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China's Rise to Dominance

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Using a variety of strategies over the past quarter century, China has achieved dominant global position in an ever-expanding list of industries. It has now moved from a rule-taker to rule-maker. How China acts and how the West responds will shape international affairs for decades.

By far the most important geo-economic development of the first quarter of the 21st century has been the rise of China as a manufacturing, trading, and now technological power. In 25 short years, the country has increased its share of the global gross domestic product (GDP) to 17% from 4%. Over the same period, it has increased its share of world merchandise exports to 15% from 6%. China dominates global manufacturing activity even more, having overtaken the US as the world's leading manufacturer in 2010, and now enjoying a one-third share of the world total.

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That is broadly comparable to what Great Britain enjoyed in its imperial pomp of the late 19th century, before the rise of Germany and the United States, and comparable also to the dominance that the US commanded immediately after World War II. More significantly, China in the last decade has caught up with the US and others, taking market (and increasingly technological) leadership in virtually every industry of the future, whether it is clean energy (solar, wind, and also nuclear), electric vehicles and batteries, robotics, drones, or 5G telecommunications. In electronic chips and artificial intelligence, it has done enough to be a potential threat to current market leaders, and a potential winner.

In most of these, China has achieved costs that undercut rivals. That goes for electricity too, giving it an edge when it comes to the power-hungry data centres that underpin the artificial intelligence (AI) business.

Such a dramatic rise, the full extent of which has only recently come to be recognised in even informed discourse, resonates now through the geopolitical and strategic spheres. The unipolar moment that followed the collapse of the Soviet Union has given way to a world with two superpowers. China is a more multi-faceted challenger to American dominance than the Soviet Union ever was. Countries around the world have felt the strains of adjusting to the Chinese phenomenon, having had to deal with trade imbalances, job losses, a decline in manufacturing competitiveness, the loss of technological leadership, and shifting financial flows.

There have been knock-on effects on not just international relations and strategic calculations, but also domestic political currents and economic ideology. The very countries (led by the US) that were loudest in advocating the virtues of free trade and the primacy of markets have given in to more nationalistic impulses, introduced government subsidies for manufacturing along with arbitrary tariffs, and turned to the once-derided industrial policy.

Three Phases of China's Rise since 2001

With bilateralism replacing multilateralism, the World Trade Organization (WTO) has been hobbled as a global trade arbiter. Ironically, it was China's admission to the WTO in 2001 that helped its continued rise to prominence, as the West miscalculated Beijing's intentions and potential. In the quarter-century since that event, China's rise to global leadership has been marked by three broad, overlapping phases. The baseline in 2001 was that the country had already established itself as an export-oriented manufacturing hub for labour-intensive products that needed relatively simple production technologies. In the subsequent transformations, the first phase saw already impressive economic growth rates accelerate, with a peak rate of an eye-popping 14% in 2007.

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The sharply rising incomes for the billion-plus population created a vast domestic market that attracted the world's leading companies. This plus enormous domestic investment (mostly by the state and state-owned companies in the initial stages) served to establish an unparalleled domestic production base, backed by the most modern physical infrastructure. In a remarkably short period, this gave China global leadership in mainstream industries like automobiles and steel-making, along with trading power because of massive export surpluses.

The second phase has been marked by the transition from leadership in the established industries to a technological catch-up, and latterly leadership, in carefully targeted sunrise sectors identified in the Make in China announcement of 2015. The 10 chosen sectors included robotics, new materials, and aerospace, among others.

The programme has achieved success by adopting a managerial-style approach at the political level. It has relied on technological foresight and the integration of information technology with manufacturing. Subsidised finance has played a key role, along with strong domestic research and development (R&D). These efforts have been further strengthened by effective alignment of policy and regulatory support. Altogether, these measures are aimed at reducing external dependence. This 360-degree approach has created mutually reinforcing ecosystems that can roll out new, cost-efficient products at unmatched scale and speed. This is best demonstrated by the dramatic pivots achieved by Xiaomi, going from mobile phones to internet services, lifestyle products to physical retailing, and most recently to electric cars, all in 15 years of its founding.

The third phase, currently under way, has been a period of intensifying macro-economic and strategic contestation between the established superpower and the challenger, even as the latter seeks breakthroughs in the technologies of the future, not just to copy Western technology or play catch-up. In its full implication, this is a societal and systemic challenge. If the Western response (especially that of the US) is confused or ineffective, the global strategic balance could shift faster than anyone would have predicted just five years ago.

This scenario, of Chinese industrial dominance and societal or civilisational assertion, runs parallel to the quite contrary perception of a troubled Chinese economy. To be sure, growth rates have slowed and may be even slower than the official statistics let on. The population is shrinking. And the manner of the country's rise has led to international resistance, tension, and containment action.

China's GDP ($19.2 trillion) may or may not grow to equal the US ($30.5 trillion), but in terms of per capita income the US is so far ahead (more than $89,000 vs less than $14,000) that the question of catching up does not even arise for the foreseeable future. Even in purchasing power parity terms, US per capita income is more than three times China's. It is also true that the Chinese economy faces structural problems, with troubled real estate and financial sectors, a dangerous deflation trend that has persisted for three years, and provincial governments (often the drivers of change) saddled with heavy debt. The premature talk of the yuan displacing the dollar as an international currency is just that. Finally, the increasingly determined Western attempts at containment will put sand in China's

wheels, especially if trade restrictions prevent the use of large export capacities that then become liabilities-a trend that is already evident in sectors like electric vehicles. An industrial shake-out may therefore be in store even as deflation persists.

Expanding Dominance

While these issues cloud China's future, they do not negate the dramatic changes of the past quarter century, and the reality that China has displaced the US and other advanced economies from their positions of leadership, even dwarfed them, in a steadily expanding list of industries and technologies. Chinese dominance of the renewable energy business is widely recognised, but less so in other sectors.

> German car makers find that Chinese car makers offer equivalent quality at much lower prices, and therefore are downsizing even as they fear the previously unthinkable, a possible wipeout.

When it comes to nuclear power, for instance, China is currently building 30 reactors (half the global total) and plans to add six to eight reactors annually-at costs reported by Nuclear Business Platform to be significantly lower than in Western economies. It is a similar story with industrial robots. The International Federation of Robotics reports that the country now installs as many industrial robots in a year as the rest of the world combined, and six times more than the country ranked second (Japan). China also has by far the world's best 5G cellular telecom network, which will help it in the deploying of artificial intelligence applications at scale and in real time. Similar acquisition of leadership in other critical markets and technologies (like electric vehicles) is changing global dynamics in ways that trump GDP size.

There is now the real prospect of the 21st century coming to be seen as belonging to China, as the 20th century was an American century, and the 19th century was dominated by the British.

The Chinese way of doing things-a one-party state with a "socialist market economy", marked by central direction on goals and system-wide alignment of objectives and actions, yet sufficiently decentralised to leave room for local initiative, and designed to exploit an economy that offers unmatched scale-has already demonstrated its impressive efficacy. If such a system continues to score successes, it would pose questions to more plurally democratic, market-driven "bottom-up" systems, precisely because the Chinese system is basically not replicable.

Consider, for instance, the impact on the world's third largest economy, Germany, which has long been Europe's industrial powerhouse. German car makers find that Chinese car makers offer equivalent quality at much lower prices, and therefore are downsizing even as they fear the previously unthinkable, a possible wipeout.

Germany's chemical and engineering industries face similarly unprecedented challenges. The country's famed *mittelstand*, comprising the medium-sized companies with technological depth and manufacturing prowess that have been the backbone of the German economy, finds that Chinese competitors have moved rapidly from low-cost to high-end manufacture, with cost advantages that are said to average an astonishing 30%, according to the founder of a Frankfurt-based consulting firm, Thin Ice Macroeconomics. Others speak of even greater cost differences. A *Financial Times* report on the decline of Germany industry cites the case of a Munich-based compressor maker looking for a new wire-processing machine. The quote from a Swiss firm was 130,000 euros, while a Chinese firm quoted less than 28,000 euros.

The Centre for European Reform estimates a threat to 5.5 million German jobs and 20% of GDP. The challenge is a systemic crisis because Germany's ability to respond is hobbled by much higher power and labour costs, sclerotic regulations and a general slowness to change. This shows how China's manufacturing prowess and pivotal speed have hardwired its competitive advantage.

The stage was set for China's 21st century transformation a full quarter-century earlier, when it shed its Maoist baggage and decided that to get rich was glorious, a pithy statement usually attributed to Deng Xiaoping, Mao's successor as strongman. The early successes were in low-cost, labour-intensive manufacturing. This mimicked the earlier rise of smaller countries in Asia.

Like South Korea, Taiwan, and others which had demonstrated the route to export-oriented success, China used its factor advantage of low-cost manpower. That advantage survived into 2000 and beyond. Despite rapid economic growth in the 1990s, the country's per capita income at the turn of the century was only one-sixth of the world average. It had an even smaller percentage of the incomes in the developed countries that were its principal markets. By making full use of this cost advantage in a way that a similarly endowed India notably failed to do, China achieved global leadership in the manufacture and export of shoes, clothes, toys, furniture, and knick-knacks of all sorts. Why China was better able to exploit its advantage tells us that there was more at play than just labour costs.

China's Approach

From the beginning of Communist rule, China has shown significant institutional, organisational, and mobilising capabilities that other large countries, including India, did not possess. This systemic strength made it possible for China to implement drastic changes-whether good or bad-in its policies and their roll-out. This stands in stark contrast to India's history of gradualism, where change often occurs at a near-glacial pace.

> Conversations with diplomats who have served in Beijing confirm that the Chinese communist party recruits people from the best universities. Their progress up the party ladder depends very much on their ability to deliver results.

For instance, within a year of Mao asking villagers in 1955 to join rural cooperatives that henceforth would own or farm land collectively, an astonishing 98% of land had been handed over to cooperatives. When Prime Minister Zhu Rongji began a privatisation programme in the 1990s, the number of workers in state-owned enterprises fell rapidly from 110 million to 70 million. While citing these numbers, China scholar David Zweig estimates that 65 million lost their jobs because of the reforms. As for the industrial picture itself, in 1978 state-owned enterprises accounted for 78% of industrial output. By 1996, that had dropped to 31%.

The ability to make sweeping changes can also cause instability of a kind unknown in India. For instance, after Mao's disastrous Great Leap Forward played out, the GDP fell by 27% in 1961, only for growth to recover to an average of 14% from 1963 to 1965, after the campaign ended. Both ups and downs demonstrate organisational and mobilisational capability. Used to better purpose in more recent decades, this has facilitated the implementation and roll-out at scale of new strategies, policies, and methods. This has allowed China to secure pole position in many industries in the new century, even without technological leadership.

Allied with this has been China's ability to deliver on policy objectives by connecting research with its practical application. The country has brought together academia and industry, finance, and a workforce with the required education. These efforts are supported by policy and infrastructure, creating a whole-of-society engagement. Tight feedback loops and continuous innovation have further strengthened this process. All of this has combined with an enormous ambition to be world beaters. For instance, the country has a $140 billion, 20-year plan for global robotics leadership.

Integral to China's approach has been the strategy of crossing the river by feeling the stones. When new policies were put in place after 1978, the red carpet was initially laid out for entrepreneurs and investors in just four special economic zones. When that approach proved successful, the programme was extended first to 12 coastal cities near ports, and then to all coastal areas.

It is true that many elements in the package have distorted the market. The decentralisation of decision-making also led to sometimes counter-productive competition between provinces. As a result, there has been a succession of macro-economic imbalances and structural defects. But Beijing has so far found ways to deal with them, defying decades of dire predictions by Western observers.

In this context, David A. Bell argues in *The China Model* that China's party-state operates a political meritocracy. He suggests this system is superior to electoral democracies in delivering techno-economic-managerial results. Whether this argument holds true in all cases and over time is debatable, and the downside risks of a one-party system are obvious. However, conversations with diplomats who have served in Beijing confirm that the Chinese communist party recruits people from the best universities. Their progress up the party ladder depends very much on their ability to deliver results.

Entrepreneurship

In the standard Chinese playbook, entrepreneurs and companies are welcomed with free or subsidised land, low-cost finance, and cheap inputs like electricity, state subsidies and capital support, plus market seeding through public procurement. Subsidies have of course been an essential part of the story, and crucial to China's industrial success. The majority of industrial subsidies (estimated in 2019 at nearly a quarter of a trillion dollars) have targeted the chemicals, machinery, metals, and automotive industries as well as the sunrise sectors. The full scope of subsidies is difficult to assess because of the many forms in which concessions are given.

> Perhaps more important than technology theft, Chinese companies improved in quality and technological capability by becoming part of global supply chains.

Subsidies are not the whole story, of course; far from it. Rapid economic growth was owed to many other factors. And it is the rapidly growing domestic market that facilitated the transition from being the labour-intensive assembly end of production chains to integration up the value chain. Given its 1.3 billion people, it did not take long in the new century for China to become the world's leading market for cars and elevators, which are seen in its mushrooming residential towers. China has also become the top market for a wide range of electronic and other consumer gadgets, as well as all kinds of machinery.

Three transitions happened along the way. Though international companies like Volkswagen had initial leadership in many Chinese markets, their place was progressively taken by home-grown firms that may initially have been joint-venture partners who learnt by copying. Perhaps more important than technology theft, Chinese companies improved in quality and technological capability by becoming part of global supply chains. This involvement helped them learn, adapt, upgrade, and improve on what they were doing. And, third, it helped that there has been a progressive displacement of state enterprises by private sector firms like BYD and Huawei,

which now dominate the scene.

Key to recent successes has been an ability to anticipate the future and then work quickly to achieve it. The relatively recent success with robots, for instance, traces back to a call for a robotics revolution by Xi Jinping in 2014. There followed a national robotics development plan in 2016. Serious work on artificial intelligence, the latest field in which China is playing catch-up with the US, goes back to it being made a national priority in 2017. The electric vehicles story began even earlier, in the early years of the new century.

These developments have been accompanied by an impressive record of creating new physical infrastructure. The rapid growth of China's superfast train network, for instance, saw the first operating line in 2008 grow in the space of a short decade into a grid comprising 29,000 kilometres of track, making it by far the world's largest such network. This was matched by simultaneous progress from initial dependence on foreign companies for technology and train sets to self-reliance-mirroring similar developments in other fields of enterprise.

China's Supremacy Today

By 2010, after years of record-setting growth, China had emerged as the world's second largest economy, its GDP having multiplied five-fold in a decade, to $6.1 trillion. It had become a manufacturing and trading power with advantages of scale that only the US could match, with the crucial difference that China continued to grow more rapidly than the US as it climbed up the income ladder.

> Chinese companies like Huawei and Xiaomi, BYD and Haier, Tencent and Baidu function with a level of ambition, speed, and determination that matches the dramatic rise of the tech giants of the US.

Today, therefore, Chinese output dwarfs the US in almost every traditional industrial sector, and some new ones. China generates more than twice as much electricity as the US, and it produces over 11 times as much steel and 23 times as much cement. China also manufactures three times as many cars and accounts for well over twice the smartphone sales seen in America. In the global context, China accounts for 46% of the world production of basic metals, 36% of electrical equipment, and 32% of electricity generation. Its shipyards' share of new ship orders has grown from less than 10% in 2000 to 65%, dwarfing the erstwhile leaders Japan and South Korea.

Importantly, its national champions emerge not just through government diktat but also intense competition. As an example, the country has over 100 electric car models in the market. So the winners who emerge are fit for global competition-as was the case in an earlier age with Japanese companies like Sony and Matsushita. Chinese companies like Huawei and Xiaomi, BYD and Haier, Tencent and Baidu function with a level of ambition, speed, and determination that matches the dramatic rise of the tech giants of the US.

Global Disruption

Many countries benefited from China's rise. Markets that were increasingly flooded with Chinese goods saw low prices and an absence of inflation, benefiting consumers. International companies that housed their production facilities in China, even as they shut down facilities in their home countries, enjoyed a boost to their profits that led to outsize stock market valuations, benefiting shareholders. China's sustained growth, at a pace and scale with no historical precedent, boosted global growth and trade. This expansion created widespread effects across the world.

> Much of this was possible, it was said, because China with its single-party political system and state-dominated command economy functioned in ways that Western and other market-oriented economies could not mimic.

So it looked win-win, until it was not. For, as already noted, China's dramatic rise has led to economic disruption in other countries. There has been a hollowing out of several industries in what until China's ascent had been the world's leading industrial powers, and the loss of millions of manufacturing jobs (some of it because of the parallel development of increasing automation).

While the benefits of trade are supposed to be mutual, it slowly ceased to be viewed that way as trade flows became steadily more unbalanced; China now exports 40% more than it imports. Its trade surplus of close to a trillion dollars is more than the GDP of 90% of the countries in the world. Countries and companies that found themselves unable to compete with what was coming out of China complained that the country was not playing by the rules. So the manner of China's rise has provoked resistance and tension. As others saw it, China was subsidising its producers in complex ways that could not be properly diagnosed because of its opaque financial and

other systems. It was practising a mercantilist currency policy by deliberately pegging the yuan at a low exchange level. Indeed, despite the large trade surpluses, the yuan has been losing ground against the dollar.

And it was stealing the proprietary technology of companies that set up manufacturing facilities in the country in mandatory partnership with local entities that then set up their own, separate factories with the technology that they had first got from their international partners. Indian manufacturers complained that Chinese companies were charging less than the bill of materials that went into a product. Much of this was possible, it was said, because China with its single-party political system and state-dominated command economy functioned in ways that Western and other market-oriented economies could not mimic.

That is not the whole story, of course, as becomes clear from a documentary film, *American Factory*, jointly produced in 2019 by Barak and Michelle Obama's Higher Ground Productions and available on Netflix. The film tells the story of a Chinese company, Fuyao Glass, which took over a shuttered factory in Ohio and hired local workers to make windshields for cars-only to find that the American workers simply could not match the productivity levels of workers back in China. Despite cultural tensions and the threat of industrial action, the owners persisted, even sending American workers to study work practices in China. Eventually, the company became a viable entity-pointing to reasons for the decline of American manufacturing that are homegrown and cannot be blamed on Chinese skullduggery.

The film's story line points importantly to a broader shift in work intensity and productivity norms, to which one could add manifest differences in state capacity. These go beyond what can be neutralised through Trumpian tariffs. Looking again at superfast trains, China has laid out two-thirds of all the high-speed rail tracks in the world in the last 17 years. In comparison, California spent $7 billion over more than 15 years, trying to lay a high-speed railway track between San Francisco and San Diego; less than 10% of the track has been laid while the project cost has trebled. Britain, in turn, has had to abandon half of an HS2 project to build a high-speed line from London to Manchester and beyond, stopping short at Birmingham (with less than 200 km of track).

Focus on Emerging Sectors

This history prepares the ground for the second phase of China's 21st century story: its determination, as announced in 2015, to shift from leading established industrial markets to taking the lead in emerging sectors. This shift has been made possible by the business and government foresight described earlier. It has led to what can only be described as industrial coups in many foundational industries of the next few decades, riding on the strategic opportunity presented by climate change and the need to move away from fossil fuels.

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China now accounts for an overwhelming portion, between 50% and 90%, of annual solar and wind energy installation, electric vehicles and their batteries, the materials that go into these, and even the equipment to make these products. Chinese companies are four of the

five largest in the wind turbine business, with the largest being Goldwind, while eight of the nine largest solar manufacturers are Chinese, led by Jinko Solar.

Such dominance has been built on enormous investments in research in all these sectors, to gain cost and other competitive advantages, and mastery (for instance) of the full range of competences required along the entire solar panel value chain from making polysilicon and ingots to slicing them into wafers and wiring the individual photo-voltaic cells before they are packaged into solar modules. Chinese companies have established cost advantages that companies in other countries cannot hope to match for the foreseeable future.

Electrical Vehicles Story

Electric vehicles offer an instructive story on how China turned the tables on Western and Japanese car companies that were still focused on internal combustion engines, by switching its focus to electric vehicles before anyone else. The reliance on EVs was apt for several reasons, for they would reduce air pollution in the cities and reduce the country's dependence on imported oil.

China made breakthroughs in battery technology and acquired scale, which now help it to produce electric vehicles at lower cost than in other countries. The country also laid out a network of charging stations much larger than in other countries, which facilitated the consumer switch to electric vehicles. The end result is that China is able to turn out electric cars and trucks at a price and on a scale that other countries can only dream of doing.

> In another demonstration of China's capacity to drive change and deliver explosive growth, EVs and hybrids went to 48% of the automobile market in 2024 from 6% in 2020 .

Serendipity played a role. Just as Taiwan's dominance in semiconductor manufacturing was made possible by recruiting Morris Chang- who had been passed over for leadership at Intel-China found its equivalent for the electric vehicle industry in Wan Gang. He is now recognised as the father of China's EV industry. Wan had been a victim of Mao's Cultural Revolution, sent off to a village to learn from peasants, before he found his way to a small private university in Germany, Clausthal, to pursue a PhD. He then joined Audi, where he happened to meet a visiting Chinese minister touring the Audi plant. One thing led to another, and before long Wan had moved back to China and become a fierce advocate of electric vehicles. In 2007, he became perhaps the only non-Communist minister in the Chinese government, in charge of science and technology. From that position, he pushed for research in all the technologies relevant for the EV business.

There followed the usual Chinese playbook of coordinated government action focused on a clear goal. Subsidies were handed out for EV companies (up to a handsome $10,000 per vehicle, it has been said), the bill totalling nearly $30 billion over a decade. The

country's vast public transport sector began buying electric vehicles for their bus and taxi fleets, providing an EV market before retail buyers had made the switch.

Provincial governments offered support in various ways. Shenzhen, home to the market leader BYD, completely electrified its fleet of public buses. In the big cities, where car sales were rationed, EVs were given priority. In little more than a decade, China accounted for half the global sales of EVs. And in another demonstration of China's capacity to drive change and deliver explosive growth, EVs and hybrids went to 48% of the automobile market in 2025 from 6% in 2020.

It is interesting that the government's incentives for EV makers were not restricted to Chinese companies and included the American-owned Tesla, which was encouraged to set up a giant local factory. Tesla's presence acted as a stimulant to homegrown companies to measure up on technology and productivity. Tesla, in turn, was probably pushed to excel by the local competitors. But it is telling that Xiaomi, a tech company that makes mobile phone handsets, laptops, and TV sets, has successfully diversified into electric cars-a transition that Apple failed to make despite reportedly spending $10 billion. In fact, Ford's CEO currently drives a Xiaomi SU7 model and says he loves the car.

China may be about to repeat its success with electric vehicles in the field of hydrogen fuel cell trucks-a sector where Japanese companies were early leaders. However, China has now taken the lead in building infrastructure for hydrogen trucks and has reduced fuel costs to a third of those in Japan, since the fuel is a by-product of steel production. As a result, China now accounts for the majority of hydrogen truck sales. Toyota has warned that Chinese groups are rapidly dominating supply chains and thereby embedding future dominance.

Dominating the Competition

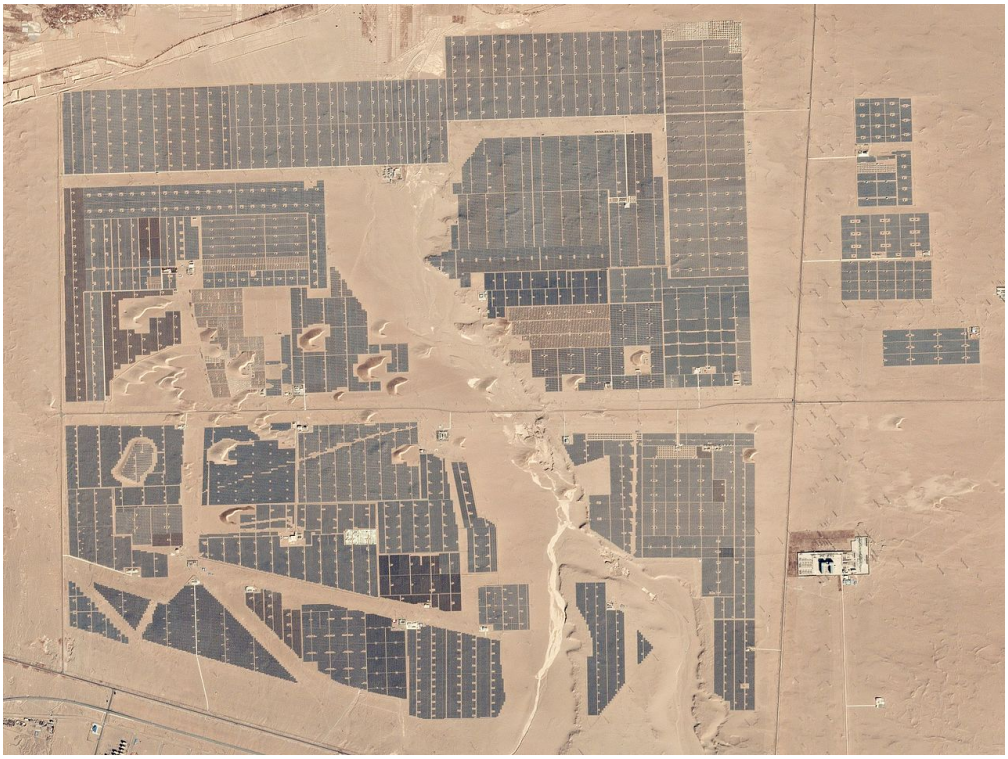
China chose to plough its own furrow when it came to batteries, which can account for 40% of the cost of an EV and are critical to the performance and safety of EVs. Lithium nickel manganese cobalt (NMC) batteries were the early frontrunners in the West, but China chose to focus on unfancied lithium ion phosphate (LFP) batteries. The latter had been out of favour on account of their lower energy density, which meant they were bulkier and heavier for delivering a given output.

> Where China has not acquired leadership is in the manufacture of chips. Although it has ramped up the production of semi-conductors for use in everyday products, Taiwan and the US still lead in high-end chips.

Undeterred, Chinese companies spent years researching LFP, substantially increasing its energy density. LFP batteries continue to be heavier and bulkier, but they have turned out to be about 20% cheaper (since they do not contain expensive materials like cobalt and nickel), are safer, and last longer. Having seen their technology bet pay off, Chinese companies are now able to undercut the battery market. Helped by the country's ability to scale up production quickly, LFP batteries have gone to 40% in market share from 10% in just four years, while NMC's share is down to 25%.

One of the biggest Chinese makers of these batteries, Contemporary Amperex Technology Co. Limited (CATL), has now partnered Ford to set up the first LFP battery plant in the US-marking a partial shift in US battery preferences. Other LFP battery units are also coming up in the US, while Tesla's Chinese cars use LFP. Research continues on new ways to make batteries for EVs, and LFP may yield to semi-solid state batteries. Contemporary Amperex is in a leadership position with the new technology as well, along with newer Chinese firms.

In solar energy, China's initial interest in the field was to feed large German demand. The government provided tax and other incentives to attract investors while (ironically) German companies provided the manufacturing lines, technology, and training. In due course, as reported by the International Energy Agency, China has established a more than 80% global market share, in the process bringing costs down everywhere for photo-voltaic (PV) cells. The US, which pioneered solar panels, once had a dozen companies making PV ingots and wafers. Today, none exist. It helped that China has hugely outspent the US and other countries in clean energy innovation, investing $50 billion in the PV value chain since 2011 (10 times more than Europe). Part of the pay-off is that it now accounts for well over half the world's solar jobs.



Where China has not acquired leadership is in the manufacture of chips. Although it has ramped up the production of semi-conductors for use in everyday products, Taiwan and the US still lead in high-end chips. China has also been denied access to the extreme ultraviolet (EUV) lithographic process and equipment needed for high-end chip manufacture, for which the Dutch Advanced Semiconductor Materials Lithography (ASML) enjoys a monopoly.

Nevertheless, China is finding ways to get around these blocks, though its production processes still lag. Its 7 nano-metre (nm) chips now feature in Huawei's mobile phones, and the Semiconductor Manufacturing International Corporation (SMIC) has reportedly achieved a breakthrough with producing 5 nm chips, while Xiaomi has designed a 3 nm chip, only the fourth company in the world to do so.

Controlling the Supply Chain

While looking for leadership, if not dominance, in the key industries of the future, China has focused with great foresight on control of the materials required for clean energy and other sunrise industries, as well as for the electronics and defence sectors-materials such as cobalt, nickel, and graphite. In many, if not most of these, China accounts for the bulk of production, and an even greater share of refining capacity. Except for nickel and copper, China produces more than it needs and is therefore a leading exporter. Where the country does not have enough domestic supply of the basic material, it acquires mining rights, as with cobalt in the Congo; or it leads in refining capacity, as with Indonesian nickel. One way or other, the country has acquired leadership or dominance in most of the critical materials.

> The IEA's Global Critical Materials Outlook for 2025 report says that between 2020 and 2024, China accounted for between 73% and 98% of the global increase in the refined production of copper, lithium cobalt, graphite, and rare earths.

The story is no different with rare earths like neodymium and dysprosium (used to make magnets for EVs) and lanthanum (used in batteries). The ores for these are found in China, but exist in other countries as well. Yet, China more or less controls the market for most of them.

Despite attempts by many countries to diversify supply, China seems to be strengthening its choke-hold. The International Energy Agency's (IEA) *Global Critical Materials Outlook* for 2025 report says that between 2020 and 2024, China accounted for between 73% and 98% of the global increase in the refined production of copper, lithium cobalt, graphite and rare earths, the only exception being nickel, where China had a significantly lower share.

It is instructive, in this context, to look at why China controls 95% of the supply of raw gallium. Gallium compounds are used in electronic chips, LED lighting, solar panels, and laser diodes, among other end uses. Raw gallium is a side-product from converting bauxite into aluminium. China has plenty of bauxite but ranks only seventh for its reserves (only slightly larger than India's ore reserves). Yet, it produces nearly 60% of the world's aluminium, and through that has established 95% dominance in the production of gallium.

Triumphs in Emerging Industries

Many of the critical industries that China has developed are highly polluting, and this may be one reason why other countries with stronger policies to control industrial pollution have not progressed as far as China. Still, it is hard to explain China's dominance of the solar business when solar panels were invented in the US. One of the reasons may be that Chinese leadership flowed from the critical role of individuals like Wan Gang, who pushed for EVs.

> Once again, China is not a technological leader in the field, but it has won out on the production and adoption of industrial robots, becoming the world's largest market.

Wan's counterpart in the rare earths business was Xu Guangxian, who graduated from Columbia before returning to Peking University and then set up the State Key Laboratory of Rare Earths Materials Chemistry and Applications, for research into rare earths. Like Wan, Xu went on to hold powerful positions in the country's scientific community, advised Beijing on restricting exports of rare earths, and is considered the father of China's rare earths chemistry.

Yet, individual brilliance and leadership may be just the icing on the cake. For the success stories get multiplied in sunrise sector after sunrise sector. For instance, China projects that the drone market will grow five-fold in a decade. The sector has already received the usual state support in the form of subsidies and tax relief.China does not yet have technological leadership over the US in the field, but it already enjoys leadership in the market for the commercial use of drones in agriculture spraying, parcel delivery, fire-fighting, security operations, survey work, and other applications. While commanding a 70% share of the market, China is also demonstrating future technological leadership by accounting for the bulk of drone patents.

And then there is robotics, important in the context of China's declining industrial workforce and the country's determination to lead the world in smart manufacturing, but also because of the potential presented by humanoid robots outside of industrial settings. Once again, China is not a technological leader in the field, but it has won out on the production and adoption of industrial robots, becoming the world's largest market.

Robot density is now more than 400 per 10,000 manufacturing workers, slightly ahead of Japan and Germany but behind South Korea, which has a density of 1,000 to 10,000. As reported by the *South China Morning Post*, Morgan Stanley forecasts that the Chinese robot market will more than double to $108 billion by 2028 from $47 billion in 2024, an annual growth rate of 23%, while humanoid robots will number 302 million by 2050. There is talk of entire factories being manned by robots, leading possibly to the setting up of dark factories that do not need lighting, heating, or break time because no people work in them. The scale of ambition is such that a single province, Guangdong, is spending billions of dollars for machine substitution.

Such triumphs in the emerging industries mark the second phase of China's rise, achieved mostly in the last decade. As already noted, the first phase had been marked by the establishing of dominance in traditional mainstream industries like steel, cement, and ships. The continued successes in the second phase have led now to what might be called the third phase, in which the contest has implications for the global power balance.

Global Contestation in the Third Phase

Western countries are now fully aware of the scale of the Chinese challenge, leading to growing attempts at curbing and containing China. Other than trade restrictions (which could pose challenges to the sectors that have large export surpluses), the attempt is to deny technology and technology-intensive products. China's response is to look for scientific and technological leadership, thus going beyond copying western technology or playing catch-up.

> If the name of the game is acquiring intellectual firepower, individual US companies have much larger research budgets than the largest Chinese firms, but at a national level the picture is more balanced.

If the name of the game is acquiring intellectual firepower, individual US companies have much larger research budgets than the largest Chinese firms, but at a national level the picture is more balanced. The Organisation for Economic Cooperation and Development (OECD), which represents the affluent economies, in its *Main Science and Technology Database, 2025* estimated a couple of years ago that total Chinese R&D expenditure had grown to about half of US expenditure in nominal dollars in 2023, and 96% of the US figure when using purchasing power parity ($809 billion for the US and $781 billion for China), with Europe trailing at $496 billion.

The US-based Information Technology and Innovation Foundation, a think tank for science and technology policy, runs a Hamilton Index that tracks where countries stand on strategically important industries. By 2020, China dominated seven of the 10 industries in the index (the US led in the other three). The list included sectors such as pharmaceuticals, information technology and services, computers, electronic and optical products, machinery, chemicals, transport equipment, and metals. While Western countries (notably the US, Britain and Germany) pioneered almost all the technologies and industries in the Hamilton Index, their current production is dominated by China, which in every way was a latecomer. What is particularly telling, therefore, is that rising Chinese production in these 10 industries has come at the cost of the erstwhile industrial leaders. The Group of Seven (G7) club of leading economies saw their share of the Hamilton industries drop by an astounding 28 percentage points between 1995 and 2020, while China's went up by 22 points. So this has been very much a zero-sum game.

In the newest game in town, namely rare earths, China accounts for close to 70% of production, with the US far behind at 11%. In virtually every Hamilton industry, the primary contest is between the once sole superpower and its current challenger. All other countries are essentially bit players. That is perhaps to be expected since the US and China together account for about 44% of world GDP, with Germany third at 4%.

The same point is made by the Australia Strategic Policy Institute's (ASPI) Critical Technology Tracker. This tracker assesses countries' positions in eight critical technologies, which the Institute divides into 64 sub-categories. These technologies range from advanced materials to artificial intelligence, and from gene technology to robotics. A tally of the ASPI rankings says the US led in 60 of the 64 of the sub-categories during the five-year period from 2003 to 2007, while China led in three. By the time of the five-year period from 2018 to 2023, the picture had changed dramatically. China now led in 57 of the 64 categories-with the US usually but not always occupying second place in those sectors.

On another metric, which is scientific research output, an index produced by *Nature* magazine by tracking 146 selected nature science and health science journals, says that seven of the top 10 universities in science research are Chinese, with the only US university in

the list being Harvard. In the full list of the top 250 institutions listed in the Nature Index, Chinese universities outnumber their US counterparts by a massive margin. There are of course rankings and rankings, and these particular ones may be unfair to America's established strengths, reflected even now in US dominance of the Nobel science prizes. In a ranking of the most innovative economies, compiled by the World Intellectual Property Organization (WIPO), the US in third place comes in well ahead of China at 11th. When it comes to innovation quality, the WIPO puts the US in first place while China comes in 15th.

The US leads in areas such as aircraft engines and the space and defence industries, as well as in fields like neuroscience and molecular biology. It is also ahead in some key industrial sectors.

But China's technological catch-up is undeniable, powered in part by a societal techno-optimism that welcomes new technologies like artificial intelligence, even as many Western societies worry about what it might mean for workers and society as a whole. The message in all this seems to be that, as has also happened earlier with other countries, market leadership comes before technological leadership. In China's case, the latter too is being achieved progressively.

(By way of an aside, India does quite well in some of these rankings. It is typically among the top 10 on the Hamilton list of industries, and among the top five on the ASPI's list of critical technologies, but much lower in the WIPO listings. Even where India does not score well, it registers as a rising presence. It is unclear how much this matters, given Chinese and US dominance of both lists as well as the extent of their leadership, and India's failure to properly shoe-horn R&D, business, policy, regulation, factory-floor productivity, and infrastructure into an integrated system, which also delivers scale and export competitiveness.)

As always, defence remains a frontier sector. Here, China seems to enjoy substantially lower costs, and not just for manpower. Its J10C fighter aircraft, for instance, is estimated to cost barely half of equivalent French or American aircraft. With annual defence expenditure of some $300 billion, small when compared to the trillion dollars spent by the US, China is nevertheless able to challenge American military might in its part of the world.

While the US remains the primary military power, China is now turning out about twice as many new submarines annually as the US, while launching new aircraft carriers and destroyers too at an accelerating pace. It has also displayed impressive advances in fifth generation fighter aircraft, missile, and satellite warfare technology, some of which deploy lasers and achieve hypersonic speeds. In comparison, Europe-with a combined defence budget that is bigger than China's-struggles to supply Ukraine with materiel to defend itself against Russia.

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Western attempts at reversing the shift of manufacturing prowess have not proceeded smoothly. America's attempt to expand its chip production base by getting the world's leading Taiwanese chipmaker to invest in a US plant has brought into focus the higher costs in the US system. Factory construction costs are much greater than in Taiwan, according to an official of TSMC, which has set up plants in Arizona. That is partly because of labour costs but also the cost of permits, occupational safety and health regulations, the learning curve costs, and so on. TSMC's founder and former chairman Chang has said that the company's chips made in Arizona cost 50% more than the chips made in Taiwan.

Meanwhile Western attempts to prevent China from gaining ground in the newest areas of technology have had some effect; they will probably delay a further Chinese rise, not stop it altogether. While the US has prevented China from getting the EUV lithography equipment needed for making the most advanced chips, China (as already noted) has nevertheless improvised and done workarounds.

China's Semiconductor Manufacturing International Corporation (SMIC) is said to be only three years behind Taiwan's Taiwan Semiconductor Manufacturing Company (TSMC) when it comes to chip manufacture. Similarly, DeepSeek surprised Western observers by developing a large language model that is far more cost effective than its US counterparts.

Necessity may have been the mother of invention; China did not have enough high-end chips and was forced to make do with less. After Washington put restrictions on Nvidia's sale of its chips (preferred for AI applications) to China, Huawei worked on its own Ascend chips for AI use. The scarcity of Nvidia's chips has encouraged Chinese companies to try Ascend and adjust to using Huawei's technology. Huawei is now building a network of facilities in Shenzhen with the intention of developing local alternatives to Nvidia, Dutch EUV monopolist ASML, and Taiwan's TSMC-an all-in-one gambit that is without precedent, with implications for future AI leadership. Nvidia now believes that the US curbs have helped build a formidable new competitor and undermined US dominance of AI. Nvidia's CEO, Jensen Huang, predicted recently that China is poised to overtake the US and will win the AI race.

While that may be, Western companies still hold many cards. Huawei's R&D budget is an impressive $25 billion but it is much smaller than that of, say, Amazon's $90 billion. China has clear leadership on the number of robot installations, but Western companies still lead in robot technology. In a high-tech field like precision ball bearings, critical to many engineering industries and products, Western companies offer better product quality though China is catching up. And when it comes to AI, eight of the 10 platforms with the maximum users are American. Even with ships, China once again has the maximum orders but Japanese- and Korean-built ships have higher value.

Having proved that it can survive and work around technological sanctions and trade restrictions (sometimes by relocating factories in other countries), China has demonstrated that it can give as good as it gets in the global power game. It was the only country to stand up to President Trump on tariffs, hitting back with countermeasures. In April 2025, it went on the offensive, imposing export curbs on seven rare earths used in EVs and wind turbines. America's motor industry warned immediately of disruption in production. President Trump responded with a phone call to his Chinese counterpart. After a series of ups and downs, more tariff threats and patch-up meetings, the two countries have called a truce, but trade hostilities could begin again.

China Ascendant

China has reached a critical stage in its rise to global leadership and power. The dramatic success of its Make in China programme, launched in 2015, stands in contrast to India's lack of progress with a similarly named programme launched at the same time. China is taking on the role of rule-maker or rule-breaker, having moved beyond being a rule-taker. The world now waits to see how it will use its newfound strengths.

> Will its future conduct reflect the essential nature of power, or will it be accommodative of other interests by recognising the wisdom of restraint and cooperative conduct on the part of a would-be hegemon?

Till a little over a decade ago, China was still talking of a peaceful rise. Its behaviour since then has turned more assertive, if not openly coercive-denying rare earths to Japan, for instance, when there was a dispute some years ago over a fishing boat collision near disputed islands. To be sure, the country has stepped back from a brief phase of "wolf warrior" diplomacy that was seen as counter-productive, but this may mark a change of style more than substance.

Its use of the Belt and Road Initiative to win influence in the emerging and poorer economies has helped it gain (among other things) access to critical materials, while it has more or less become the key player in forums like the Shanghai Cooperation Organisation and the expanded BRICS forum. But will China try to become a global exemplar, as the US was seen to be in many circles until recently? Will its future conduct reflect the essential nature of power, or will it be accommodative of other interests by recognising the wisdom of restraint and cooperative conduct on the part of a would-be hegemon?

And what of the Western response? American dynamism is undeniable, while Europe and Japan have their areas of strength. But under the pressure of multiple social and economic challenges (immigration and racial tensions, trade pressure and high costs, growing inequality, a perceived shortage of "middle-class jobs", ageing populations and unsustainable welfare budgets, massive debt and low growth rates), Western societies confront questions about their identities, systems and defining philosophies.

Countries under pressure or in relative decline can make erratic choices or lose self-belief, seek a way out through conflict, or reluctantly accept rather than fight the reality of a new ascendant power. It remains to be seen which it will be for the West. The answers to such questions will define the coming quarter century and beyond.

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The essay was corrected on 30 November for an error stating that China was currently building nuclear power reactors in four other countries. It is currently building a reactor only in Pakistan.

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