	**$ 0.6**	**$ 17.3**	**$ 84.0**	**$ 161.5**
Discounted Cash Flow	**$ 0.46**	**$ 11.07**	**$ 43.02**	**$ 66.14**
Network Value	**$ 120.70**			
Token Price	**$ 283.98**			

Figure 55 - Implied present value of network and estimated token price

Note that the net fees generated in 2024 for the base case example were approximately equal to the $167.5 bil estimated if Chainlink powered the global derivatives industry. As this estimation did not include a multitude of other industries, we believe it is a reasonable base case.

A sensitivity matrix was then created to estimate the price of the LINK token as the growth rate of the DeFi space was varied against the public float of the LINK token. As discussed in the TVS model, when staking goes live the public float will decrease.

Token Price Sensitivity Analysis [$]

		DeFi Growth Decay Factor [%]					
		-10	-9	-8	-7	-6	-5
Public Float [mil]	**425**	153	204	284	422	680	1215
	400	163	216	302	448	723	1291
	350	186	247	345	513	826	1475
	300	217	288	402	598	963	1721
	250	261	346	483	718	1156	2065
	200	326	433	603	897	1445	2582
	150	435	577	805	1196	1927	3442
	100	652	865	1207	1794	2890	5164
	50	1304	1730	2414	3588	5780	10327
	25	2608	3461	4828	7175	11560	20654
	10	6520	8651	12070	17938	28900	51636
	5	13039	17303	24139	35876	57801	103271

Figure 56 - Estimated price of LINK utilizing DCF model, in dollars, given specific public float and DeFi growth rate

We believe by 2024 a significant number of tokens will be removed from the circulating supply. As such, for the base case inputs and with a public float of 50 million tokens, the best guess token price on December 31st, 2024 is $2414.

The final DeFi TVL values for each decay factor can be seen below.

DeFi Growth Decay Factor [%]	Final DeFi TVL [tril]
-5	688.92
-6	315.70
-7	164.53
-8	95.26
-9	60.11
-10	40.68

Figure 57 - Final DeFi TVL on December 31st, 2024. Note a -5% decay factor yields a value similar to the WEF total DeFi market estimate

Potential flaws in this model include the assumptions for discount rate, DeFi market growth, node operator growth, and node operator fees. Provided that many new nodes in the network will likely utilize a staking pool or ready-made infrastructure (such as what LinkPool offers), these costs will differ depending on node. Similarly, the costs were estimated based on the cost of AWS servers as well as typical monthly subscription for premium APIs that provide market price data. These numbers will fluctuate and are likely incorrect. It is important to note though that there aren't any stringent hardware requirements for operating a LINK node like there is for operating a Bitcoin node (ASIC and electricity costs). As such, regardless of the values selected they are likely negligible compared to the potential fees generated by the node. The only large "capital" requirement is holding LINK to gain access to these cash flows. One can see how this dynamic will produce large inflows into the LINK token, with unmotivated sellers.

8.3.3 P/E Ratio Valuation Model

A more simplistic way to value the network is to multiply the networks fees by the P/E ratio of a similar company.

$$P/E\ Ratio = \frac{Market\ Cap\ per\ share}{Total\ Earnings\ per\ share} \qquad \textit{Equation 6}$$

$$Price = \frac{P/E\ Ratio * Fees}{Supply} \qquad \textit{Equation 7}$$

The P/E Ratio of Google at 36.57 is a reasonable choice, considering it is near the S&P 500 average and is also a "data" company. Continuing with the $13.4 billion in fees example, which would represent fees generated from 8% of the derivatives market, the calculation would yield a LINK price of $1225.10 with 400 million tokens in circulation. This could maybe be seen as a conservative estimate because it does not factor in the supply reduction that comes with staking.

8.3.4 Mcap/TVL Model

A common way the relative value of Layer 1 protocols is measured is by the market cap divided by the sum of TVL locked across all applications on the protocol. With CCIP live, Chainlink will effectively be a layer 0 protocol, securing value across many blockchains simultaneously. In this sense, it seems appropriate to measure the value of Chainlink by the Total Value Secured, or the sum of TVL across all chains. When both CCIP and staking are live (it is likely they could go live at the same time as CCIP will rely on oracle networks staking LINK to secure bridging), this valuation model makes even more sense because there will be a direct tie between token price and TVS.

As seen on the Chainlink website, at this time TVS hovers around $83 billion. With a market cap of $13.6 bil, this puts the TVS/Mcap ratio at 0.16. Navigating to Defi Llama, the Mcap/TVL ratios are displayed for every Layer 1 Chain.

Name	**TVL [$ bil]**	**Mcap/TVL**
ETH	146.81	3.46
LUNA	16.61	1.02
BNB	16.53	5.83
AVAX	11.03	2.19
SOL	10.05	6.62
FTM	5.79	0.95
MATIC	5.16	2.22
LINK	**83.3**	**0.16**

Once CCIP goes live, with just the confirmed users (AAVE, Celsius, ENS), Chainlink TVS will nearly double. CCIP alone will have a higher TVL than any layer 1 blockchain, including Ethereum. Already, Chainlink Mcap/TVL ratio is an order of magnitude less than even the most conservatively priced L1s. Although this does not predict absolute value, it is clear Chainlink is incredibly undervalued compared to L1 chains.

8.3.5 Model Observations and Flaws

I want to emphasize that these are incredibly rough models with many assumptions, most of which are likely wrong. We would go so far as to say we are very likely wrong. Trying to predict price is a fool's errand because there are so many variables that factor into it.

Ultimately, there is no way to predict the prices that contract creators will pay for securing their contracts. Not only will they go back and forth with node operators on prices, but node operators will be competing with each other to secure contract jobs, creating another dynamic that affects prices. This is will occur for every type of contract. There will be thousands of different types of contracts from insurance, derivatives, trade finance, or enterprise-blockchain interoperability contracts that will all have different staking requirements and market dynamics.

To conclude, the key insight is that as network usage increases there is a built-in mechanism for supply reduction. As DeFi starts to grow, the expected fees are significant and will create an incentive for node operators to hold tokens to gain access to future cash flows. The vast majority of tokens are held by early

investors and node operators who are highly unmotivated sellers. Combining these factors lead us to believe that the public float will decrease multiple orders of magnitude than where it sits now. This will lead to a large appreciation in the price of the LINK token.

8.4 Summary of Value Proposition and the Ethereum Debate

Chainlink is effectively a network which creates definitive truth, such that it can be utilized in a new digital domain which allows tamperproof, deterministic agreements. In any instance value is exchanged via a smart contract, a payment is made to the node operators of the Chainlink network. It is an open-source bridge where any human can not only participate, but is incentivized to participate in a specific way due to its tokenomics model. It also connects any and all legacy systems to this new digital domain.

Recalling the 4IR stack, the goal of this paper has been to identify the lowest layer of investible infrastructure for the 4IR. Every smart contract has two parts, the on chain and off-chain component. Chainlink is the critical off-chain component, and in many cases Ethereum (or other Layer 1 protocols) are the on-chain component. Both are necessary for tamperproof execution of hybrid smart contracts. Which one is the better investment, though?

We believe Chainlink is the better choice because its addressable market is the *entire* smart contract domain. Unlike Ethereum, which is competing with multitudes of other public and private blockchains, Chainlink is **blockchain agnostic** and will work with whichever base layer protocol wins, or the combination of winning protocols. Via CCIP, applications will be inherently cross-chain, but in every case utilize Chainlink. Although Ethereum currently has dominant market share, one can't deny that other projects have some potential to change that. For one, China will use the BSN (who is partnered with Chainlink), not Ethereum. Solana, currently the base layer protocol with the 2nd largest market cap, has taken a large amount of market share from Ethereum in 2021. What it shows is that price is king, and people are willing to let go of decentralization and security to have faster transactions and lower fees. If layer 2 scalability or the transition to Eth 2.0 is delayed, there is a non-zero probability that Ethereum starts to lose more dominance. Note that the largest layer 2 scalability solution by value locked is Arbitrum, which utilizes Chainlink [33].

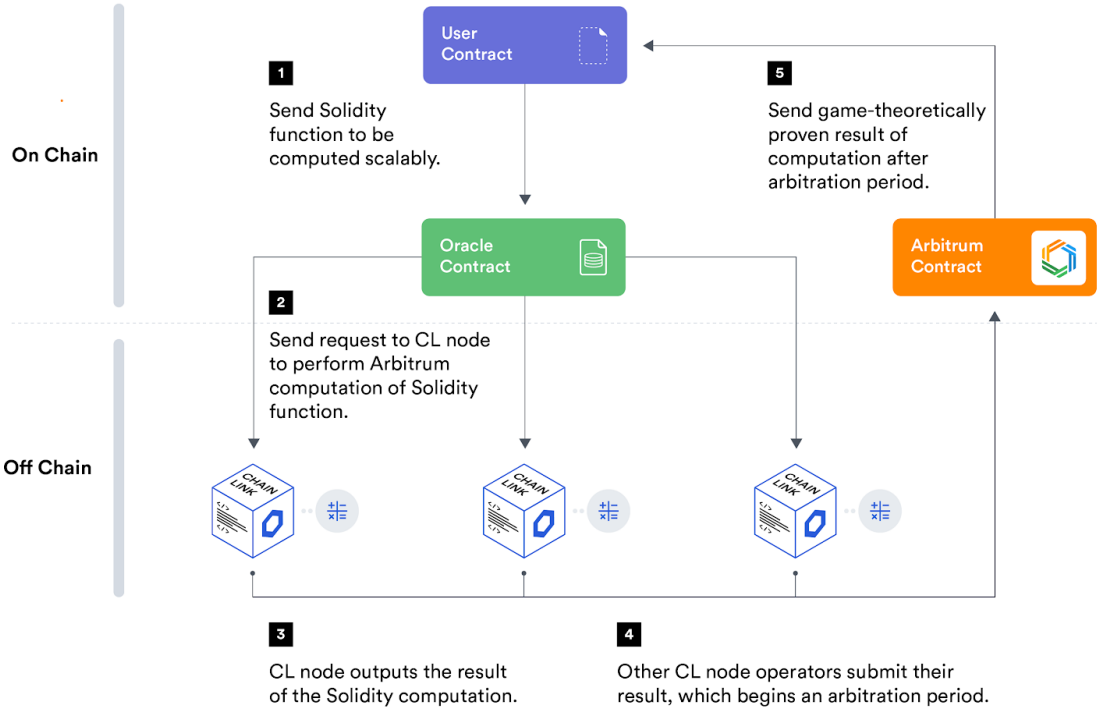


Figure 58 - Arbitrum and Chainlink architecture

If Arbitrum is the main solution to how Ethereum scales (which is the pathway for Ethereum to maintain market dominance), this means that Chainlink will be even more critical to Ethereum's success than it already is. Note that Arbitrum validators will likely stake LINK against their attestations for the rollup process, leading to further LINK supply reduction. Finally, what if enterprises start coming into the space on private blockchains? If the DTCC offers an enterprise derivative project on Hyperledger Fabric, for instance, all of a sudden Ethereum's market share won't look so dominant. The ISDA is composed of over 900 members in over 70 countries. If each member had its own full node on a private blockchain, that would actually be very decentralized. Each member could enter into legal contracts as well (which isn't possible with a fully decentralized network), and the legal fees would be partly offset by 0 gas costs. We are still early stage, and the *absolute value* of adoption is relatively small. All it would take is one enterprise project built on a different blockchain to flip the current narrative that ETH is king.

Chainlink, on the other hand, has a greater first-mover advantage than Ethereum relative to the domain of decentralized oracles, and has a significant technological lead on any competitors, as the team began developing Chainlink in 2013. The blockchain trilemma necessitates that different blockchains have different strengths and weaknesses. This creates an environment where it is easy to see multiple winning protocols. Even if this follows a power law distribution and Ethereum is at the top, we believe it is likely Ethereum will split market share some way or another. A decentralized oracle network does not have these fundamental trade-offs. Instead, networks will compete based on their technology and level of security they can maintain. Because Chainlink is currently the standard and the only decentralized oracle network that secures any sizeable DeFi value, users and protocols will continue to choose it, in turn reducing fees (making it more attractive for future users to choose Chainlink) and making it more secure (by providing more payments so that oracle networks can add nodes). The only way another network will take market share from Chainlink is if they solve fundamental cryptography research problems first. We

have a hard time believing any team can compete with Ari Juels and Chainlink Labs on this front. Not only do they have a 5+ year advantage, but they also have some of the best cryptography researchers in the world on their rapidly growing team of over 250 employees. Currently Chainlink has over 90 job openings as well, and is well on track for over 300 employees.

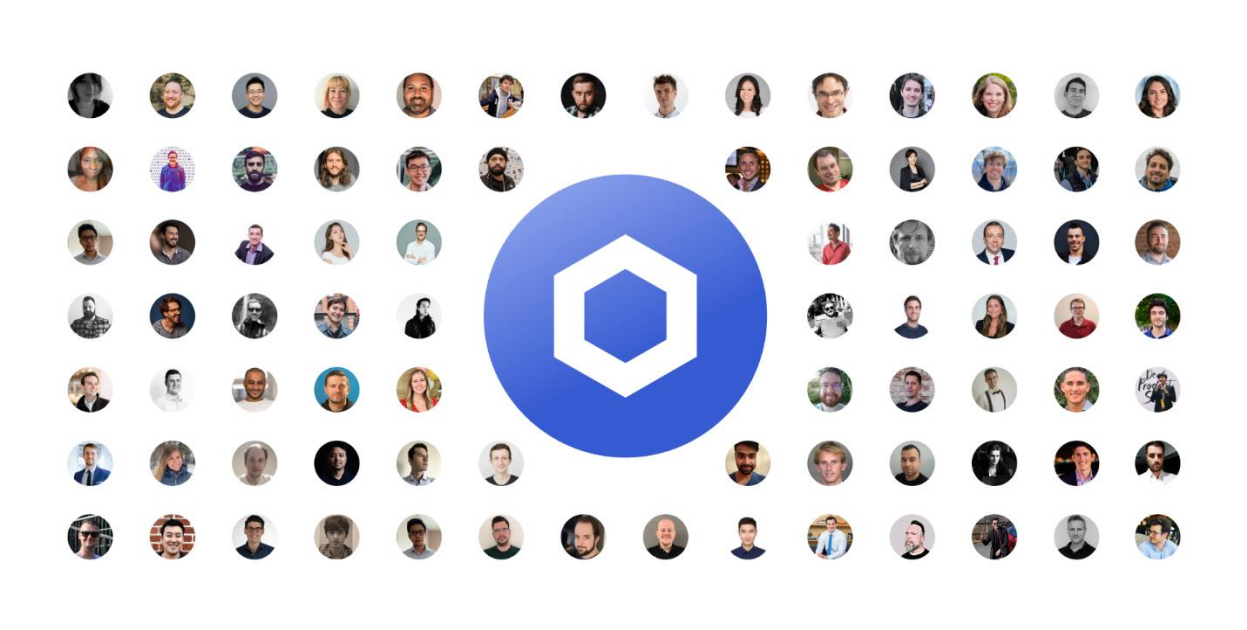


Figure 59 – The Chainlink Labs Team is rapidly growing

Finally, the current market cap of Chainlink is more than 20x less than that of Ethereum. Considering it is equally as important for the execution of hybrid smart contracts, Chainlink is effectively an arbitrage play on Ethereum and the smart contract economy. If one is bullish on Eth, then they necessarily must also be equally bullish on LINK.

With this all said, Abstraction Capital is very bullish on Ethereum, particularly due to the EIP-1559 proposal and Eth 2.0 upgrade which will cause its inflation to likely go negative. EIP-1559 will burn a portion of the gas used for all transactions[60]. Also with the upgrade to Proof of Steak (PoS) with Eth 2.0, users with at least 32 Eth will be able to deposit their Eth and earn anywhere from 5-25% on it per year, depending on the number of stakers. This number will likely begin around 25% and decay below 5% over time.

As such, we remain bullish on Eth 2.0 due to these incredibly strong tokenomics, but how do they compare with Chainlink? Eth burning from EIP-1559 appears to only scale with network fees, and not TVL/TVS. The same amount of fees will be burned regardless of transaction size, as fees are dependent on transaction *type*. This means a $10 trillion dollar contract will cost the same as a $1 dollar contract. Once scalability is fully live, gas fees are going to be orders of magnitudes lower. So although there will be exponentially more transactions, they will cost almost nothing. If this scalability happens on rollup chains, then the vast majority of transactions won't even take place on Ethereum, they will take place on sidechains. If Chainlink and Ethereum power the global economy one day, the number of transactions on Ethereum will likely out-pace the reduction in gas costs that scalability provides. On the other hand, the Chainlink price doesn't

[60] Permanently reducing the total Eth supply

only scale with fees, but it scales with *total contract value*. If a 1 trillion-dollar derivatives contract is settled, then millions of dollars' worth of LINK will need to be staked. This puts significantly more supply pressure on Chainlink than Ethereum. We believe the cryptoeconomic incentives created by the Chainlink staking mechanism will decrease the supply much more rapidly than burning fees will drop the supply of Eth. Although the APY with Chainlink staking is uncertain, if it can get to or above 5%, then it would be on a competitive plane with Ethereum.

One can argue about value capture all day, but the truth of the matter is both have excellent staking mechanisms as well as a finite supply or low to negative amounts of inflation. Even if the tokenomics came out a wash, LINK's market cap is still over 20x less which makes it a better risk-adjusted bet. Considering that there is a non-zero, albeit small, chance that Ethereum can lose market share to competitors, we believe this makes Chainlink the better investment at this point in time.

9 Conclusion

We would like to conclude this paper with a quote from Eric Weinstein regarding Blockchain Technology:

"The reason I was interested in it [Bitcoin] was more complex. If Bitcoin was digital gold, and gold was quantum mechanical wave, then some group had created a:

1) Novel
2) Locally Enforced
3) Digital
4) Conservation law

Called the Blockchain. *And money was but one thing it could be*. Can you imagine. Some group was creating as-if physics inside the network. Bitcoins to me were 'waves' propagating not in vector bundles, but on networked computers as substrate. This was genius."

Looking back through the industrial revolutions, the main thing that stands out was the shift from analog to digital systems. Zooming out, humans have just barely crested the digital age. This trend of digitization is accelerating, and it must be noted that the digital world has no laws that govern it. Creating a system of physics which allows the replication of a physical conservation law inside the digital domain – effectively automated private property rights – will allow for complex technologies to be constructed which before were not possible. Bitcoin was the first use case of blockchain technology, but as Weinstein said so elegantly that is but one thing it could be. The protocols which become critical, base level infrastructure to this future of distributed computing will be used as prevalently as the internet. Distributed systems will soon become the basis for trustless interactions between people, enterprises, and autonomous cyber-physical systems.

Private property rights are a pillar of Western Civilization, but a more fundamental technology is the idea of a contract. A human on their own can only do and create so much. Without collaboration, not only are humans capable of much less, but there is higher incentive between humans to compete and destroy each other, which diminishes the net expected outcome of all parties. When humans began to organize in societies where contracts could be enforced, productivity growth skyrocketed.

Smart contracts represent a fundamental 0 to 1 shift where counter-party risk between individuals in contracts goes to 0. Never before in human history has this property existed with contracts. They also decrease costs orders of magnitude and have instant settlement time.

Although the trend of digitization cannot be ignored, we must not forget the world of atoms - the 4th Industrial Revolution will be defined by more than just blockchain technology. Currently the blockchain space is hyper-focused on DeFi, because simply that is the only thing that can be done with the technology in its current state. It is no surprise the space came to fruition after Chainlink launched. As Chainlink continues to upgrade to v2.0, the space will evolve in tandem. We believe strongly that investors are overlooking the coming enterprise adoption and AI driven automation use-cases that hybrid smart contracts will enable.

Although DeFi could end up being the largest market which is disrupted, there are going to be thousands of companies which develop other 4IR technologies which will likely interact with the blockchain layer. Technologies like AI & machine learning, robotics, IoT, genetic implants, quantum computing, 3D printing,

virtual and augmented reality, biotech, biomaterials and protein printing, energy storage, and more will be created. The convergence of these technologies will result in advanced cyber-physical systems that will interact autonomously with humans and each other. These systems will be 100% data driven, and will require Chainlink as an input layer for trustless data, or as a blockchain abstraction layer to trigger a hybrid smart contract when they interact with other autonomous systems. Chainlink therefore is not just a bet on the DeFi ecosystem, but also on most categories of general data-driven AI software and cyber-physical systems.

As a result, we believe Chainlink is uniquely positioned to become the largest cryptocurrency as the standardized middleware between the real world and this new digital domain. Similar to how the internet unlocked computers true potential, Chainlink will do the same with Blockchain technology. It does not compete with governments, enterprise, or this growing decentralized world – it is instead synergistic with each of them. The world's data will pass through the Chainlink network as it is sold to node operators who filter it and send it to smart contracts, providing tamper-proof, counterparty risk-free execution of any scriptable business logic. Chainlink will also connect any legacy enterprise system to the Blockchain so that enterprises can interact with every blockchain environment necessary to conduct economic activity. Unlike a company who monopolizes an industry and can extract high fees which hurts end-users, when a protocol is completely open-source and owned by no single party it is actually beneficial for it to have a monopoly – it becomes a public utility, just like the internet. As the standard blockchain middleware protocol, end-users will always select Chainlink to get the lowest fees and highest security possible as nodes compete to provide their services. The more users, the lower fees for everyone. Data aggregators and sellers will choose Chainlink because they get access to a single market with the greatest number of customers where they will be able to make the most money. Finally, developers will choose Chainlink because it has the most resources and tooling to create applications quickly. Any person or entity can participate in this network and earn passive income, whether as an individual or through a staking pool. Every incentive is aligned to create a positive feedback loop of expansion. Chainlink's network effect will only become larger, further securing its position as the standard middleware for the 4th Industrial Revolution.

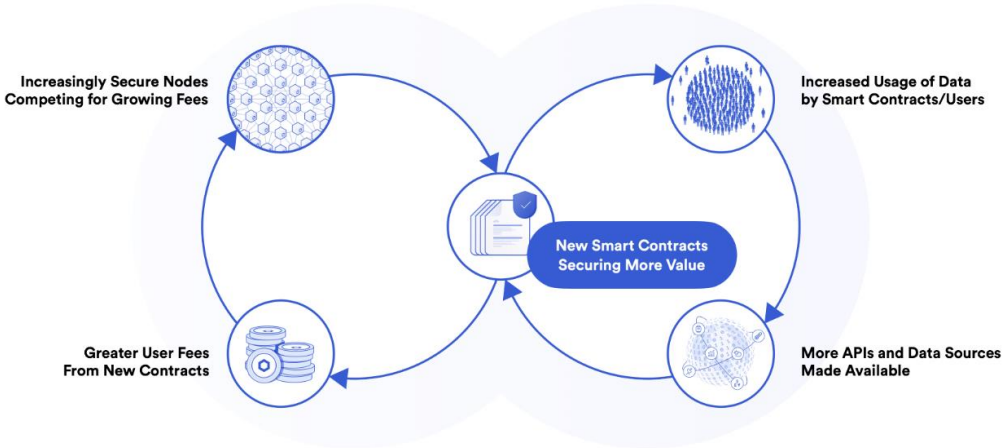


Figure 60 – The Chainlink Network Effect

The most fundamental game-theoretic incentive is to live a prosperous life. We believe ethics is incredibly important to any company, as improving peoples' lives is effectively a secondary effect of productivity growth. The Chainlink team constantly talks about the social impact of hybrid smart contracts in their videos and fire-side chats. Also, in his role at Cornell, Ari Juels is personally working on smart contracts which incentivize positive human outcomes, such as incentivizing re-forestation[61].

Sergey Nazarov, in every presentation he gives, always explains *why* he was interested in devoting his life to solving this problem: "What we are all really talking about, when we talk about blockchains and smart contracts, is various forms of technologically enforced agreements that create a parallel legal system which is not dependent on corrupt people driven dynamics, and never in history has there been a system that can properly allow people to agree that could not be corrupted by people. And that is extremely significant for both the developed markets that have huge systemic financial risk that is consistently manipulated by people, small groups of people, to their benefit and to the detriment of larger society, and very importantly, to the people in the emerging market which don't have a local legal infrastructure that can provide a certain agreement to them, but do have all the ability, desire, appetite for risk, and even in many cases resources, to come together and engage in the collaborations that would come to change their lives and the lives of those around them. So, if you are ever wondering why blockchains or smart contracts matter, they matter because they change the way the world works, in a way that changes your life and my life, and the lives of billions of other people."

Daniel Shapiro
Chief Investment Officer
Abstraction Capital

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10 Disclaimer

Nothing written in this paper should be considered financial advice by Abstraction Capital. Invest at your own risk, and never more than what you can afford to lose.

11 Change Log

1. 17 November 2021
    a. Added Section 7.3 – Blockchain Interoperability – Cross Chain Interoperability Protocol

12 Further Research and Resources

- https://link.smartcontract.com/whitepaper v1.0
- https://chain.link/whitepaper v2.0
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Please email us at contact@abstraction.capital if you want access to our DCF model

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