Impact of Technology on Business, Economy, and Society - A framework-based approach

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ABSTRACT

This paper explores the impact that Science and Technology makes on Society. It introduces a framework to assess impact across multiple areas of impact and discusses quantitative and qualitative ways of measuring that impact. In the end it provides a basic frame of reference for being able to be proactive to assess impact of a new scientific or technological area across multiple dimensions of impact. Through the multiple dimension approach, the framework also exposes various risks and opportunities associated with technological and scientific advancement. The impact framework provides a common, consistent and a comprehensive way of understanding the impact that past technologies have had on humanity and enables us to predict impact of forthcoming and new technological and scientific advances. Such an Impact Framework also provides a good basis for planning Technology Ecosystems, Technology adoption plans and Technology roll out details. Through an understanding of impact on societal dimensions, the framework also sets the first dialogue on Policy interventions that are needed for a specific scientific or Technological area.

INTRODUCTION

Science and Technology have always been and continue to be a crucial cornerstone of human development. Science is an attempt to understand how nature works and to be able to harness the powers of the laws of nature to either answer the fundamental questions to reality OR create technology that can make human life and existence, better, safer, more efficient and create opportunities for all round progress. While the aim of science and technology is to create a better future for humanity, science and technology can be used in ways which may create negative impact of varying levels. Some of the negative impact may stem from the use of science or technology for a clearly negative or harm causing intent. Yet very often the positive and negative sit on a continuum of a gray scale, where Good or positive impact is on one end of the scale and the Bad or the negative impact is on the other end of the scale. This means that there are finer aspects to understanding the impact before we can classify it immediately as good or bad. e.g one could argue that on one hand Internet has brought in extensive amount of connectedness, which forms the basis of many useful applications and capabilities across the network, it is also arguable that social media networks which rely on the internet and connectedness cause mental and emotional harm to people, in cases where people are addicted to these networks. The opportunity thus is always to use technology and science for the benefit of humanity, while planning for the risks associated with negative use and setting boundaries and regulations to prevent intended or unintended harm.

Let's consider emerging technologies like Artificial Intelligence and Quantum. AI systems have been adopted over a period, yet there continues to be advancements in AI methods and algorithms, thereby expanding the scope of impact as well as the depth of impact in several scenarios. On the other hand, now, we are at a cusp of the evolution of Quantum Related Technologies. Quantum Physics is a unique science, postulates of which are reasonably well understood when it comes to a description of Quantum Behavior, Quantum Field Theory etc. the potential of Quantum Computing is also well understood. The area of Quantum Computing is however evolving and while there is rapid progress on all fronts, there is no one who can draw a timeline map with a very high degree of certainty for the evolution of this technology. Having said that, the impact of Quantum related technologies is likely to be very high and the impact will be in multiple dimensions. This would be true for any technology that is new and evolving. Being able to provide foresight into the actual nature of impact that a new technology can bring in, can be a very useful tool.

This paper introduces a framework which will provide the basis for understanding the impact of a scientific or technology area across multiple dimensions. The framework is then validated against the information available from the past. This is somewhat conceptually like how AI systems are made to learn, by looking at the past data. Once validated, the framework can be used for new areas as well.

STECH Impact Framework

Introducing the STECH-IMPACT framework which provides a comprehensive view of the impact across multiple dimensions. After an examination of the United Nation SDGs, the focus of the Industry and areas that are driven by regulation etc., It was concluded that the most interesting, Comprehensive , concise and useful identification of dimensions across which impact should be measured are: Impact on Business and Economy, Safety and Security, Ecological impact, Society and the way we live, World Structures /Geopolitical impact and Impact on Human Wellbeing and Healthcare.

Fig1. THE STECH- IMPACT FRAMEWORK

The Multiple dimensions of Impact

Technology impacts many areas. The above diagram provides a framework to bucket impact in specific areas. The purpose of this division is many-fold:

- The areas collectively provide a 360-degree view of various elements of impact

- Each of the Areas can be studied by a specific group of people who understand Technology but are also specialist in some other areas which helps them address the impact area. For example, the Impact of Technology on Society can be studied by Social Scientists along with Technologists, whereas the Impact on Human Well Being can be studied by Health professionals alone or in partnership with some technical experts.
- Identification in multiple impact areas allows for association of specific quantitative and qualitative methods for measuring impact across each of the

impact areas, thereby reducing overall complexity of such a measurement effort

- Impact in one area can lead to scenarios that create impact in other areas as well. Cross linkages across multiple impact areas are also relevant.
- Sometimes the impact of one Technology may be to make obsolete other technologies or give a boost to other technologies. Those things are noted down as impact to Industry and serve as input to the STECH IMPACT framework for the technology impacted.

The following examples from the past tell us the impact of many of the technology areas in the past under each of these impact areas. This reference to past information allows us to validate our framework against historical technologies that created significant impact across each of these multiple dimensions of impact.

1. Business and Economy

In an article titled "Quantifying the Economic impact of the Internet' by John Quelch[1] the economic value from the internet in the US alone is described in 3 distinct categories

Employment value. About USD 300 billion, or around2 percent of U.S. GDP.
Payment's value. About USD 175 billion, which comprises
of USD 20 billion of advertising services, USD 85 billionof retail transactions (net of cost of goods), and USD 70 billion of direct payments to Internet service providers. Moreover, advertising-supported Internet creates annual value of USD 444 billion.
Time value. At work and at leisure, about 190 million people in the United States spend, on average, 68 hours a month on the Internet. A conservative valuation of this time is an estimated USD 680 billion.

If we look closely, this is significant high impact. With the internet, almost every business, whether it is retail, banking or even education and healthcare- they have all become digitally enabled and are delivered in extremely new formats, creating reach and connectivity like never before, cutting down middlemen at several stages of the Service/Product Cycle.
While this is an interesting example of measured economic impact, we also want to follow a more rigorous and clear process. The World Economic Forum states that there are 5 ways in which technology impacts the economy

- Through Direct Job creation
- Contribution to GDP growth
- Emergence of new services and IndustriesWorkforce Transformation
- Business Innovation

Most of these parameters can be measured Quantitatively and/or qualitatively.

2. Society and the way we live

A good example of understanding the way society changes with technology is to examine the impact that mobile devices have created.

As per bankmycell.com, there are 4.88 billion mobile phones users around the world around mid-2021. This means that almost 61 percent of the world population have a mobile phone. This has created an unprecedented connected-ness, access to data and has redefined people's lives in many ways. Some examples:

Social Interactions: Lot of social interactions have shifted to the digital platform. While it allows people to stay connected wherever they are, it has also created a whole range of psychological and physical health issues because of the overuse of mobile phones. There are also issues around security and privacy that have become more relevant

Education: Today Mode of Education has changed to include several digital formats, including formats which make it easy for somebody owning a small screen device like a mobile phone to be able to get education online. This is a great opportunity to provide education to people whose physical access to certain locations may be limited.

The flip side to this change in the way we conduct our lives is the emergence of new kinds of social problems, mental health issues associated with spending more time online and disconnecting with the physical world.

3. World Structure/Geopolitical

International Organizations that promote Global Collaboration and Peace like World Economic Forum (WEF) and the United Nations (UN) have Technology focused groups. WEF releases a report which outlines its plans to use technology to meet the Global Goals on Sustainability. Reports like this become a guiding beacon for Industry and Governments around the world to work towards. The United Nations has a Commission on Science and Technology for Development (UN-CSTD). This Commission was setup in 1993 replacing an earlier Intergovernmental Committee on Science and Technology, which itself was setup in 1979.

We get used to these new structures, but a closure examination will reveal that the nature and magnitude of impact of Technology has grown over time in so many ways that there is a need for new types of Organizations to manage Global Discussions and Decisions around the Technology use. Apart from these entities, there are International regulatory and Standard bodies today such as International Telecommunications Union (ITU) for Telecom and International Standards Organization (ISO) for defining standards across a myriad of technologies. ITU was founded in 1865. Each of these organizations have national counterparts which came into existence mostly in the early 90s. In fact, not so far long ago. The Issue of Data

Privacy has led to several different regulations which are country specific and while today we do not have an International Regulatory Body around Data, as we move forward, the pace of technology is changing, and new technologies are going to demand new kind of regulations, standards and mechanisms for Global Collaboration.

New technologies are a major redistributor of power among states and a significant force shaping international relations. Technology becomes a leverage for Bilateral and International Trade relations and supply chains dependent on such relations can create Economic impact across the world like a ripple effect.

We are seeing more and more technologies as part of the agenda for Bilateral and Multilateral entities. Quantum is on the Agenda for AUKUS (Australia, UK, US) and QUAD's formation of the Critical and Emerging Technologies group is a good example of this trend.

With the need for Global Collaboration, Global guidelines, and even Global regulation for some technology areas, we will see the emergence of new Entities to support these efforts.

Understanding and documenting the impact on Geopolitics and the involvement of International Agencies sets the right context for an understanding of the needs and mechanisms for driving International Standardization Efforts as well as International Co-operation in these areas. It also sets the tone for the Ethics and Regulation related discussions to manage the Risks associated with the area.

4. Human Well Being, Productivity and Health

There has been a tremendous amount of progress in health- care, biotechnology, medicines that have not only served to save more people from diseases that were once considered terminal, but there has also been a huge improvement in human wee-being and the result is an increased human life span-The average life span of human being has evolved from 40s to 80s in the last 100 years. A look at the data from 1950 shows a massive change across regions as is visible in this graph from UN world Population Prospects 2017.

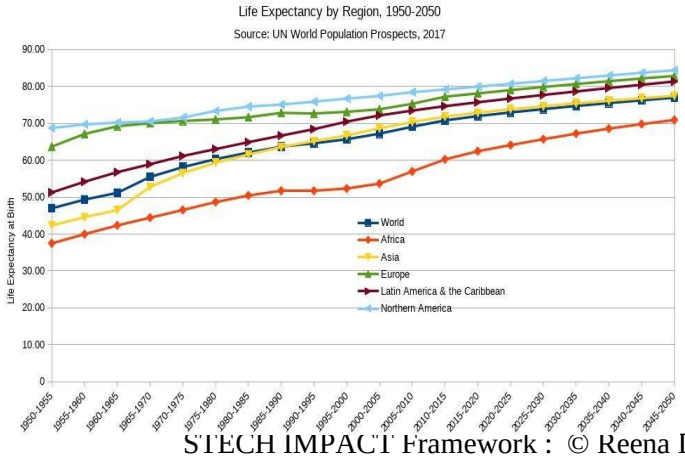

Fig2. Life Expectancy by region

Advances in Biotechnology, bionic devices and robotic and laser-based surgery have revolutionized mobility, recovery, and quality of life post massive health problems with humans. Genetics and associated research have opened new paths in preventive as well as gene targeted therapy. As we look at the benefits of technological progress on human well-being, there are also challenges which were not envisaged well. In India and several other parts of the world for example, earlier in the century the new then invention of ultrasound was grossly misused for female feticide in a population which craved to have a male child. Laws and Regulations had to quickly be put in place to criminalize sex detection of fetus using ultrasound. This is just one example. We want to be able to use a framework which allows us to project and estimate the impact of an upcoming technology on such impact areas so that we can take proactive measures for ensuring that all science and technology is used for the human good. The ongoing debate about the use of CRISPR tells us how serious the ethical consideration can sometimes become. As we look at the human ability to alter genes, and if the technology is not regulated, will we have more and more designer babies in the future? What will that do to humanity? Will it create two distinct races on the planet? - on One side a super race which evolved from the people who had the money to get gene editing done for their offspring and on the other hand where the natural gene selection process is creating ordinary humans. These are difficult questions, the sooner we ask them and create opportunities for discussion and action, the better off we are as a race to manage our future.

Using the framework to examine this impact helps us establish the right baseline for detailed planning for the Ecosystem and the next steps

5. Security

Science has given us a handle to understand reality at the micro and the macro level in the Universe. When we started to understand how things work at the subatomic level, it revolutionized the discovery of new materials, our understanding of Astrophysics, and this in turn impacted almost every Industry on the planet. However, this came after we had paid the price of using nuclear fission for the creation of an atomic bomb and we built the understanding of how this technology could not only potentially wipe out humanity but render our environment toxic to any form of life. So, understanding the impact of any science on the Safety of Human beings and Humanity as a race is important. let's examine a few such scenarios

Increasingly Interconnected Systems

The world today is increasingly connected through the internet. This interconnection is a complex combination of people, things, and systems. This interconnection creates several opportunities for Collaboration and information availability. This continuous availability and instantaneous transfer of information across the globe has produced enormous positive impact.
Despite the positive impact there are instances, such as data breaches for academic institutes, for industry and even Government agencies that have happened in the past. The breaches lead to the leakage of sensitive data, financial, military or personal data.

While the automation of power grids has been a very welcome progression in the power industry. However, automation has been exploited by people who have deployed cyber-attack methods to introduce malware and launch cyber-attacks on the automated power grids resulted in nationwide blackouts in many countries, for example, the cyber-attack on Ukraine power in 2016 and cyber-attack on hydropower generation plant in New York in 2013.
The solution to this is not to stop technological progress in this direction, but include proper guidelines and regulations when needed

6. Supply Chains

New advancements in Internet of Things, Communication mechanisms, Artificial Intelligence etc. has served to help make supply chains and logistics much more efficient. However, this is just the tip of the iceberg. Radically new technologies disrupt existing supply chains and create new ones, sometimes altering the geographical distribution of the end-to-end Value chain for a particular industry. A good example of this is how the entire EV supply chain has evolved in the US, thanks to TESLA, the giga factories, the solar roof, and the charging network that has been built by TESLA across the US.
So new technological advances and an Ecosystem Approach can lead to changes in the Supply Chain Dynamics. Documenting the same and understanding how it impacts the associated industries, provides a strong framework for the drivers of Economic Growth in a region.

7. Ecological Impact

Until very recently, the conversation around AI and Ecology were around the role that AI can play in supporting the Climate efforts happening on the planet. There were lot of case studies on how AI systems helped to save power, reduce consumption of critical resources, optimized supply chains, etc.. Its only recently that the conversation has significantly shifted towards the energy cost of training Deep Learning systems and the kind of Power requirements that are there for AI systems. In an article in IEEE Spectrum, Neil C Thompson etal state that for a mere 5 percent reduction in the

errors of a deep learning model, the amount of additional data that is required to train that model is 25 times and this in turn introduces a computational cost of 390625 (54) To explain this more clearly, they mention that the additional computation power would create as much Carbon dioxide as the city of New York creates in a month. This is the point where the cost of the technology on humanity becomes non-viable. We know that computational capabilities are also threatening to plateau out and new computational technology like neuromorphic computing or Quantum computing need breakthroughs.
Extrapolating this kind of impact and working out alternatives is one of the things that can be tremendously benefited by applying a formal framework for estimating potential impact across multiple dimensions for a new technology.

TIMELINES

While we examine the Impact framework, we also need to consider timelines of impact. At a very high level we can divide the impact timeline into
•Short term
•Medium term
•Long term
This timeline could indicate different levels of impact across each of the Impact areas. As we look at a technology, its applications, expected risks and opportunities and project them along the time-frame, it give us some idea of the sequence in which we need to address various societal impact areas associated with the technology, how soon we can start seeing the benefits, what are the timelines for guidelines to be established etc.
The measurement of the timeline of impact would be a map created specifically for each technology and the scope of the study. E.g the Technology Maturity curve could be used as the base, The innovation Life Cycle could be extrapolated on top of it or specific sub areas . Other very technology specific analysis may have to be done. E.g We are already working on assessing timelines based on the Knill Theorem for Quantum Solutions.

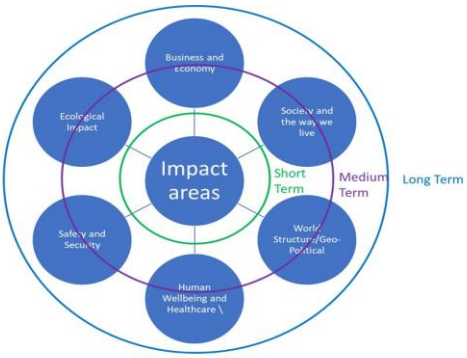

Fig3. STECH IMPACT framework with Timelines of Impact

TECHNOLOGY MATURITY CURVE AND THE OPPORTUNITY TO BE PROACTIVE

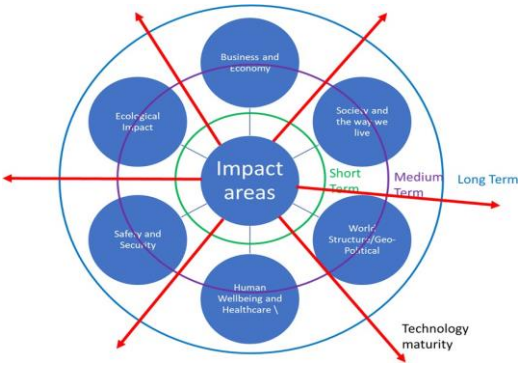

Figure 4. The STECH IMPACT Framework

Depending upon the Stage of the Technology Maturity we have an opportunity to be proactive or reactive. As the technology matures, we see that the opportunity to be proactive in anticipating impact of the new technology starts to recede and we have to start taking a reactive approach.
e.g. The Opportunity to act on Post Quantum Cryptography is now, before the technology has reached its maturity state.

CONCLUSIONS AND FUTURE WORK

This paper sets the context for a new 360-degree framework for measuring or estimating the impact of technology or science across multiple dimensions. There is an opportunity to use this framework for some impact areas or all for a particular technology or scientific are, in specific geographies or across the world. The first effort that is underway post this paper is to use this framework for Quantum and subsequently AI.

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