Exploring the Technological Frontier to Fuel Future Growth: Charting India's Trajectory for Coming Decades

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ABSTRACT

The paper aims to discuss the world of fast-paced technology from a Darwinian standpoint and examines the technological choices made by countries and the impact of such choices on their economic growth. The paper explores how a country's economic growth is dependent on the strategic technological choices they make. By clubbing together the fate of countries and companies, we intend to simplify the narrative and explore a few key aspects such as the diminishing relevance of competitive behavior and ways of adapting to and adopting new technologies to become an evolutionary driver in a technology-centric world. This review highlights the need for exploring technological advancements at the periphery in delivering sustained future growth for countries like India. Historical evidence shows that adapting to newer technologies is more important than competing in legacy industries and sectors for a country to boost its economy. Adaptability is more essential for sustained economic growth than competing. The vision for India's technological future should be to make strategic technological choices that have significant growth vectors working in its favor. Rapid technological changes mean that a country can pursue industries without having to go through the learning curve many other countries went through previously in their developmental history. In this fast-paced, techno-centric world, technological choices that are made today determine the quantum of associated economic growth in the future.

Keywords**:** Technology, Economic Growth, India, Economy

JEL Classification Codes **:** O14, O00, O39, F43, O30, O31

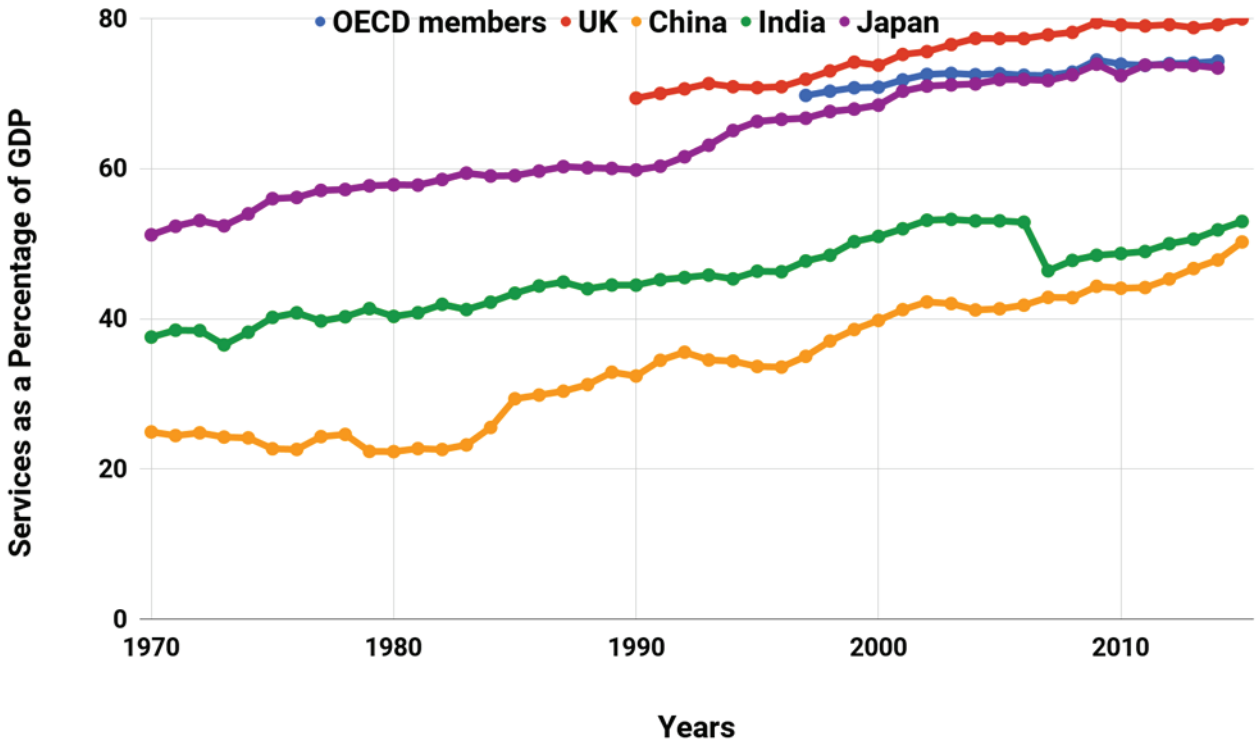
INTRODUCTION

It would be very difficult for India to match the technical capability harbored around the German IC engine nor can we attempt to build the perfect Italian espresso machine; the fact is, we don't have to. Technologies that have already seen their full day of sunshine would be difficult for another country to replicate or master and the payoff for such an endeavor is limited. Rapidly changing technologies make everyone and everything obsolete; as is the case with individuals, companies, and countries, all afflicted with the same dilemma of coping with the fast pace of technological advancements. In this write-up, we put forward the view that adapting to new technologies and skipping certain learning curves are more promising than competing with nations in technologies where they have already gained a strong foothold.

A historian looking back at history with a sense of all that has happened would be surprised by the Indian situation where such a large prominent economy has adopted Information Technology (IT) more readily than manufacturing.[1]No student of industrialization would have predicted that an economy could leapfrog what we call the fundamental path to rapid progress. Export-intensive manufacturing has been the broad strategy taken by many nations such as Germany, Japan, and more recently China, for rapid progress and economic growth. The industrial revolution in the conventional sense has not taken off in India, with the economy moving directly into services and completely neglecting the manufacturing sector. Today, economies have GDPs that are more dependent on services and structurally reoriented away from the manufacturing sector. The service sector enabled through the emergence and proliferation of IT has provided these economies with the initial spurt of economic growth in recent decades.

[1]For a detailed discussion on the growth of Information Technology in India, refer to Friedman, T. L. (2005). *The World Is Flat: A Brief History of the Twenty-first Century*. New York: Farrar, Straus and Giroux.

Figure 1: Services as a Percentage of GDP of Selected Economies



Source: World Bank Open Data—World Bank Group[2]

[2]Data for the graph is taken from the World Bank Open Data - World Bank Group. Retrieved 24 June 2017, from http://data.worldbank.org/indicator/NV.SRV.TETC.ZS

The Post-War Boom: The Technological Leap

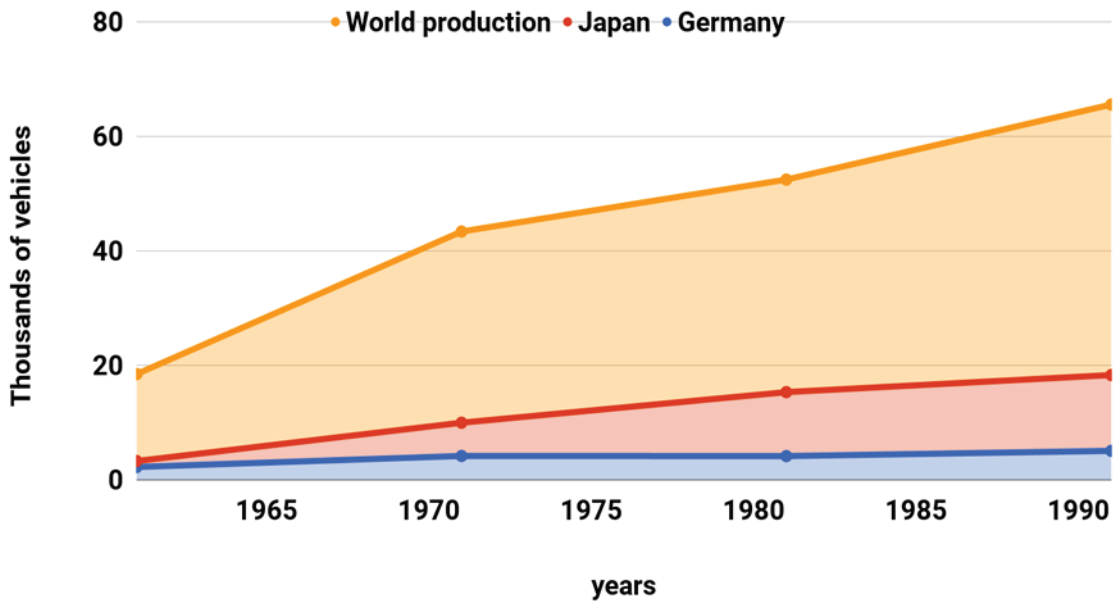
Modernization of European economies under the Marshall plan, intended to rebuild Europe after the destruction in WWII, called for significant investments for reindustrialization with technical assistance from the US.[3] Germany with its cars and Japan with its electronics[4] went straight into producing high-tech goods for export and entered industries that saw exorbitant growth going forward, bringing their economies roaring back within a short period of time. Early examples of export-led growth strategy come from Germany and Japan. When Japanese carmakers entered the US market in the 1970s, they evaded direct competition with their US counterparts. Instead, they went on to make their cars more compact and fuel-efficient and introduced them into the market at a lower price bracket. Japanese carmakers were hesitant to compete with Germany's more premium cars; they found their own niche by introducing and marketing affordably priced and fuel-efficient cars and with the high price of oil during that decade, Americans started buying more of their cars which gave them a much-needed boost. As certain sectors of the economy observed greater pace of growth than others, for example, the automotive sector in Japan, economies heavily weighted in those sectors, through exports captured the greatest volume of growth in the world market.

[3]Murray, P. (2008). Marshall Plan Technical Assistance, the Industrial Development Authority and Irish Private Sector Manufacturing Industry, 1949-52. (NIRSA) Working Paper Series. No.34. Retrieved 3 May 2017 from http://eprints.maynoothuniversity.ie/1156/1/WP34murrayfeb20081.pdf; Provan, J. The Marshall Plan and Its Consequences. Retrieved 3 May 2017, from https://www.george-marshall-society.org/; Real GDP per Capita in Germany (DISCONTINUED). Retrieved 3 May 2017, from https://fred.stlouisfed.org/

[4] For more details, see Takahashi, Y. (1993). Progress in the Electronic Components Industry in Japan after World War II. In W. Aspray (Ed.), *Technological Competitiveness: Contemporary and Historical Perspectives on Electrical, Electronics, and Computer Industries* (pp. 37–52). Atlanta: Institute of Electrical and Electronics Engineers.

Figure 2 shows the total production of vehicles by Germany and Japan relative to the booming world production in automobiles for each decade since 1961 and the subsequent capturing of an outsized market share in the automotive sector by these two countries.

Figure 2: Germany, Japan, and the World Production of Motor Vehicles (Total Vehicle and Commercial Vehicles)

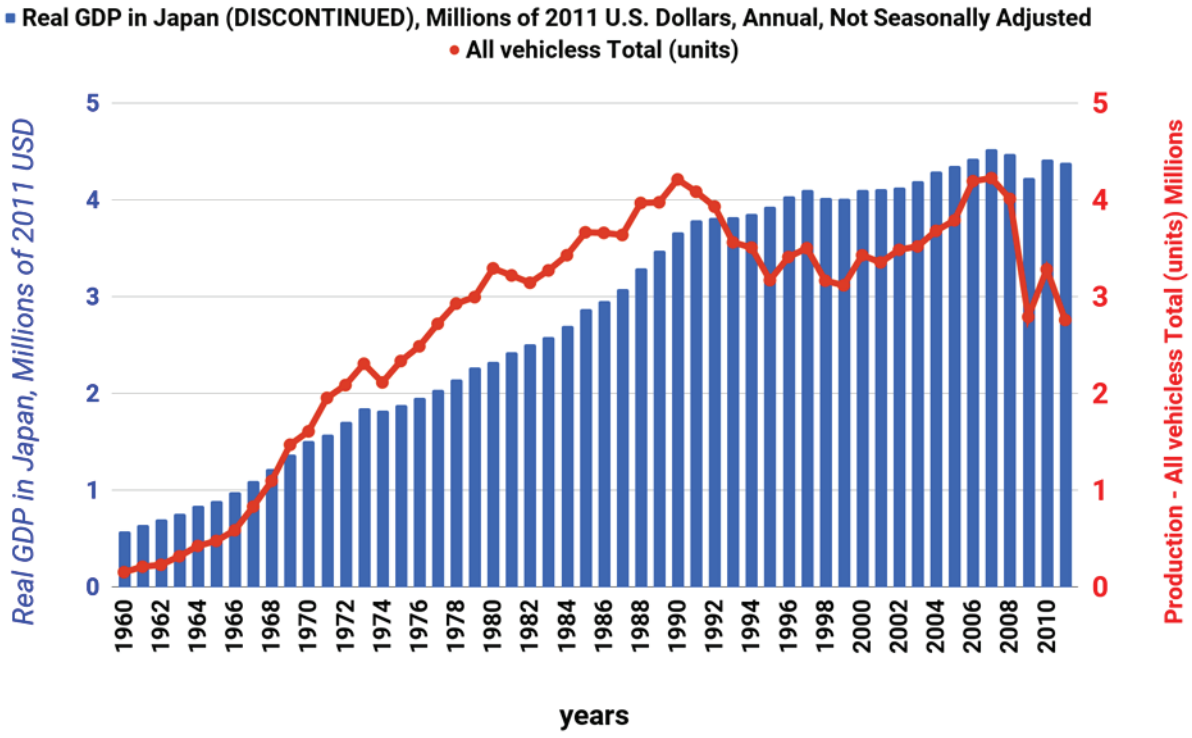


Source: The Bureau of Transportation Statistics[5]

The following figure (Figure 3) shows the growth in Real GDP in millions relative to the total vehicle production in Japan. This is a textbook example of the growth area in a technology sector boosting a country's economy. The figure shows significant growth in the automobile sector in Japan during the 1960s, 70s, and 80s.

[5]Data for the graph is taken from Table 1-23: World Motor Vehicle Production, Selected Countries (Thousands of vehicles). Retrieved 3 May 2017, from https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_23.html_mfd

Figure 3: Real GDP in Japan and Vehicle Production



Source: Multiple Sources[6]

Japan readily adopted electronics early on in the 1960s and benefitted by the rapid expansion of the electronics industry, but later on failed to transition away from thinking about electronics primarily as hardware to thinking of them as a package of hardware and software working together. They missed the rapid expansion of the software industry where much of the innovation and growth came from later on. Early Japanese coin-operated arcades were hardware based - i.e. if you wanted the arcade to play a different game, it needed significant hardware changes to do it.[7]

[6] Production in Japan: Japanese Production Volume. Retrieved 3 May 2017, from http://www.toyota-global.com/company/history_of_toyota/75years/data/automotive_business/production/production/japan/production_volume/index.html; Real GDP per Capita in Germany (DISCONTINUED). Retrieved 3 May 2017, from https://fred.stlouisfed.org/

[7] For a detailed discussion on the subject, refer to Harris, B. J. (2014). *Console Wars: Sega, Nintendo, and the Battle that Defined a Generation*. New York: Harper Collins.

However, nowadays, the console carries standardized hardware capable of playing multiple games by quickly swapping the software in it. The Japanese, whose focus was more on hardware, could not keep up their dominance when the field of electronics became more software dependent.[8]

From a Nation of Copycats to Innovators

When countries were merely a hub for early manufacturing industries like Japan was in the 1960s and China in early 2000s, they focused on producing manufactured goods using cheap labor available to them in abundance during those times. But later on in their development history, Japan came out with world-beating companies which focused on innovation and spent substantial budgets on R&D. China went from being a country of copycats as many have branded them to one of the innovators since the last decade.[9]Going from being mere manufacturing outposts to innovation centers, countries can sustain higher rates of economic growth their people deserve.

There needs to be an evolution of thought process for countries to become innovators and entrepreneurs and come up with products and services and build world-beating companies on their own. Today, entrepreneurship is on the rise in China and the country plays host to multi-billionaires who have made their fortune manufacturing and exporting to other countries. Many world renowned companies like Xiaomi, Vivo, Lenovo, and Foxconn have emerged in the last decade. Alibaba has revolutionized the e-commerce industry and is now looking to expand their horizons beyond China..10 Innovation is a necessary condition for economic growth to emerge and sustain.

[8]For a detailed discussion on the subject, refer to Cole, R. E., & Nakata, Y. (2014). The Japanese Software Industry: What Went Wrong and What Can We Learn from it? *California Management Review,* 57(1), 16–43; Takahashi, Y. (1993). Progress in the Electronic Components Industry in Japan after World War II. In W. Aspray (Ed.), *Technological Competitiveness: Contemporary and Historical Perspectives on Electrical, Electronics, and Computer Industries* (pp. 37–52). Atlanta: Institute of Electrical and Electronics Engineers; The Giants in Japanese Electronics.

[9]Thompson, C. (2015). How a Nation of Tech Copycats Transformed into a Hub for Innovation. *Wired.* Retrieved 3 May 2017 from chttps://www.wired.com/2015/12/tech-innovation-in-china

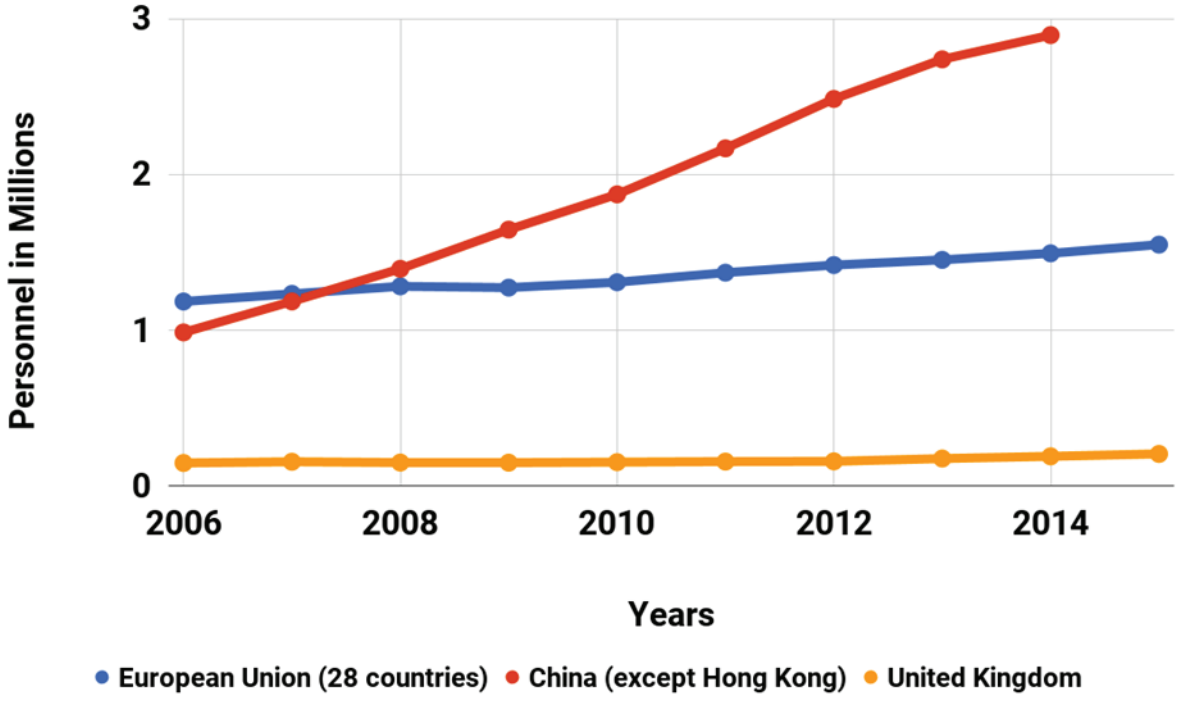
[10] Why Is Alibaba Expanding Beyond China? (2016, April 13). *Forbes*. Retrieved 20 June 2017 from https://www.forbes.com/sites/greatspeculations/2016/04/13/why-is-alibaba-expanding-beyond-china/#10a32dcb7821

According to the recent Boston Consulting Group (BCG) report titled *Innovation-Led Boost for US Manufacturing*, China will outspend the US in development cost by 2018. And China's private sector provides more funding for university R&D than even the US.[11] However, the US is still leading in R&D because of its best-in-the-world university system that is a leader in innovation and is likely to continue for a long time.

Figure 4 shows the R&D personnel working in high-tech sectors for business enterprises. We observe a tripling of people employed in business enterprise R&D in China while other countries have a modest percentage of increase.

Figure 4: Business Enterprise R&D Personnel in High-tech Sectors

Source: Eurostat[12]



[12]For details, see EuroStat: Statistics Explained (2014). Figure 2: Researchers as a percentage of R&D personnel in business enterprise sectors in 2014 (Graph). Retrieved 24 June 2017, from http://ec.europa.eu/eurostat/statistics-explained/index.php/High-tech_statistics_-_employment

World Today

When technology changes rapidly and necessitates new areas of expertise, companies of the previous generation seldom stand a chance and are overtaken by new players. Take, for instance, the case of consumer electronics companies of the current and previous generations. South Korea is currently dominating the consumer electronics field with companies like Samsung and LG manufacturing the latest consumer products beating out competitors of the previous generation like Sharp and Sony of Japan.[13]If we look at the semiconductor sector, the dominance of Intel in processing chips has come to an end and it is now in close competition with the South Korean Samsung and Taiwanese TSMC, largely because of the post-PC era where tablets and phones are more prevalent.[14]

Lately, India has also witnessed the widespread adoption of the wireless internet. India adopted wireless technology, an evolutionary jump, without deep diffusion of cabled connectivity. Having no legacy infrastructure, it is possible for India to adopt the latest low-cost technology rapidly.[15]An excellent example from a decade ago, with the introduction of cellular connectivity, the total number of wireless cellphones added in a few years surpassed the wired telephone connections installed over the whole of last half a century.

It is easier to adopt newer technologies when a country is not weighed down by older legacy capital decisions. It is a lot easier to build a new factory to manufacture next generation vehicles than to retool an existing factory to churn out new products. Similarly, it is harder to tear down an existing power generation infrastructure in a developed economy which may depend extensively on coal; we see significant additions

[13]Flat TV battle: Why Samsung, LG are dominating Sony, Panasonic. (2012, April 25). *NDTV Profit*. Retrieved 3 May 2017 from http://profit.ndtv.com/news/corporates/article-flat-tv-battle-why-samsung-lg-are-dominating-sony-panasonic-302744; Matsangou, E. (2015, February 10). Japanese brands exit the global television market. *The New Economy*. Retrieved 3 May 2017 from http://www.theneweconomy.com/technology/japanese-brands-exit-the-global-television-market

[14]Baxter-Reynolds, M. (2013, July 29). Here's why PCs and post-PC devices are different things (and why they need to stay that way). *ZD Net*. Retrieved from http://www.zdnet.com/article/heres-why-pcs-and-post-pc-devices-are-different-things-and-why-they-need-to-stay-that-way/; Worldwide Semiconductor Foundry Market Grew 4.4 Percent in 2015, According to Final Results by Gartner. (2016, April 12). Retrieved 3 May 2017, from http://www.gartner.com/newsroom/id/3281630

[15]2Gto 4G: Will Indian telecom revolution give 3G a miss? (2014, October 17). *Money Control*. Retrieved from http://www.moneycontrol.com/news/business/companies/2g-to-4g-will-indian-telecom-revolution-give-3gmiss-1539881.html

additions to capacity in the area of renewables in both India and China in recent years.[16]It is demonstrably easier to go the route of renewable energy for a developing country since it is not burdened by already existing extensively networked infrastructure on the ground.

The central argument of this review is that India should look forward to developing technologies that will promote future growth than trying to dominate existing legacy industries. Competing against already established mature industries is a lot harder than starting afresh in industries that offer the potential for rapid growth. Trying to play catch-up in a race where other players have had a head start is harder than starting to run in a new tournament that is just beginning. Simply to say, the ISRO is important for the growth of India's economy today but more so in the future as it is entering the space race which has tremendous potential for expansion in the coming decades. We should conceptually expect an industry that is currently only 0.001% of the economy to expand to 1% in the coming decades, and the country should be able to reap the greatest growth from capturing the largest share in the world market. The technology sector has become a disruptive force for the American economy. Figure 5 shows the San Francisco Tech Pulse which is a coincident indicator that represents the vitality of the US Information Technology sector.[17]The IT sector was virtually non-existent before the 1960s and topped before the Tech Bubble which imploded in early 2000. It is a gauge for calculating the composite of investment in IT goods, consumption of computer and software, employment, industrial production, and shipments in the technology sector.[18]The technology sector provided 7.5% to the U.S. economy directly in 2017 according to COMPtia's research report.[19]

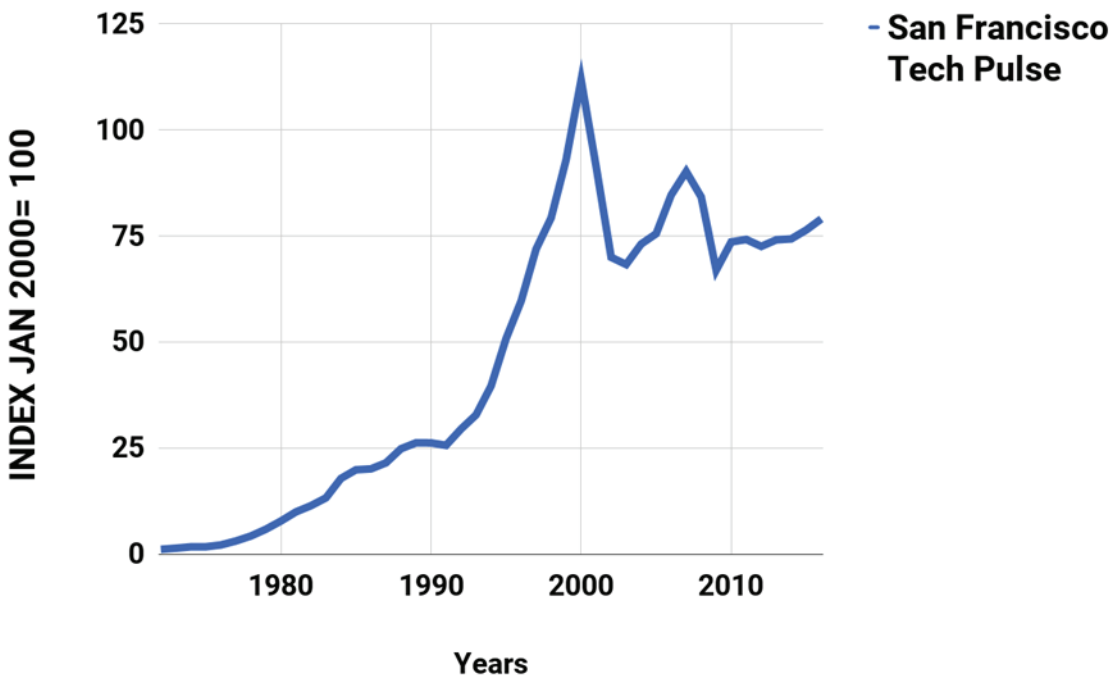
[16] China and India Lead Global Renewable Energy Transition. (2017, April 21). Retrieved 3 May 2017, from http://newsroom.unfccc.int/climate-action/china-and-india-lead-global-renewable-energy-transition/

[17] The Computing Technology Industry Association - COMPTIA. (2017). *Cyberstates 2017*. Retrieved 20 June 2017 from http://www.cyberstates.org/pdf/CompTIA%20Cyberstates%202017.pdf

[18] For details see, Federal Reserve Bank of San Francisco (2017). San Francisco Tech Pulse (Graph). Retrieved 21 June 2017 from https://fred.stlouisfed.org/series/SFTPINDM114SFRBSF

[19]See note 17

Figure 5: San Francisco Tech Pulse



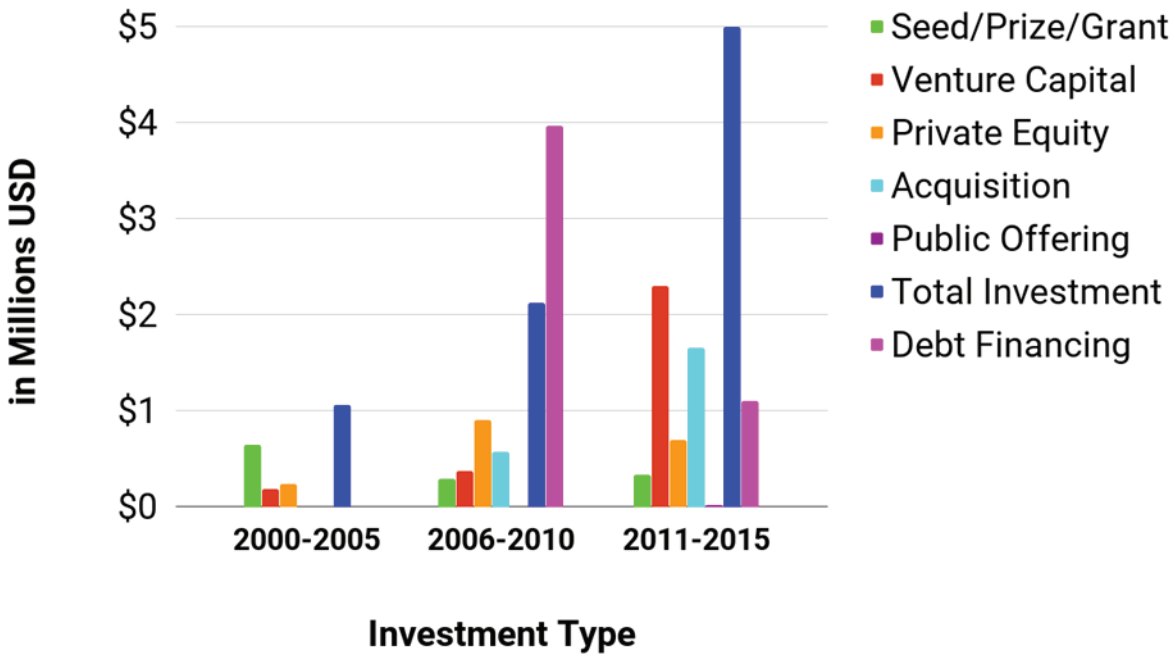
Source: Federal Reserve Bank of San Francisco[20]

Aerospace and space will receive increased attention in future and these fields require extensive investment and R&D today to make that possible. India should concentrate its efforts on deeply incorporating technologies that will be the mainstay of growth in the future and will also provide a strategic edge over other nations. Figure 6 shows a dramatic increase in Space industries in the 15 years with total investment hitting 5 Billion USD between 2011 and 2015. We also observe an increase in acquisitions in this area along with 600% increase in Venture Capital Funding.[21]

[20]See note 18

[21]For a detailed discussion, see Bryce Space and Technology. (2016). *Start-up Space: Rising Investment in Commercial Space Ventures*. Retrieved 20 June 2017from https://brycetech.com/reports.html

Figure 6: Investments in Space by Investment Type



Source: Bryce Space and Technology[22]

Through the Lens of Evolutionary Biology

Understanding the course of technological evolution can give us a hint as to where we should concentrate our efforts on to gain our share in a technology-heavy marketplace of the future. India needs industries that give it a technological edge in the future and should promote, develop, and strengthen strategic industries to serve as a platform for future innovations. History has shown us that technological revolutions observed once a generation; the electronics revolution in the 1960s, the biotechnology revolution in the 1980s, the internet revolution in the 2000s, [23] and the explosion of social media in the 2010s are a few fine cases in point. Most developed countries experienced each leg of these inflection points separately whereas India experienced a more combined singularity within a single decade.

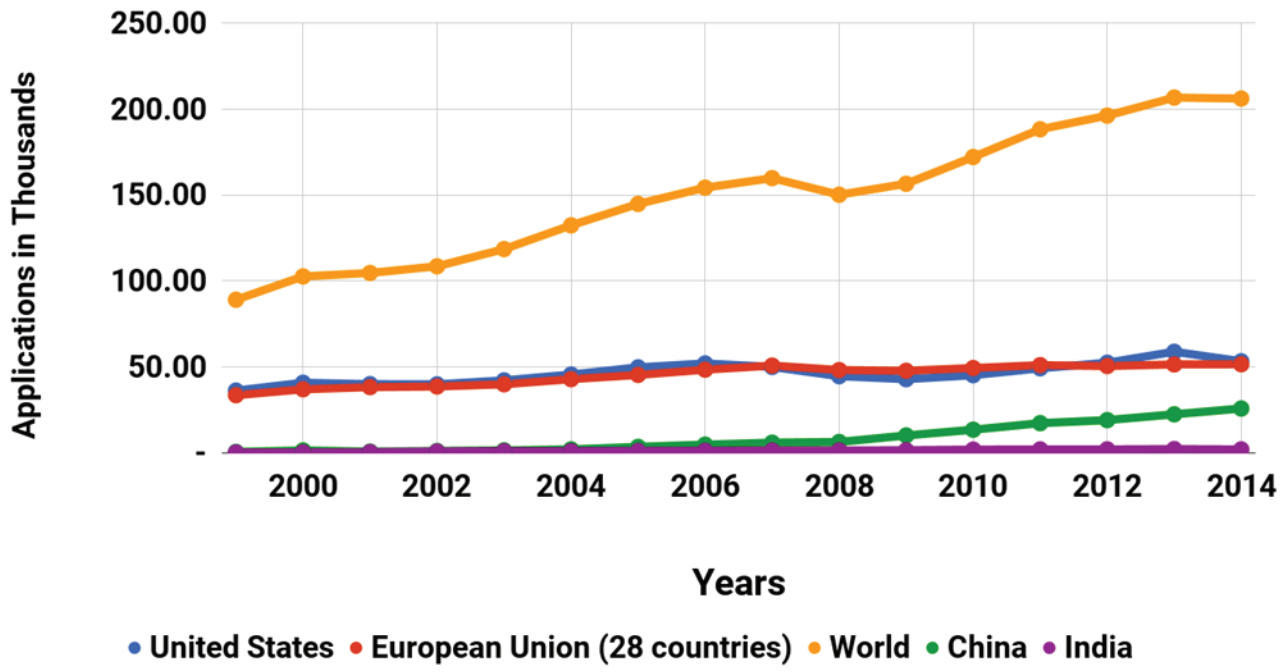
[22]See note 21

[23]Meland, M. (1999, January 14). Bubbles: From 'tronics' to 'dot com'. *Forbes*. Retrieved 3 May 2017 from https://www.forbes.com/1999/01/14/mu3.html

In this regard, a counterargument can be made that a country like India needs to focus on a wide array of industries simultaneously for growth. We may not be able to pick and choose industries we want to embrace. There is the historical precedence of smaller countries hyper specializing in one industry for intensive and focused growth rate. In India, we also have a situation where sufficient numbers of jobs need to be generated to satisfy the demographics. However, large countries are not in a position where they can specialize in only one sector or industry. A country like India cannot, in the long term, neglect manufacturing even though the world is moving towards a service-oriented economy; a vibrant manufacturing sector is still necessary to support a thriving service sector. Like they say, you cannot have an airline without an airplane. Another key point to be noted here is that, a country needs industries that effectively take care of the demand and supply cycle within it. India cannot depend on one country for its steel and another for its electronics. Substantial demand within the country needs to be met by its own supply. While building industries that are needed today, we need not and should not rule out industries that will contribute to our growth in the future. We need to have our own New York City/London for finance, California for our software and Shenzhen for our electronics.

Figure 7 represents the total patent applications filed under PCT (Patent Cooperation Treaty) in the world. We can view this as a proxy for the pace of innovation and knowledge generation the world is witnessing today. The figure also gives us insights into the exponential increase in the total number of patent applications globally in the last decade, significant growth in China’s participation, and the taking-off of India.

Figure 7: Total Patents Applications Filed under PCT Technology Domain and ICT (Information and Communication Technology)



Source: Organization of Economic Co-operation and Development (OECD)[24]

Taking a page from evolutionary biology and extending the Darwinian view to the topic in hand, one can safely assume that in a world heavily dependent on fast-paced technology, an organism's drive to adapt should supersede its drive to compete. The feature of adaptability should supersede competitive behavior in tomorrow's tech-weighted world. The evolutionary instinct to compete is void because the pace of change is so rapid that merely adapting is akin to surviving.

[24]Patents by Technology. Retrieved 3 May 2017, from http://stats.oecd.org/Index.aspx?DatasetCode=PATS_IPC

We are entering a world where adopting and adapting are more relevant than competing. Technology is a strong enough driver of change today than ever before. Competing is less relevant when there are so many factors that are working against you. The key to survival is trying not to compete but to adapt. This argument is an extension of Paul M. Romer's Theory of Endogenous Growth which argues that economic growth is driven by growth in human capital leading to innovation and technological change. Endogenous Growth Theory is based on the premise that market incentives play a vital role and a different body of knowledge is translated into new goods and services.[25]

There are very few examples that have shown remarkable ability in developing and adapting to newer technologies and have had a sustained influence on the world like that of Silicon Valley. California first entered the technological landscape with the electronics revolution in the 1960s. It went on to make a permanent mark in that highly competitive landscape by recruiting and retaining talented individuals and disrupting the world; first by making computers and putting a man on the moon, and then through its groundbreaking interventions in the realms of software, the internet, and social media. Today, this American state has come to dominate space yet again by playing host to private space companies like SpaceX and Blue Orion. It is leading the technology in driverless cars and may even take away a significant market share from the traditional German automotive companies in the future.[26] It has been disrupting one industry after the other in the last few decades by out-innovating companies and countries alike. Silicon Valley has successfully reinvented itself over and over again and maintained its edge and emerged at the forefront of avant-garde industries.

[25]For Romer's theory of endogenous growth, refer to Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(2).

[26]Ewing, J., & Scott, M. (2017, February 8). German Automakers Step Up to Silicon Valley Challenge. *New York Times*. Retrieved 3 May 2017 from https://www.nytimes.com/2017/02/08/business/germany-bmw-daimler-volkswagen-uber.html?_r=1; German Carmakers Bet on California. (2016, November 28). *Handelsblatt Global*. Retrieved 3 May 2017 from https://global.handelsblatt.com/companies-markets/germany-carmakers-bet-on-california-651791; Why Silicon Valley has the chance to dominate the auto industry. (2015, February 23). *Vox*. Retrieved 3 May 2017 from https://www.vox.com/2015/2/23/8092141/silicon-valley-dominate-cars

In an all-connected intelligent age, Silicon Valley is yet again poised to dominate the new technological platforms – everything from Intelligent homes[27] to robotics. It is effectively providing the brain and the software infrastructure for the world to run on, which will provide the US economy a growth rate that few other countries can match for decades to come.

CONCLUSION

We cannot have a compelling narrative in a history textbook which does not marvel at the rate of technological advancement achieved in this last 200 years and gravity of its influence on society. Countries that dominate industries currently will have a hard time adapting to newer technologies while nations that are slow to adapt will provide opportunities for others to thrive. The inadaptability of one nation, in other words, is the opportunity for another. To allude to the famous Bill Gates quote: "We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten. Don't let yourself be lulled into inaction". Management principles today involve asking oneself: if we started this company today what would we do? And one needs to go ahead and do it.

Having a Darwinian view of the world also means looking forward to opportunities in the technological trajectory and building the foundation for future growth. We need to chart a plan for gaining an edge in the coming decades by pushing policies that encourage the adoption of frontier technologies. The periphery is where the growth will be in the future and concentrating on the fringes of technological leaps means thinking about driverless cars, exploring space, adopting renewable energy, expanding capabilities of robots, researching composites, and building proficiency for their future expansion.

[27]Intelligent Home. Retrieved 3 May 2017, from https://www.strategyanalytics.com/strategy-analytics/what-we-do/strategic-advisory-services/intelligent-home#.WQpDr_VOK7o

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The Computing Technology Industry Association - COMPTIA. (2017). *Cyberstates 2017*. Retrieved from http://www.cyberstates.org/pdf/CompTIA%20Cyberstates%202017.pdf