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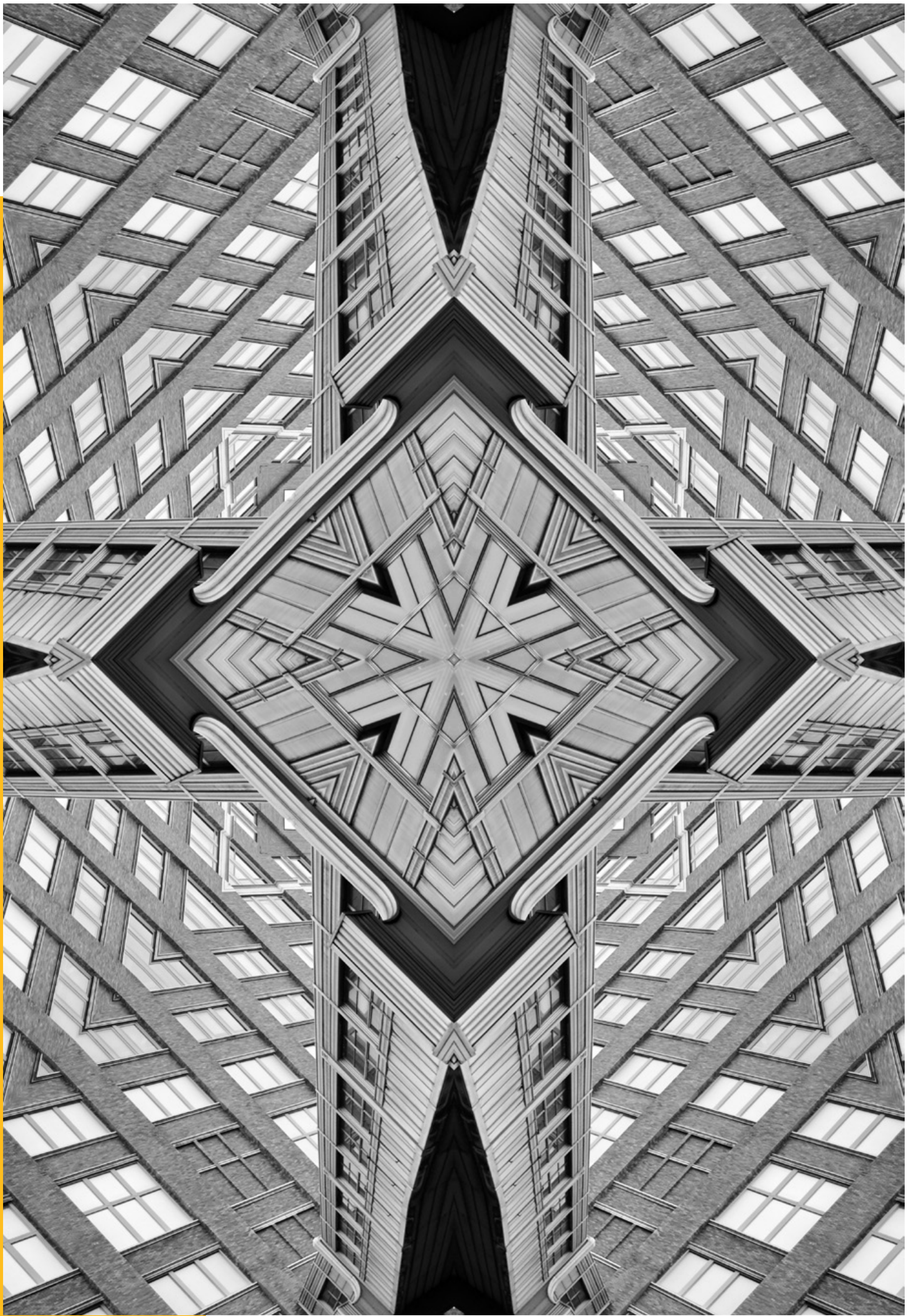

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The Role of the State in Facilitating an India-First Technological Imperative

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Abstract

The role of the state is paramount in incentivising and facilitating a continental-scale indigenous technology and intellectual property development ecosystem in India. The world's two largest economies, US and China, have amply demonstrated the payoffs of this approach through tangible socio-economic development. This paper documents successful strategies from both economies that India can emulate in its own context. It argues that multiple technology verticals crucial to socio-economic development and future-oriented growth engines will benefit from such mission-driven technology-first frameworks. The paper offers prescriptions for strengthening the state's role in facilitating an India-first technology imperative, and illustrates them in the case of the nascent electric vehicle (EV) technology development cycle in the country.

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Introduction

The Indian economy stands at a crossroads. It has recorded an average growth rate of over eight percent (in US dollars) since economic liberalisation in 1991 (receding recently with the COVID-19 pandemic)—a feat surpassed only by China. At the same time, however, this growth has been driven primarily by domestic consumption; an insufficient emphasis on the development of indigenous manufacturing has made India import-reliant, with trade deficits set to soon outpace domestic consumption-driven growth.

Over the years, India has proven itself to be an agile technology adopter and developer, given the right circumstances. Its pioneering digital public goods system, India Stack, has delivered digital and financial inclusion to the country's 1.39 billion (bn) people in less than a decade. In 2020, faced with global supply-chain disruptions during a pandemic-induced rise in demand for health equipment, India ramped up the design and production of personal protective equipment, N95 masks, diagnostic kits, and respiratory aids—going from almost-zero to near-export volumes in three months. The country also has a robust pharmaceutical manufacturing base, which has helped it remain self-reliant in troubled times and provide timely aid to other nations, for instance, through the COVID-19 vaccine programme. However, India has not invested nearly as much as needed to maintain a technological edge across all sectors. Large-scale imports are currently essential for meeting the population's needs for cutting-edge technology in electronics, medical equipment, defence, automobiles, and energy equipment. Moreover, even when domestic manufacturing fulfils a large portion of the demand, the technological designs are primarily foreign. This situation is untenable from the economic standpoint (soaring imports and patent license rates), as well as those of resiliency (foreign players dominating the cutting-edge) and national security (low defensibility, due to the dependence on other nations to meet domestic demand).

Today, a technological edge—or the lack of it—can make or break a country's socio-economic progress; indigenous technology development/production is a proven way of staying self-reliant and resilient. It is a daunting commitment, since fundamental scientific development and productionisation require long-term funding, long runways for validation and go-to-market strategies, and massive upfront CapEx for infrastructure and equipment investments. Various stakeholders must align to fulfil the vision of the nation's long-term, state-of-the-art technological advancement. At the same time, the state's role is paramount in setting the vision—facilitating it with enabling policies, arranging for the massive investments required, and incentivising other stakeholders to perform their roles.

The US and China: Technological Edge from Active State Facilitation

The United States (US) and China have created unique models for state-facilitated technological advancement that are worth examining and emulating in the Indian context. Both countries invest extensively in research and development (R&D).

United States

Before the COVID-19 pandemic, the US spent[a] three percent of its US$22 trillion (tn) Gross Domestic Product (GDP) on R&D,[1] amounting to approximately US$660 bn annually. Government R&D spending budgets generally enjoy bipartisan support, with a consensus that innovation spending is crucial to maintaining socioeconomic leadership. The US employs 4,500 researchers per million (mn) population[2]—approximately 1.5 mn specialised people who are well-funded and aligned on advancing the US's technological edge. Thus, decades of consistent investment have created multiple innovation engines geared towards high-intensity and continual output.

The US deploys five distinct strategies to maintain its technological edge:

> The US employs 4,500 researchers per million population—all well-funded and aligned on advancing the US's technological edge.

1. **Extensive Public Investment Vehicles**: The US has organisations dedicated to advancing scientific development, such as the Defence Advanced Research Projects Agency (DARPA) and the National Science Foundation (NSF), which have been functional for more than 60 years. They have overseen inventions that would eventually become some of the world's most ubiquitous, and are continuing to support frontier-technology development. The annual DARPA budget of US$3.5 bn is backed by the Department of Defence (DoD), which has a combined yearly funding of US$190 bn for research and procurement alone, enabling investments for prototypes on a large scale and for making the successful ones commercially viable.[3] With the impetus to bring advanced manufacturing back to the US, including critical sectors such as chip fabrication, quantum computing, and

a Cumulatively, including both public and private.

5G architectures, the US Senate passed the US Innovation and Competition Act in June 2021—the law seeks to push the country's ambitions of leading the development of frontier technologies. Under this Act, government tech-development funding has increased by US$150 bn, to a total of US$250 bn—doubling DARPA's budget to US$7 bn and providing an additional US$29 bn to the NSF, supplementing the already budgeted US$52 bn over FY22 to FY26.[4] Specific initiatives such as advancing clean transportation are driven separately, with top-down funding programmes. Not only does the US government invest heavily in R&D but it also expands markets for productionisation and commercialisation, by placing massive procurement orders with American technology companies so they can scale rapidly; this is as crucial as the R&D investments.

2. **Philanthropic Grants and Corporate Investments**: The US channels philanthropic capital and private-sector investment towards developing technology in university laboratories and national research centres. Companies are encouraged to invest in joint research programmes and lead the commercialisation of the ensuing intellectual property (IP), in addition to seeding chairs and professorships in universities. Top-tier schools have titles such as the Charles Schwab Professorship, the Samsung Professorship, and the Robert Bosch Chair, which attract top academic and research talent. Often, these positions are seeded for specific areas—e.g. environmental conservation, materials innovation, and computing systems—and they tend to become synonymous with technological advancement in those domains.

3. **Comprehensive Systems of National Research Laboratories Spanning Different Technologies**: Following the Second World War, and during the Cold War, the US set up a commendable range of research laboratories. Most departments and agencies such as the DoD, NASA, and the Department of Energy (DoE) have dedicated research centres and laboratories. The DoE has integrated 17 of these into a National Laboratories System that commands breakthroughs in areas such as material sciences, supercomputing, medical treatment methods, and spacecraft technology.[5] Further, the competition between these labs spurs the evolution of the frontiers of their respective research areas. They also routinely partner with industry; for example, two DoE national laboratories have announced a joint research agreement with ExxonMobil, including a US$100-mn investment over 10 years.[6] Collaborations such as these yield extensive dual-use technologies that both the state and the private sector can deploy, while also reducing taxpayer burden for research and enabling government laboratories to remain at the cutting-edge of technological advancement.

4. **Extensive Non-Term Grants to University Laboratories with Long-term Focus**: Grants with terms attached to them succeed only in bounded research; facilitating unbounded research is why the US routinely pioneers new technologies. The NSF, DARPA, and other grant-making organisations allocate considerable budgets to university laboratories for conducting open-ended research on technology verticals. The development of frontier technologies requires exploration and continuous expansion of what is possible. These necessitate non-term funding, large grants, and an expansionist mindset with the patience to play the long game. Most modern ubiquitous technologies—such as cold fusion, drone imaging, GPS, the internet, and satellite technology—are results of non-term funding from decades ago.

5. **Light Policy Touch**: The US has pioneered a first amongst public–private research modalities. With a light policy touch that accompanies its capitalist orientation, the paradigm to obtain technological supremacy is built upon a positive feedback loop of attracting the best people and investing long-term capital for the most challenging problems that need solving. The system has greatly eased the process of getting products certified, starting companies, attracting global capital to invest, incentivising investments via capital gains reductions, and listing companies successfully on their capital markets. This approach sets clear objectives, makes resources and capital readily available, promotes the active immigration of the world's best talent, is flexible on the needs of rapidly evolving technical models, and is biased towards creating wealth for all involved while prioritising national security.

> "The development of frontier technologies requires non-term funding, large grants, and an expansionist mindset."

These five distinctive strategies have placed the US at the top of the technology development leader board. Fifty years since the Second World War, the country now leads the world in state-of-the-art technological development, and no European country can compete. It has also outpaced Japan after the 1990s. Thus, on the strength of its innovation engines, the US is now the wealthiest economy in human history.

China

China remains the only country to have successfully replicated the depth of the US model of strategic public investment in R&D. By adopting and deploying the best strategies relevant to its context, China has achieved what the US has—and in half the time.

Since its liberalisation in 1978, led by Chinese President Deng Xiaoping, China has strategically deployed the transformative power of indigenous technological and IP development through various strategies described in the following paragraphs.

1. **Massive Public Investments**: China's spending on R&D hit US$378 bn in 2020, amounting to 2.4 percent of its GDP.[7] The government's focus on innovation spending has resulted in the setting up of 522 national laboratories and 350 national engineering research centres, the funding of 457,000 projects, and the grant of 3.6 million patents in 2020 alone.[8] China is focusing on fundamental sciences as well as self-reliance in critical technologies such as semiconductor chip fabrication, 5G architectures, life sciences and medical devices, clean energy and EV technology, and artificial intelligence (AI) and quantum computing. The current strategy is clear: leading the innovation pipeline in deep technology and long-term yield areas will result in leading the world.

2. **Researchers**: China has invested massive resources in developing its human capital and has a well-distributed workforce—from labour-intensive industries to hi-tech and specialised functions. The World Bank estimates that the country has 1,000 researchers per million population,[9] which translates to around 1.4 million, on a par with the US. Further, China incentivises its brightest minds to study abroad to specialise in technological development and return to deploy their skill-sets in furthering the nation's technological edge. To this end, it ensures a seamless process for the returnees as well as residents, to set up either research labs with extensive non-term funding or tech companies with considerable equity investments and grants. Both serve as excellent models to focus top talent on indigenous technological development.

> "In 2020 alone, China spent US$378 bn on R&D."

3. **Differentiated Economic Development Zone (EDZ) Model**: Since 1978, China's EDZ model has transformed the nation's outlook and provided an engaging space to experiment with various market models. It has at least 15 different EDZ models:[10] the Special Economic Zones (SEZs) and High-Tech Industrial Development Zones (HIDZs), in particular, have been crucial in elevating China's status as a technology developer. In the SEZ model, districts and zones were encouraged to compete by implementing different models for attracting foreign capital and international tech companies to set up large manufacturing bases. Estimates suggest that by 2015, SEZs accounted for 22 percent of China's GDP, 46 percent of its Foreign Direct Investment, and 60 percent of exports.[11] They have been crucial in creating jobs, accelerating industrialisation and, most importantly, deepening China's technological development. The resultant expertise and know-how have been converted into an effective HIDZ model to commercialise high-tech research output. In 2019, China's 169 HIDZs accounted for 12 percent of GDP and 22 percent of exports,[12] becoming a successful blueprint for state-facilitated technological advancement.

4. **Preferential Policy Frameworks**: China has enacted preferential policies that attract international companies to set up SEZ bases. It utilises these policies to allow domestic companies to thrive in the various EDZs. Tax exemptions for export and manufacturing companies, export tax rebates, upfront capital for starting enterprises, free or massively subsidised utilities and land, and import-duty exemptions for specific industries are some of China's high-impact policy decisions that ensure frictionless manufacturing, with the guarantee of no rule changes and the continuation of favourable terms. These special carve-outs from standard regulations are applied to sectors and enterprises that the state believes are central to its growth strategy, which includes most technology spaces.

5. **20- and 50-year Vision Statements for a Technological Future that exerts Chinese Influence Globally**: China's policymaking takes a long view of world leadership, and has set 20- and 50-year vision statements and national goals. For example, in the quest for clean transportation, China imposed a mandate on automakers requiring that EVs make up 40 percent of all sales by 2030. Recognising that Chinese semiconductor chip firms are notably absent in high-end semiconductor products, the government has laid out an ambitious blueprint to achieve 70 percent self-sufficiency by 2025.[13] In 2017, China's State Council issued the country's vision for AI dominance by 2030 in the "New Generation Artificial Intelligence Development Plan."[14] While there is valid criticism on the ease of attainment and coordination of such a lofty goal,[15] the fact remains that detailed and objective-oriented vision documents such as these serve as a fulcrum around which stakeholder efforts can be rallied.

The US and China: Technological Edge from Active State Facilitation

The US is focused on a top-down and bipartisan commitment to technological advancement and a long-term vision with consistent and risk-aware policies. The state has played a significant role by channelling the required extensive long-term investment but without micromanaging, and while trusting the capabilities of its citizens to innovate across multiple frontiers over decades. The US has also pioneered dual-use, creating technology giants in every industry—i.e., aviation, robotics, semiconductor design, and telecommunications. Indeed, there is bipartisan consensus that government funding and subsidisation of fundamental research at universities and laboratories leads to private-sector profits, which fuels the economy, perpetuates the technology innovation imperative, and ultimately benefits the nation. Moreover, the state is amongst the early adopters and most prominent clients of its companies in every sector—from Google and Microsoft, to Boeing, Lockheed Martin, and Qualcomm. This America-first doctrine has created an enormous pull-effect, making the country's technology companies multi-hundred-billion-dollar and trillion-dollar entities with monopolistic global reach.

Similarly, Chinese technological advancements have been largely state-facilitated. Since its inclusion in the World Trade Organisation (WTO), China has taken every opportunity to invite global IP transfer and manufacturing setup to build its capacities. It has actively incentivised global capital to invest in its technology companies, and to create state-blessed tech oligarchies and walled-garden competition. Consequently, China achieved in 25 years what the US did in 50: it studied the US's trajectory and strategies, selectively applied them in a modern context, and actively created new state-facilitated China-first policies to accelerate its trajectory.

> "The America-first doctrine has made US tech companies multi-hundred-billion-dollar and trillion-dollor entities with monopolistic global reach."

The Role of Public and Private Institutions in India

The Indian leadership has finally committed to indigenous technology development in recent years. The Atmanirbhar Bharat Abhiyan, the clarion call for a "self-reliant India" launched in the wake of the COVID-19 pandemic, recognises manufacturing and technology as critical for such self-reliance. Digital India continues to be expanded and deepened,[16] with new verticals such as health[17] proposed to be on-boarded using the same fundamental India Stack framework. Prime Minister Narendra Modi has announced India's focus on developing indigenous capabilities in frontier telecommunication technologies, e.g. 5G and 6G.[18] Recognising the global shortage of semiconductor chips as a critical economic crutch, the government launched the INR 76,000-crore Design Linked Incentive (DLI) scheme to start greenfield semiconductor and display fabs.[19] Motivated to move away from its dependence on China for Active Pharmaceutical Ingredients (APIs), the government launched the Production Linked Incentive (PLI) scheme for domestic manufacturing of bulk drugs and APIs,[20] fostering R&D investments to pursue economic and innovative production technologies. There are many such examples, especially in the recent half-decade, of the Indian state mobilising resources and setting tangible goals for self-reliance in technology development and deployment.

However, these announcements and scheme launches are often not proactive. They also lack the targeted commitment to technology leadership that the US and China have fiercely internalised. Notably, the drive to own the fundamental R&D and IP pipeline is missing, and India is yet to match the budget heft of the US and China in its investments. Moreover, while the plan to institute the National Research Foundation (NRF) with INR 50,000 crore in outlay over five years has been announced in successive Union Budgets since 2019, it has yet to materialise.

In India, investments in technology are often seen to be at the expense of socioeconomic development and poverty reduction. However, such a view overlooks the role of an India-first technology imperative as fuel for future socioeconomic growth. It is no coincidence that the US and China are the world's top economies today, given their commitment to cutting-edge technological advancement and the intentional creation of massive innovation engines. In both countries, the state and private players play specific roles. Each sector has certain competitive advantages, and both countries have built systems that play to these strengths. There is also carefully demarcated ground for focused public-private partnerships (PPP) in areas where neither the state nor private players alone can implement the necessary budgets and agendas.

India can study these and implement structures that similarly play to the strengths of the state, the private sector, and PPP. The interplay between the state and the private sector in India suffers from the legacy of a complicated past governed by colonial rule, aggressive socialism, economic liberalisation, and quasi-capitalism. Critical sectors still suffer from the handicaps of vague boundaries between state and private players, excessive regulations that hamper Indian entrepreneurship, unfavourable taxation regimes that discourage domestic capital investments, the state designing technology and leading the production in areas where private players can perform more efficiently (like insurance and defence), and a lack of policy and tax incentives for technological development.

The following are some lessons from the US and China that India can actively deploy to support India-first technological advancement:

1. **Role of the State:** The state's foremost role in driving technological advancement is setting vision statements that all stakeholders can align with and formulating clear policies to facilitate their realisation. In India's case, the vision is to develop and deploy indigenous technologies for the welfare and economic prosperity of the citizenry. Citizens, entrepreneurs, scientists and technologists must see the state publicly commit to building a tech-first future for India. The state, for its part, can create a conducive atmosphere for technology development with every tool in its arsenal, including capital commitments, IP development frameworks, tax incentives, advance procurement of critical materials, a decadal commitment to stability in taxation, export-import policy consistency, and investing in world-class research infrastructure. Since deep technologies require long-term investment to commercialise, the state would do well to begin the process soon. Most importantly, the state must trust the capabilities of technology developers and give them the playing field they need to stay apace with their counterparts in the US and China.

2. **PPP Models:** For premier technology development and commercialisation, there are several intersections where India can successfully deploy PPP models. For example, the newly instituted National Research Foundation (NRF) can deploy massive non-term grants to academic research institutes for IP development. India needs at least 20 more grant-making organisations such as the NRF for specific verticals and end-use cases. Private universities, colleges, and public institutions can utilise these grants to conduct research in the interest of the Indian economy. Moreover, large philanthropies and companies can be invited to seed chairs and professorships at research institutions to oversee the research and IP development. These investments will be crucial in incentivising the reverse migration of Indian technologists settled abroad, to build indigenous technology in India. Private companies in their respective technology spaces can be invited to enter research joint ventures with academic and research institutions, both government and private. Technologies that have a bearing on governance and national security, and can also be commercialised, may be developed in dual-use

mode jointly with private companies, with the specific understanding that the company has the right to commercialise the technology in various markets while the government or military uses the technology for governance or national security. Dual-use models can be utilised significantly in India, just as it is used in the US, and are increasingly becoming essential for national security and defence.

3. **Private Sector**: India's private sector has served as a growth engine for the economy, especially since the liberalisation of 1991. It contributes over 80 percent to GDP growth, 90 percent to employment, and 75 percent to gross capital formation.[21] Therefore, the government must focus on opening up further and harnessing the full might of the private sector for technological development, productionisation and commercialisation, and large-scale manufacturing. Both the US and China have successfully demonstrated the value proposition of doing this. In addition to the policy/tax incentives and PPP models discussed earlier, the state and Central governments can encourage the private sector by placing large-scale procurement and installation contracts with these companies. Continued deregulation of industry, removing the need for licences for routine functions, expediting land acquisition for operations, and building quality infrastructure are some ways in which governments can fuel the growth of the private sector. It is also important to remember that not all technological revolution is built solely on hi-tech advancements: for change to propagate to every stratum of the society, many low-tech install bases are required. For example, in the telecommunications revolution, the *kirana* store owners played a significant part by facilitating cell phone charging, prepaid recharge, ringtones, and other value-added services, making telecommunication services easily accessible to bigger populations. A massive flow of revenue continues to the *kirana* store owners, supplementing their incomes. Thus, for fast adoption and dissemination, the state should encourage and incentivise bottom-up transformations in the private sector—both hi-tech and low-tech—in other technological areas as well.

> "The state must give tech developers the playing field they need to stay apace with their counterparts in the US and China."

The following section explores the strategies outlined above in the context of India's EV sector.

Case Study: India's EV Industry

Of the many sectors that can benefit from indigenous technology and supply chain development in India, electric vehicles (EV) is currently most significant. It is now globally acknowledged that EV is the future of transportation. Since road transportation contributes to three-fourths of worldwide vehicular emissions, installing large EV install bases will be crucial to meeting the COP26 commitments, as part of which, India has committed to reducing its carbon intensity down to 45 percent by 2030, including 1 bn tonnes of carbon emissions from the total projected emissions.[22]

A crucial advantage of rapid EV adoption in India will be its contribution to the country's self-reliance: India's most challenging balance-of-payments problem is large-scale crude oil imports. The debt obligation stands at INR 1.3 tn over the next six years,[23] which may only worsen as Indian domestic consumption continues to rise. Additionally, India has a significant advantage in terms of the install base of internal combustion engine (ICE) cars, with only 50 million compared to the 200 million in the US and 150 million in China. On a per-capita basis, India's numbers are minuscule. About 84 percent of vehicles in India are two- and three-wheelers, which are much easier to convert to EVs and are closer to economic parity with ICE vehicles.

Compared to the developed world as well as China, India can leapfrog over the ICE and go straight to EV, just as it did with fixed cable telephone and wired broadband to directly adopt mobile and wireless internet. However, to capture this opportunity to reduce reliance on imports and develop the capability sustainably, India must invest aggressively. While the US and China are leading the way in EV technology, no country has yet emerged as an unbeatable leader in the space. With proactive investment in innovation, R&D and incentives-based manufacturing, India can take up this mantle while also becoming a technology provider to other nations.

To become an EV technology leader in the next 10 years, India needs each stakeholder to undertake specific roles in growing the ecosystem, right from technology development to production and adoption. The entire fleet of road vehicles must be rapidly converted; this includes two-wheelers, three-wheelers, light commercial vehicles, heavy commercial vehicles, and buses. Finally, the deployment of resources and the mandates of the government, private players and public institutions must be planned carefully with a 10-year roadmap.

Case Study: India's EV Industry

The Role of the Government

While the Indian policy setting has considerably oriented towards EV adoption on paper, there is a lack of the implementation heft needed to back it up with massive investment and policy incentives. The National Electric Mobility Mission Plan (NEMMP), launched in 2013, set an ambitious target of seven million EVs on the road by 2020, but the number of EVs on the road today is lagging substantially behind this target. However, India's efforts so far have successfully created a momentum for EV adoption in the country.

In 2015, the National Automotive Board launched FAME Phase I (Faster Adoption and Manufacturing of Electric Vehicles) with an INR 9-bn outlay.[24] Both NEMMP and FAME I channelled the energy towards creating a broader ecosystem for the manufacture and adoption of EVs. Backed by the policy push, Original Equipment Manufacturers (OEMs) started showing active interest in launching EVs. Riding on this momentum, the government launched FAME Phase II in 2019, with a total outlay of INR 100 bn over three financial years—INR 15 bn in FY20, INR 50 bn in FY21, and INR 35 bn in FY22.[25] Approximately 86 percent of this comprise demand incentives for retail and fleet purchases as well as public transport EVs.[26] On the infrastructure side, 2,636 charging stations are planned in metros, urban conglomerations, and highways.[27] This policy push can help subsidise adoption until EVs reach purchase parity with ICE vehicles and spur more OEMs to offer electric variants.

FAME works to incentivise the demand side. To advance the supply side, the government launched the National Mission on Transformative Mobility and Battery Storage (NMTMBS). The NMTMBS is centred around Phased Manufacturing Programmes (PMP) for localising production across the EV value chain, starting with giga-factories for battery and cell manufacturing. State governments are now taking the lead with different models for driving full-stack battery manufacturing and vertically integrating it into EV manufacturing.[28] When these plans come to fruition, the domestic cost of the EV will reduce considerably. The critical component here is building expertise in developing Tier-I battery technology.

However, FAME-II's outlay, at INR 100 bn (US$1.3 bn), is much less than the US$60 bn that China spent on jumpstarting its EV industry between 2009 and 2017 alone.[29] The Indian government must take a leaf out of the US's and China's playbooks to incentivise creating technology giants that can make multi-sector investments. Currently, China is the largest EV market, accounting for roughly 50 percent of global sales.[30] An estimated 46 percent of EV sales in China in 2018 were for the public sector.[31] In addition to providing demand incentives and public-sector procurement, China has mobilised large sums of public and private capital into EV technological advancement. Xiaomi is the latest private company to enter the EV race in China, with an initial US$10-bn investment in a market with hundreds of companies competing for a share.[32] The trend of technology companies, whose incumbent business may not revolve around the automobile sector, placing large bets on the EV market signifies the evolving and all-encompassing nature of technology development: leading the technology edge allows companies the flexibility to enter and dominate new technology verticals.

India's planned investment of INR 100 bn does not adequately incentivise the development and productionisation of technology required to compete in the global EV market. Domestic OEMs require an enormous boost to compete with EV-forward foreign auto companies such as MG and Hyundai. Further, the amount is insufficient to convert the whole fleet, including 2W/3W/4W, light/heavy commercial vehicles, and buses. It is also important to view India's current inadequacy in the global context, wherein President Joe Biden has announced a US$174-bn budget towards transforming the American electric car market alone.[33] This includes purchase rebates and tax incentives for customers to buy EVs made in the US, along with grant programmes for state and city governments and private companies to build a network of 500,000 chargers in this decade.

> "Leading the technology edge allows companies the flexibility to enter and dominate new tech verticals."

Worldwide, EV development has become the proverbial chicken-and-egg conundrum. Since it starts as a small market, organic incentives for technology development and productionisation are slight until the market expands, which can only happen when new technologies and products enter the market. Therefore, a top-down government push is essential, making the state's role paramount, as China has demonstrated.

1. **Setting Technology-Focused Policy Incentives**: While India has already taken initial steps towards EV adoption with FAME I and II, the state must push more aggressive manufacturing and technology development incentives. Most policy incentives today are geared towards consumer adoptions, such as state-wise subsidies, tax deductions on EV loans, and the reduction of the GST component for EV purchases,[34] with consumer

incentives in FAME II being predicated on Li-ion batteries with higher battery capacity, enabling pro-consumer features and product parameters. However, these policies do little to support tangible technological advancement. India needs a sweeping overhaul of road and transport taxation that gives every segment—from long-haul to micro-mobility—clear incentives to start planning for the adoption of EVs. For example, one of the industry expectations for accelerating e-mobility adoption is fixing the inverted duty structure for EV components such as batteries and charging and swapping services.[35] The administration must proactively sift through all the applicable tax and duty structures to identify and correct such irregularities, in addition to providing tangible tax incentives, to simplify the process and incentivise manufacturers. Alongside a Central government mandate, individual states must adopt the evolution of their jurisdictions on priority.

2. **Advance Procurement of Critical Metals and Rare Earth Elements**: The state's role is to forge multilateral agreements to secure essential supply chains and commit to advance procurements of critical materials. For EVs, this means rare earth elements and metals such as lithium, nickel, and cobalt, which are at the core of battery chemistry and design. At present, India is heavily dependent on global supplies for these materials. China has been securing multiple supply chains for more than a decade and now controls, directly or indirectly, 70 percent of the world's lithium supply and significant sourcing and processing of rare earth elements.[36] It also produces 75 percent of the permanent magnets—another vital component of the EV motor that uses rare earth elements.[37] The Indian government has taken the first steps by creating "Khanij Bidesh India," an INR 100-bn ($1.3 bn) joint venture (JV) between three state-owned companies, to secure sourcing for critical materials starting with South America.[38] Direct access to these materials will serve as a tremendous boost to domestic OEMs. In turn, an indigenous EV ecosystem will provide leverage to further secure large-scale contracts. The state must secure multiple such agreements for critical materials across the EV value chain to mitigate single-source risks and adapt to global shortages.

3. **Inviting Battery Makers**: China is investing billions in indigenous battery manufacturing, and Chinese companies such as BYD and CATL have taken the top five global positions in the business. It is estimated that 107 of the 142 global lithium-ion battery mega-factories under construction are in China.[39] However, non-Chinese Asian incumbents such as Panasonic (supplier to Tesla, Honda and Ford), LG Chem (supplier to Hyundai, Tesla, Volkswagen and Volvo), Samsung SDI (supplier to BMW, Volkswagen and Volvo), and SK Innovations (supplier to Volkswagen, Kia and Daimler) continue to lead the innovation edge.[40] Indian policymakers must make every effort to invite these Tier-I battery giants to set up giga-factories in the country, with attached R&D centres.

4. **Disincentivising Petrol/Diesel Sensibly**: Faster EV adoption necessitates both incentivising the buying of EVs and disincentivising petrol/diesel. The government has already placed hefty tariffs on petrol and diesel, which serve as practical tools, but only when combined with tax incentives to build the supply side of EV technology. The state is working towards this to some extent; for example, the GST on EVs is only five percent compared to 28 percent for ICE vehicles. However, if indigenous technology development is not incentivised properly, the sector will continue relying on global supply chains and imports. Consequently, the disincentives on fossil fuels will only benefit international suppliers.

> "Khanij Bidesh India will secure sourcing for critical materials and serve as a tremendous boost to domestic OEMs."

5. **Improving the Power Infrastructure**: There is considerable variation in the charging requirements of 2W, 3W, retail 4W, light commercial vehicles and heavy commercial vehicles, and buses. The battery capacities vary, as do charging times and whether chargers operate on high voltage AC. Thus, different solutions will be required for residential charging, depot charging, and charging in commercial establishments (e.g. shops, malls, and parking areas). Establishing public charging infrastructure will be crucial to driving EV adoption. China has shown the way by building dense charging infrastructure that has kept ahead of EV adoption. India has almost-zero public charging infrastructure. While the Government of India has planned nearly 2,700 chargers, it must drive a much larger ecosystem to make the EV dream a reality. A critical part of this will be to incentivise grounds-up technology development for charging to serve the unique Indian use-cases.

PPP Models for EV Technology Development

Batteries constitute 40 percent of the EV price, not including the import duties and patent licences. Thus, indigenous battery technology is critical to a thriving indigenous EV technology development ecosystem. There is substantial ongoing research connected to batteries where India can take a leadership position—cell form factors, novel variations of Li-ion batteries that utilise materials India can procure more efficiently, new battery chemistries that move away from Li-ion altogether (e.g. metal-air, Li-metal, Li-sulphur, organic batteries that replace the need for metals, supercapacitors and solid-state), and sustainable battery recycling methods.[41] Since India lacks significant technology development, these are generational opportunities to drive a step-function leap forward and install new frontier research hubs.

EVs also present other R&D and technological development opportunities. EV motors and controllers are significantly different from those used in ICE vehicles—this necessitates the development of new technology. Moreover, EVs use entirely new components such as AC-DC converters, DC-DC converters, inverters and onboard chargers, control unit architectures, and e-axles. The larger EV ecosystem also requires R&D for new fast-charging capabilities that need to keep pace with the EV technology development. Technological development for these components requires significant investment. While the private sector can lead this effort in multiple ways, the government must set the long-term vision and provide upfront capital investment.

In India, PPP models have already been successfully employed across industries. The unique multi-platform initiative India Stack was built, and continues to be expanded, by an enterprising partnership. Deep-science sectors, such as advanced cell chemistry research, are steadily being incorporated into the government's PPP frameworks. It is time for India to accelerate the pace, to keep up with the innovation engines in the US and China.

There are five pillars to harnessing the power of PPP towards EV technological development and manufacturing:

1. **Non-term Grants to Academic Research Institutes for IP Development**: India's Top 100 academic institutions concentrate exceptionally qualified human capital and must be incentivised to become massive generators of world-class IP. To this end, extensive upfront investments are required, especially in deep-science sectors such as energy, batteries, and materials engineering, to buy the necessary equipment and employ specialised

researchers. However, most Indian grants do not provide this upfront cost, often causing India's top researchers to leave the country for better opportunities. Countries such as the US and several European nations offer non-term or non-lapsable grants that provide research teams with the capacity to set up state-of-the-art laboratories with top-class equipment and hire the best talent to tackle significant problems such as battery energy density and new materials research. Following the example of the US and China, which have already demonstrated that the only way to mass-produce quality technological IP is via its academic institutions, India must now prioritise the development of its academic institutions as innovation hubs.

2. **Philanthropies/Corporations to Seed Chairs and Professorships**: The Government of India must incentivise philanthropies, corporations, endowments, and foundations in the country to seed chairs and research professorships for EV technology development. Large philanthropies will benefit from supporting technological advancement towards clean energy initiatives in India, and corporations in the energy and automobile sectors from funding research that they can utilise in their commercial operations. With its announcement that Corporate Social Responsibility (CSR) funds can be channelled towards R&D,[42] the government can invite companies to utilise CSR funds for research to seed chairs and professorships for EV technology development. These funds can also be used to provide prestigious scholarships for Indian students going abroad to study EV technology, who will then return to set up laboratories for technological development. Instituting professorships for which such returning scholars can compete will be an added incentive.

3. **Joint Research and Commercialisation with Academia**: EV-specific technologies such as new battery chemistries, motor and controller architectures, and fast-charging modalities together present a market opportunity of INR 150 bn by FY25 in India alone.[43] Automakers and battery manufacturers are keen on developing new technology. With adequate push from the government, academic institutions can position themselves as worthy partners for joint ventures with companies, to explore new frontiers, with the former providing the research methodology and the latter, industrial expertise. However, Indian companies have rarely had the opportunity to partner with academia for technological development, with only the top 50 universities and colleges in India—particularly, the "Institutes of National Importance"—being worthwhile candidates for such partnerships. The patent lack of non-term grants for funding deep-technology research impedes the development of research teams and expertise in academia. The government must offer non-term grants as discussed above, to build expertise and incentivise research JVs between companies and academia.

4. **Joint Research and Commercialisation with Public Research Institutions**: Today, public research institutions such as the Defence Research and Development Organisation (DRDO) and the Indian Space Research Organisation (ISRO) are mainly developing their technologies in silos and subsequently releasing Requests For Qualifications (RFQs) for industries to productise the technology. For example, the ISRO released an RFQ to productise the Li-ion batteries they designed for space applications.[44] This was developed several years ago, using only the taxpayers' money. Since it is only now going out for productionisation, the process will take longer, because the technology must be reformatted into the required form factor and other consumer specifications. This is reminiscent of India's erstwhile socialist era and not only creates redundancy but also wastes taxpayer money. These institutions must instead formulate JVs with companies to jointly develop dual-use technology, incorporating productionisation for commercial operations from the very start. Thus, it is crucial for the government to incentivise these ventures and encourage the development of dual-use technology.

5. **Dedicated PLI schemes for EV-Related Manufacturing**: Indigenous technological development is ineffective in a vacuum and needs manufacturing and production pull-effect to deliver its full value. The "Make in India" initiatives have demonstrated some success in this regard. For instance, in 2014, India was racking up mobile import burdens worth US$8 bn. 'Make in India' has not only reduced this mounting mobile import burden but also created export surplus volumes. Today, the nation exports worth US$3 bn[45] and is the second-largest mobile manufacturer globally.[46] Following this success, Production Linked Incentive (PLI) schemes were launched for 13 critical sectors, including advanced battery cell manufacturing, with an outlay of INR 18,000 crore to set up a total manufacturing capacity of 50 GWh. Twenty companies, including Reliance, Ola Electric and Tata Chemicals, have reportedly expressed interest in the PLI scheme.[47] The administration has realised that incentives linked to value creation and exports spur indigenous manufacturing. Thus far, indigenous manufacturing efforts have mostly worked for low-value sub-assembly; the long-term need is to incentivise full-stack design and manufacturing schemes across the country to build true indigenous sufficiency. The PMP scheme for EVs must be expanded into a full-scale PLI programme for each major EV component. If done promptly and in alignment with the nation's vision of an energy-independent future, India's EV industry can replicate the success of its 2W auto giants and become an export powerhouse for other emerging economies.

Private Sector: Leading Investments

Today, the leading edge of investment in EV technology development is the private sector—specifically, startups. While most established automakers and OEMs are focused on building vehicles with imported technology and components, startups such as Ola, Yulu and Ather are developing new technologies that can drive EV adoption in the country.

Different vehicle segments in India have wide-ranging parameters for electrification, and each will expect a different inflection point in adoption. Startups in the 2W and 3W segments are seeing the fastest adoption but face challenges in upfront cost, despite having a favourable total cost of ownership (TCO). Light commercial vehicles are most used for intra-city logistics, and there is a solid case to be made for them to go electric as quickly as possible. Since mass demand for buses is still perceived to be led by public transportation requirements, startups do not expect initial traction in this segment. Similarly, the adoption for retail 4W will be significantly delayed, since most car sales in India are still under the INR 1 mn range, where EVs cannot yet compete. Consequently, fleet operators are expected to lead the first wave of demand, since the electric car TCO is far more efficient. Over 20 percent of the 4W fleet market is expected to be electric by FY25, driving the startups to focus more on this use case compared to retail.

Ola leads the charge among startups towards an EV future. Its 35-year-old founder announced Ola's 2W plan with a US$300-mn equity and debt raise and the launch of its 500-acre mega factory in Tamil Nadu in early 2021.[48] The "Future Factory" is amongst the most extensive two-wheeler facilities globally. At full capacity, it is designed to manufacture over 10 mn scooters, constituting 15 percent of the world's total 2W production. Ola has also decided to enter the 4W race, with a global design centre in Bengaluru solely focused on the PV (passenger vehicle) segment.[49] Its 4W plans may also include an offshoot platform to cater to fleet operators.

In addition to its manufacturing ambitions, Ola has committed to setting up a hypercharger network across India—taking a leaf out of the Tesla and Chinese EV playbook. It aims to install more than 100,000 stations across 400 cities over five years, which could support both the 2W and 4W platforms. Being one of the most prominent mobility startups globally, Ola's ambitions are well-placed, considering the perceived value of the total addressable market as well as that to be extracted by being first to market in India. The confidence that Ola's multi-hundred-million-dollar fundraise has lent to the EV story is palpable in the startup community, already stimulating the incumbent auto OEMs to announce their own grand designs to enter the EV race. TVS, for instance, jumped on the bandwagon recently, announcing a JV with BMW to develop EVs.[50] Top automakers such as Tata Motors and Mahindra and Mahindra, too, have launched aggressive plans to capture market share while battling foreign companies such as Hyundai and MG, which have long-range EVs already available.[51]

Yulu, now the country's largest last-mile EV network operator, typifies another exciting model led by startups in the EV space. With over 10,000 micro-mobility electric scooters online, this approach allows end-users to rent a bike within seconds on the app and hop from point to point within the city.[52] This on-demand self-driving model integrates EVs, IoT, and intelligent operations to give urban commuters a flexible option to rickshaws, taxis, and other last-mile ICE alternatives. Yulu recently announced plans to raise additional equity and deploy another 10,000 units of their new custom-designed 2W for delivery fleets.[53] Companies that offer food delivery and hyperlocal services, such as Swiggy, Zomato, and Dunzo, plan to evolve their fleets from ICE to EV aggressively. Amazon India is working with several automakers—Mahindra Electric, Hero Electric and EVage[54]—while aiming to have 10,000 EVs deliver parcels in India by 2025.[55] Yulu and other similar companies plan to cater to this demand and grow a multi-use EV network in parallel. Now backed by Bajaj Auto, Yulu will likely have a role in the incumbent's entry into this segment.[56]

Some startups are also attempting other models in the EV space. Ather, for instance, has taken the full-stack OEM approach to design a premium electric 2W from the ground up and will now expand its retail network nationwide through auto distributors. Companies such as Exponent Energy are attempting to compress the charging cycle for large battery packs used by LCVs from eight hours to 15 minutes.[57] Others are helping *kirana* retail store owners in urban areas to add an EV charger to the services they provide to their customers.[58]

> Startups such as Ola, Yulu and Ather are developing new technologies that can drive EV adoption.

Case Study: India's EV Industry

Between 2019 and 2021, Private Equity and Venture Capital investors have channelled over US$672 mn into the Indian EV sector.[59] However, while it is admirable that entrepreneurs are taking up the mantle for EV technology development, this alone will not lead to systemic change, especially if India must switch to EV within this decade. It is unsustainable for frontier technology developers to be the largest investors in EV technology development: the most reliable path forward is to drive the transition via state facilitation, as done in the US and China.

The EV story does not need to remain restricted to the hi-tech companies; indeed, the ecosystem will require a large install base of low-tech support. Just as a new economy was formed when *kirana* stores took up cell phone charging—prepaid, ringtones, and other value-added services—during the telecom revolution of the mid-2000s, EV charging can serve as a new revenue generator for offline retail stores. The industry could support a whole new lane of micro-entrepreneurship for charging, battery swapping, fleet management and repair, recycling, and more. The potential for bottom-up transformation is another reason the state must seriously support the acceleration of this industry.

All cities and states must partner with startups and invest in nurturing their development. Yulu has partnered with city governments to install charging zones and dedicated bike lanes along major urban routes. Ola has partnered with state governments to set up some of the largest EV manufacturing sites in the world. This is a start, but to achieve the scale of transformation needed in India, the country requires hundreds of such startups to develop the frontier of EV adoption. Tesla, now the world's most valuable EV company, famously received a US$465 mn loan from the state of California to build its manufacturing plant in Fremont.[60] While at the time this was perceived as chasing fool's gold, not only did Tesla repay the loan (with interest) in three years but the US also scaled a leading global EV company in the bargain.

Innovation tends to surprise most industry observers but is always apparent in hindsight. The Indian government must not miss this generational opportunity to partner with startups, nurture them into category creators, and set a new example on how the country can leapfrog technological cycles to aim for truly inclusive prosperity.

Conclusion

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There is no substitute for active state facilitation of frontier-technology development—this is demonstrated by the trajectories of the US and China. A country of India's size cannot afford to oscillate on this matter. While this paper has examined the importance of state-facilitated technology development in India's burgeoning EV industry, many other critical sectors require similar massive and continuous investment, regulatory decongestion, positive reinforcement loops between various stakeholders, and most importantly, the patience to play the long game.

If the Indian state machinery starts the process with a complete focus on technology domination today, the results will be evident in a decade in the form of world-class R&D, hundreds of companies competing to outpace each other in IP development, state-of-the-art research laboratories in universities, and a wildly successful export industry catering to global demand for top-tier technology. The Indian government must now set the top-down tone for a decadal step-function leap.

"India's critical sectors require massive and continuous investment, regulatory decongestion, and positive reinforcement loops between stakeholders."

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