ECN230 SRP session 20. Strategic Policy and Economies of Scale

Strategies in Mature Economies

Introduction

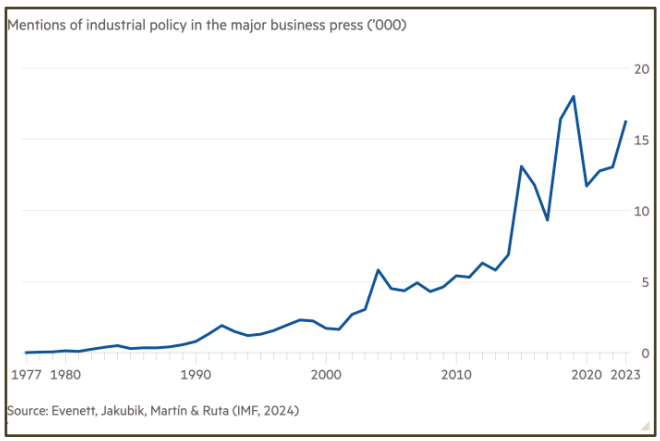
In mature economies, the policy space that governments have to intervene in support of their economic strategies is limited. World Trade Organization (WTO) rules and the commitments undertaken by developed countries were intended to discipline their use of trade policy. Tariff protection was restricted and quotas prohibited. Tariff rates have ceilings that are relatively low (that is, until the Trump administration began tariff wars by raising US rates above their ceilings in 2018). Rules limited support to industry too. Industrial subsidies are prohibited, except for R&D (research and development). Fiscal support can be provided in special cases such as for regional support, disaster relief, or a national emergency. Support for agriculture is allowable depending on their type, but policies or programs that directly restrict market access or encourage production or are more constrained. Agricultural export subsidies became prohibited in 2020.

Despite these constraints, governments have found ways to pursue intervention through fiscal stimulus and industrial policy (either as workarounds of WTO rules or suspension of EU state aid rules). The global financial crisis (GFC) of 2007-09 and the euro crisis that followed it ushered in fiscal stimulus to help airlines, large-scale manufacturing and retailing enterprises, and banking and financial firms in their recovery. The post-pandemic policy response assisted firms that were negatively affected by the lockdowns and disruption of supply chains. Industrial policy in developed economies had already been coming back in favor since the rise of China as a manufacturing hub and a rival exporter of more sophisticated products.

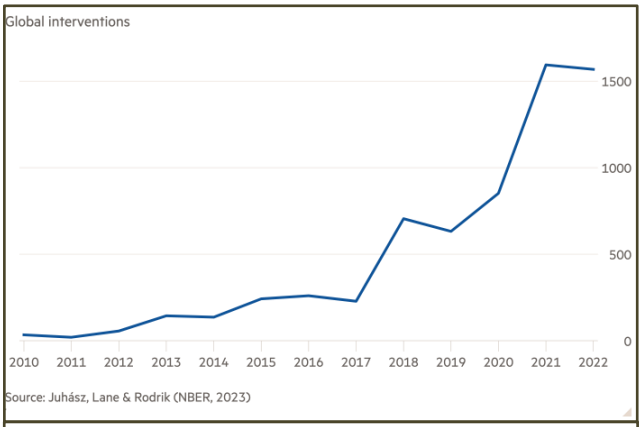
Industrial policy's comeback

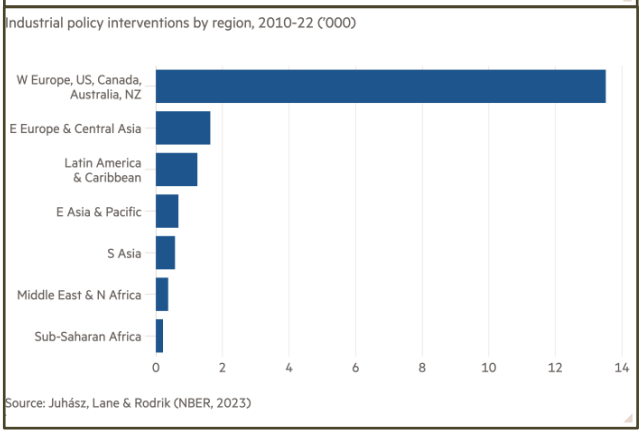
Crises have a way of getting people to reassess tarnished ideas. The policy of fiscal stimulus languished in the intellectual wilderness until the GFC meltdown forced governments to spend to prop up aggregate demand. As rich countries struggled with an anaemic economic recovery, it was the turn of industrial policy. The idea of government intervention to influence the composition of a country's output had long been derided by economists for breeding inefficiency, reducing competition, encouraging lobbying and saddling countries with factories producing products nobody wanted. In the aftermath of the GFC, industrial policy found some vocal champions [1].

Industrial policy is a powerful motivator for government intervention. The evidence that industrial policy has become more pervasive as both an idea and a practice is clear. "The Return of Industrial Policy in Data", published by the IMF (2024), shows a market increase in mentions of industrial policy in the business press over the past decade (see chart, mentions of industrial policy) [2].



A paper on "The New Economics of Industrial Policy" by the National Bureau of Economic Research and co-authored by Reka Juhasz, Nathan Lane and Dani Rodrik, shows a steep increase in industrial policy interventions worldwide, from 228 in 2017 to 1568 in 2022 (see chart global interventions). These have been predominantly implemented in high-income countries (see chart, interventions by region), probably because they have more fiscal room to do so [2].



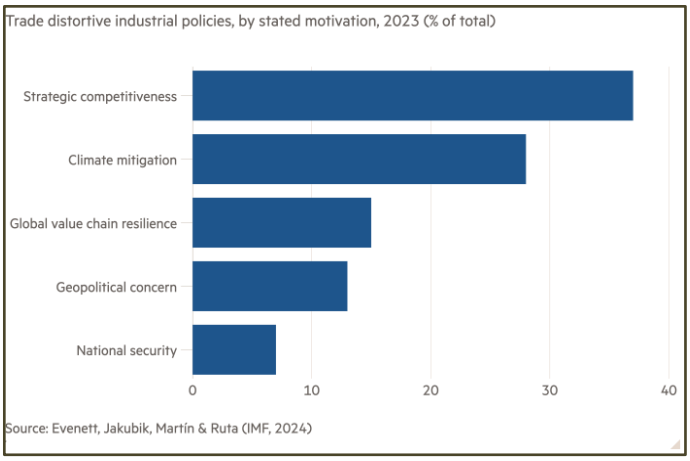


There are many rationales for industrial policy (see chart, by motivation). However, economists recognise three valid arguments for such interventions. The first concerns "externalities", or uncompensated benefits provided by a firm. The most obvious come from what workers and other firms learn from it. There also exist national security and other social externalities. The second argument concerns co-ordination and agglomeration failures: thus, a number of firms may be viable if they start together, but none may be viable if it starts on its own. The final argument concerns the supply of public goods, especially location-specific public goods, such as infrastructure. Note, crucially, that none of these is an argument for protection. Protection is a poor way of achieving such wider social goals [2].

Industrial policy works if it changes the structure of the economy in a beneficial direction. There are well-known reasons why the attempt could fail. Lack of information is one. Capture by a range of special interests is another. Thus, government may fail to pick winners, while losers may succeed in picking governments. The more money is on the table, the more the latter is likely to be true [2].

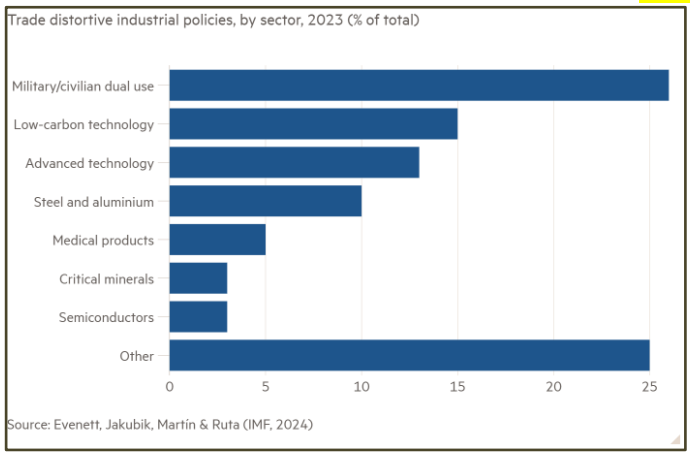
Yet failure is not the only risk. Success is too. Industrial policies run the risk of provoking international retaliation. South Korea used protection of domestic markets as an indirect way of subsidising exports, thereby creating successful new industries. But it was a small country, under US protection. For larger countries, international repercussions must be considered. This is something China has learnt, with

its race to dominate new "clean" technologies and strategic sectors (see chart, industrial policy by sector). That has motivated retaliation in both the US and EU, further worsening relations among the economic superpowers [2].



The most striking example of industrial policy is the US "Inflation Reduction Act", initiated under the Biden administration, which has multiple goals from supporting and promoting place-based manufacturing to lowering emissions. This contrasts to the Trump administration's use of tariffs either to protect manufacturing or reshoring it. Bipartisan politics in the US has three positions: nostalgia for manufacturing, hostility to China, and indifference to the international rules that the US itself helped create [2].

The wisest way to pursue industrial policies is to target the identified problem as precisely as possible while minimising damaging side-effects on international co-operation, trade openness and domestic economic performance. But with the death of "hyperglobalisation", has come a loss of appetite for multilateral solutions and policy restraint [2].



Subsidisation and promotion of exports

Import substitution, with its distortion of domestic investment and its intense protectionism, has long fallen out of fashion [3]. Reshoring of manufacturing under Trump administration 2.0 is a repackaging of this idea.

However, the promotion of international competitiveness led governments down many roads that economists shudder to tread. Subsidies and export subsidies of all shapes and sizes have been tolerable stand-ins. Research demonstrates that the theoretical basis for export subsidies is dubious, and that their empirical effects can be downright scary [3].

Political leaders often double as a commercial traveller. France's President de Gaulle once refused to meet a Japanese prime minister, dismissing him as a "transistor salesman". Leaders now make exports a central part of their foreign policy. A US president puts in a word with a Saudi prince and snatches an order for Boeing from under the nose of Europe's Airbus. A European president flies to Beijing and returns with trade deals; other westerners fume – outwardly about human rights, inwardly about lost businesses [4].

There are several justifications on offer for the existence of (export) subsidies. They include the need to nurse infant industries; to compensate for protectionism abroad; to overcome credit-market problems faced by small and medium-sized firms; to promote employment; and to keep trade balances positive. The subsidies can range from simple ad valorem payments to companies based on the size of their export sales, to complex systems of tax credits, loans, insurance policies and price supports [3].

How do governments support domestic firms and/or promote exports? In principle, there are three main methods at their disposal: (1) subsidising directly or indirectly; (2) manipulating the exchange rate; and (3) trade activism and promotion [4].

The simplest is a direct or indirect subsidy. A direct subsidy is illegal by WTO rules. If WTO members' industries are injured by another's industrial subsidies, then a case can be brought before the WTO's dispute-settlement system: the result may be an end to the subsidy or compensation [4].

Indirect subsidies can be a legal means around WTO prohibitions on subsidies. Governments can still find channels through which to pump resources to national champions. They can subsidise (R&D). Under WTO rules, governments may pay up to 75% of a firm's industrial-research costs, or half the costs of product development. There is a respectable economic argument for this: a firm undertaking research may not secure all the benefits from it; these can accrue to everyone, in the form of better-educated scientists or a new product (e.g., a pharmaceutical or drug) becoming available. Governments have an interest to encourage this. The trouble is that in practice they are poor at picking good research projects; markets are rather better [4].

Governments wanting to grow their national economies more quickly think that, with a well-chosen subsidy here or a finely judged tax break there for R&D, they can give their industries a friendly shove and so speed their economies along. Economists are usually more sceptical [5].

Yet even sceptical policy-makers often claim that high-tech industries are an exceptional case. Such industries, they say, have a "strategic" value to the economy because new technology is an engine of long-run productivity growth; a country can get ahead economically if with a technological edge. It makes good economic sense for governments to promote technological advance: left to itself, a market fails [5].

Why? One possible reason is that in some high-tech industries, such as semi-conductors, firms "learn by doing". The more they produce, the fewer mistakes they make and hence production costs fall. The snag is that a firm may not be able to capture all of the benefits of this. Some benefits "spill over" to other firms when, say, good workers change jobs. Similarly, some of the benefits of the firms' R&D spending may go to rivals, who adapt it to their own ends. Such spillovers blunt firms' incentives to learn and to spend on R&D. Moreover, the benefits of technology promotion are unlikely to rest in the domestic economy; firms abroad benefit as well [5].

Governments can help domestic producers expand markets by financing exports through "export credit guarantees", which insure exporters against the risk of default by their customers. In the past, governments used to subsidise exporters by guaranteeing loans at below-market interest rates. OECD countries signed a self-denying ordinance, intended to eliminate such beggar-my-neighbour subsidies on credits of two years or more. Many European governments have also increased private-sector involvement in their short-term export-credit operations, bringing market discipline to bear on them. [4].

Governments can also offer "tied aid", requiring the recipient of aid to buy goods from companies in the donor country. The aid is often given for foreign policy as much for commercial reasons, and might be categorised as "aid" not "trade". In December 1996, the OECD adopted new guidelines on tied aid, as they did with provision of loans at below-market interest rates, aimed at ensuring that only projects that cannot be commercially financed benefit from such aid. Governments have used these means of subsidising exporters to a lesser extent than in the past [4].

Manipulating the exchange rate is the second broad way in which governments can boost domestic production and exports. By weakening the local currency, a government makes exports cheaper in foreign-currency terms (and foreign goods more expensive in local-currency terms). This helps exporters in the short run, but not in the long. Depreciating raises import prices, and if workers maintain the purchasing power of their wages, then labour costs must rise, too. Eventually much, if not all, of the initial gain is lost through inflation [4].

The third form of government assistance for exporters is trade activism, which amounts to simple information-gathering activities to facilitate trade (and perhaps to overcome a market failure problem that limited exports). Commerce departments and trade ministries spend lots of time and trouble gathering business information of every sort on foreign markets. Firms can do this for themselves singly (if big enough) or collectively – and many do, but small firms, especially, get a sort of free ride from embassies set up for other reasons. Diplomats spend time gathering information about local markets, showing the flag at trade fairs and arranging business meetings [4].

Trade promotion is exemplified by the high-profile trade missions. European politicians and diplomats have long acted as export boosters. Asian tigers have also made big efforts. The (South) Korean Trade-Investment Promotion Agency, for example, has a network of offices round the world [4]. However, export-boosting funds can be misallocated. In the late 1990s, roughly two-thirds of the US funding went to promoting food exports, reflecting the food lobby's clout, rather than its needs. At one point, California's raisin growers secured $4m to advertise their raisins in Japan – a sum exceeding the US Commerce Department's entire Japan budget. With greater transparency in annual reporting on export promotion, the US Trade Promotion Coordinating Committee reduced such misallocation. Money slowly shifted from the food lobby to other industries [4].

Rich and poor countries alike have used export subsidies to enhance their presence on world markets, perhaps doing more harm than good. These policies bring with them some huge problems. Any company coddled by a subsidy has less incentive to improve its bottom line (and hence make the subsidy unnecessary). Whether subsidies are complex or as simple as ad valorem payments, their perpetuation relies on the interests of industries whose scope and lifetime they have extended. Inefficiency therefore begets inefficiency Tax revenues used for subsidies are distributed in a way that makes them regressive. Export subsidies, in general, take money from broad-based tax revenues and are transferred to corporate shareholders. Artificially low prices depressed by subsidies can force more efficient producers in importing countries out of business. Besides harming domestic producers in poor importing countries, export subsidies may crowd out competing trade from other countries. Initiatives, such as the promotion of growth in total factor productivity, have proved more successful and less distortionary in the developing world [3].

Governments fond of subsidising industrial R&D might be less eager if they knew where the benefits went. Although international spillovers of R&D and learning-by-doing are hard to measure precisely, some studies should give policy-makers pause for thought. Douglas Irwin and Peter Klenow, University of Chicago, find that there were large spillovers in the US's semiconductor industry (one favoured by that country's industrial policy).[1] They reckon that when a US firm makes an extra semiconductor, the spin-offs for others are worth about one-third of the first firm's gains. Japanese firms gained just as much as other US ones. Thus, it would seem pointless to favour US semiconductor companies on nationalistic grounds [5].

David Coe, an IMF economist, and Elhanan Helpman, of Tel Aviv University, studied the relationship between R&D and productivity in 22 industrial economies between 1971 and 1990.[2] They linked increases in "total factor productivity" (TFP) – ie, gains in output which cannot be explained by extra labour or capital – to changes in the stocks of R&D (estimated by cumulative R&D spending less depreciation). They found, predictably, that an increase in a country's R&D stock boosted its own TFP. On average, a 1% increase in a G7 country's R&D stock increased its TFP by 0.23%. Oddly, the 15 smaller economies studied gained proportionately less: a 1% increase in their domestic R&D stocks lifted their TFPs by only 0.08% [5].

Research spending also raised productivity in foreign economies. The authors reckon around a quarter of the global benefits of R&D investment in G7 countries went to foreigners. The biggest spillovers came from the US, which has the biggest R&D stock. A 1% rise in its stock lifted TFP in the other 21 countries by an average of 0.04% [5].

Small economies benefited more from foreign R&D than big ones. So much so, say Coe and Helpman, that in small industrialised economies foreign R&D spending may have a bigger effect on productivity than home-grown research. A 1% rise in the foreign R&D stock (measured by the sum of foreigners' R&D stocks, weighted by their share in the home country's imports) in 1990 would have increased TFP by 0.26% in Belgium and 0.16% in Ireland. Had 1% been added to the US's foreign R&D stock, its TFP would have been a paltry 0.03% higher [5].

How can one country's R&D benefit foreigners? Mainly, suggest the authors, through international trade. By importing from technologically advanced economies, countries acquire higher-tech inputs that make their own industries more efficient. Furthermore, importers may be able to work out and then copy the technology developed by foreign firms. Less directly, international trade forces economies to become more efficient: as a by-product, companies should become better at developing new technology and imitating foreign methods [5].

[1] "Learning-by-Doing Spillovers in the Semiconductor Industry". *Journal of Political Economy*, December 1994

[2] "International R&D Spillovers". *European Economic Review*.

Thus, the more open an economy is to imports, the more it should benefit from foreign research. Smaller economies tend to import more than bigger ones, so they tend to gain proportionately more. Belgium's imports were worth nearly 90% of GDP in 1990; the US's were only 11%. Governments have another reason to beware of spurious "strategic" arguments for supporting firms. Positive spillovers cannot be kept within national boundaries: subsidising locals often means subsidising foreigners too [5].

Support for national champions

Northvolt was supposed to be a battery pioneer, a symbol of European competitiveness and an example of industrial policy done right. In Nov 2024, Northvolt, Europe's best-funded startup filed for bankruptcy. The firm did not fail for lack of investment. It raised $15bn in total, including nearly $5bn in grants and loans from the governments of Canada, the EU, Germany, Poland, and Sweden [6].

But it struggled to get anywhere, owing to incompetence and bad luck. Its main battery factory, located in a remote part of Sweden operated at a small fraction of its capacity, incurring huge losses. Some lessons hold. First, investors should not take it for granted that when governments back an industrial champion, they will keep throwing money at it forever. The banks that lent to the firm, the pension funds that bought its shares and the carmakers that lodged orders for its batteries all did so on the assumption that it was a safe business entity [6].

Second, when politicians try to back national champions in areas where technology is rapidly evolving, they are likely to waste taxpayers' money. That is especially true if the champion in question is far behind the market leaders. Governments often base their industrial policies on the "infant industry" argument, which says that domestic firms in new industries need protection until they are viable. The trouble is, if they are too far behind, they may never catch up with their foreign rivals – and support may simply allow them to grow flabby. However, Northvolt spent lavishly on lab-level breakthroughs and next-generation technologies but never worked out how to commercialise them and never came close to matching the world's best battery-makers [6].

A better way to nurture high-tech industries, which need not cost taxpayers anything, is to smoothen the way for foreign direct investment. This is a proven means to spread know-how from one country into another. The US and the West have fallen behind China and other Asian countries in some crucial areas, including large-scale chipmaking and clean technologies such as solar power and EVs. The way to catch up is to let leading firms in those areas open factories in the West. Asia leaned from the West by welcoming its best companies. Now the West needs to learn from Asia [6].

The problem becomes that as other governments support their national firms it makes it politically difficult to not do likewise. The marketplace is corrupted by the presence of government. So do you sit on the side and pontificate about Adam Smith, or do you enter the fray [4]?

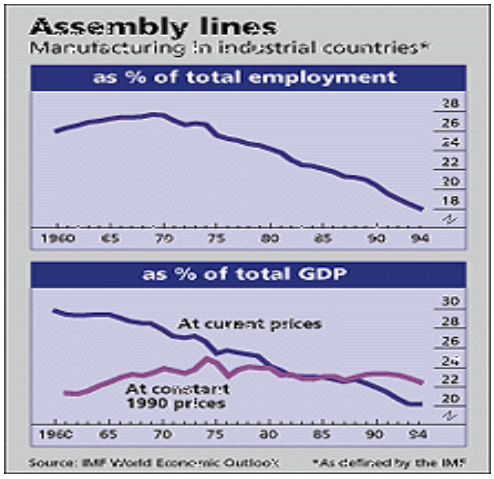
Deindustrialisation: A North-South trade externality?

Talk of "deindustrialisation" can strike fear into the hearts of workers, manufacturers and politicians in rich economies. The reason for this phenomenon, the relative decline in manufacturing jobs in rich countries, is widely misconstrued. This decline in jobs has coincided with the rapid increase in manufactured exports from developing countries, e.g., China and Brazil. Rich-country voters assume that these upstarts are stealing their jobs, and that the solution lies in job subsidies and trade barriers [7].

There is no doubt that manufacturing provides fewer jobs than it used to. The share of manufacturing in total employment in the rich economies fell from 28% in 1970 to 18% in 1994. In the US, less than one worker in six (and falling) works in manufacturing; in the EU one in five does. Even in Japan, a country cited as fostering its manufacturing sector, less than a quarter of the workforce is in manufacturing. More than 70% of US workers are employed in services, and growing [7].

The trend is clear. Its causes less so. Two explanations commonly offered for deindustrialisation are: (1) as a country becomes richer, its consumers buy relatively fewer manufactured goods and relatively more services; and (2) there is an alleged migration of manufacturing jobs from rich countries to poorer ones. In a careful analysis of the numbers[3], the IMF suggests that neither explanation captures what is really going on. A bigger cause of change by far is that productivity is growing much faster in manufacturing than in services [7].

Manufacturing's share of GDP measured in current prices has fallen, suggesting that deindustrialisation reflects a shift in spending from goods to services. The rise in the nominal value of services in GDP reflects a rise in the relative price of services. In constant prices the share of manufacturing output turns out to have remained broadly stable from the 1970s to the 1990s in the rich economies as a whole (see chart, manufacturing) [7].



There are differences between rich countries. The share of manufacturing in GDP fell in the US since the 1970s. The losses in the US were offset by a rise in Japan. This, according to the IMF's analysis, was not due to shifts in domestic spending, but to changes in US-Japan manufacturing trade: the US had a widening trade deficit while Japan's trade surplus widened [7].

Have increased imports from developing countries played a big role? The IMF concluded that trade had only a small impact on manufacturing jobs in rich countries as a group, mainly because their overall trade balance in manufactures had hardly changed: their increased imports from low-wage countries were matched by increased exports. Trade between developed and developing countries may have affected the mix of manufacturing jobs—reducing unskilled jobs relative to skilled ones—but the net effect was probably modest [7].

[3] *World Economic Outlook*, April 1997. This subject is treated in more detail in "Deindustrialization: Causes and Implications", by Robert Rowthorn and Ramana Ramaswamy, IMF Working Paper, April 1997.

Instead, argues the IMF, the decline in manufacturing jobs mainly reflects sectoral differences in productivity growth. In 1960-94, service-sector output and manufacturing output grew at roughly the same pace in rich economies. Productivity in manufacturing, however, rose more than twice as fast as in services. This shifted employment from the more productive manufacturing sector, where fewer workers are needed to produce a given increase in output, to service industries where labour is needed and is more intensive. Improvements in farming productivity caused the same thing to happen in agriculture over the past century. Having made up 50% of all US jobs in 1860 farming employs only 3% [7].

As a country gets richer, it is inevitable that a smaller proportion of workers are needed in manufacturing. This trend, which began in the US and spread to Europe and Japan, is visible in the Asian tigers. The share of manufacturing jobs fell in Hong Kong in the 1970s, and in Singapore, South Korea and Taiwan in the 1980s [7].

The IMF estimates that faster productivity growth in manufacturing relative to services could account for two-thirds of the drop in the manufacturing's share of employment in rich economies since 1970. Official figures can exaggerate deindustrialisation: manufacturing firms that once employed their own accountants or cleaners now hire them from outside firms – jobs that are reclassified as part of the service sector [7].

If the popular explanations for the relative decline of manufacturing employment are wide of the mark, so are the conclusions commonly drawn from it. Those fretting over the "decline" of manufacturing portray service jobs as inferior, unskilled affairs. In fact, many such jobs are increasingly likely to be in highly skilled areas such as teaching, financial services or information technology [7].

Deindustrialisation causes problems in economies unable to absorb the workers released by manufacturing. Those making calls for subsidies or trade barriers miss the point. As manufacturing continues to shrink in an economy, overall growth will increasingly depend on boosting productivity in services. Policy should therefore focus on removing obstacles (such as trade barriers and regulation) to such productivity growth, and creating a labour market in which workers can move freely from factory employment to services. Protection and subsidies push just the wrong way [7]. ◆

Economist, "Manufacturing problems: About that renaissance", 11 Nov 2023, p. 69.

Advocates of industrial policy have long argued that manufacturing possesses special powers. Industry's demands lead to technological progress; the goods it produces must pass the muster of global markets, which drives up efficiency. Some then take things further. When countries grow richer, manufacturing moves overseas as firms seek to reduce labour costs. This, they say, justifies tariffs and subsidies to protect manufacturing and boost growth.

The problem is that, of late, manufacturing's powers seem to have vanished. Oct 2023 data show that US GDP jumped by 4.9% at an annualised rate in the third quarter of the year. Nearly 80% of output is made up of services, but one might expect manufacturing at least to pull its weight, given its supposed powers. In fact, labour productivity in manufacturing fell by 0.2% at an annualised rate, meaning that the boost to growth was driven by services. To make matters worse, productivity in the manufacturing sector has been in secular decline since 2011—the first decade-long fall in the available data (see chart productivity). Some economists think it is probably the first such fall in US history.

What has prompted the reversal? Mr Cass's favourite explanation, trade policy, can be dismissed. US manufacturing employment fell sharply in the early 2000s, in part owing to the integration of China into global trade. Some think that this "China shock", which led to a wave of outsourcing, also caused productivity to decline by reducing the incentive for US firms to invest. Yet productivity grew until 2011. Moreover, it also subsequently declined in sub-sectors that are mostly domestic and immune to trade, including cement and concrete production.

A better clue is provided by what went well in earlier decades. During the 1990s and 2000s manufacturing productivity soared, with the production of computers and electronics, especially semiconductor chips, leading the way. Gains seem to have topped out at around the time things went wrong more broadly, in the early 2010s. All told, more than a third of the overall slowdown in manufacturing since 2011 is accounted for by computers and electronics.

Yet problems with computers are not the whole story. Productivity has fallen in both durable manufacturing, which includes most tech, and the non-durable sort, which includes items like cigarettes and clothes. Fourteen out of 19 manufacturing sub-sectors, from machinery to textiles, saw declines during the 2010s. Perhaps all those computers have been put to poor use. The US may be a technology superpower, but when it comes to using tech in the physical world it lags behind others. It ranks seventh out of 15 countries in the adoption of robots per worker, according to the Information Technology and Innovation Foundation, a think-tank. South Korea, the world leader, uses over three times more robots per worker. And after adjusting for average wages—richer countries tend to be more advanced—America ranks 11th.

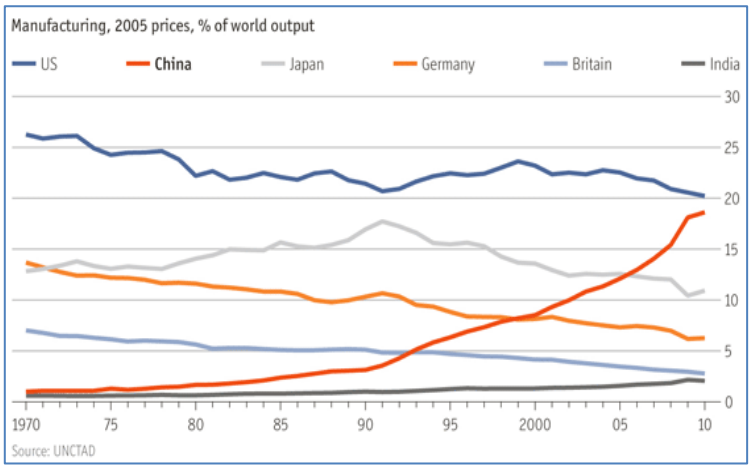
But it is not clear whether there was a big change in US manufacturers' adoption of tech, compared with other sectors, in the early 2010s. Indeed, the evidence points in the opposite direction. As Chad Syverson of the University of Chicago notes, the ratio of capital to labour has actually grown slightly faster in manufacturing than in the private sector as a whole.

If investment has not plummeted, it must then be paying fewer dividends. Low-hanging fruit might have been plucked more eagerly in manufacturing. This idea is supported by the fact that industrial productivity growth has slowed across the rich world, even if not by as much as in the US (see chart, % change in manufacturing). The extra bit of US underperformance is trickier to explain. Economists throw out a boatload of hypotheses. The US is known to have laxer antitrust enforcement than its peers; perhaps scrutiny was especially needed in the manufacturing sector. Maybe US manufacturing was more advanced when robots arrived on the scene, so had less to gain. Some have even argued that because US software and internet sectors have been so lucrative, talent has been diverted away from older industries.

Could things change? The Biden administration hoped that US industrial-policy subsidies for chip production and green tech would lead to a manufacturing renaissance. The idea is to boost productivity by enticing companies and investment to cluster in a given region, much as Shenzhen in China used its status as a special economic zone to become an impressive manufacturing hub. A breakthrough in robotics or artificial intelligence could push things along, just as information technology led to a surge in productivity from 1995 to 2004.

Manufacturing still matters but because of services

For more than 100 years, the US was the world's leading manufacturer, but shared top spot with China in 2010 at about 20% of world output (see chart on manufacturing). In the decade to 2010, the number of US manufacturing jobs fell by about a third. The rise of outsourcing and offshoring and the growth of sophisticated supply chains enabled companies the world over to use China, India and other lower-wage countries as workshops. Prompted by the GFC, Western policymakers reckoned it was time their countries returned to making stuff to create jobs and prevent the export of more manufacturing skills. That supposes two things: that manufacturing is important to a nation and its economy, and that these new forms of manufacturing will create new jobs [8].



Plenty of research shows that manufacturing is good for economies, but in recent years some economists have argued that there is nothing special about making things and that service industries can be just as productive and innovative. It is people and companies, not countries, that design, manufacture and sell products, and there are good and bad jobs in both manufacturing and services. On average, though, manufacturing workers do earn more, according to a report by Susan Helper of Case Western Reserve University, Cleveland, for the Brookings Institution, a think-tank in Washington, DC [8].

Manufacturing firms are also more likely than other firms to introduce new and innovative products. Manufacturing makes up only about 11% of the US's GDP, but it is responsible for 68% of domestic spending on R&D. According to Ms Helper, it provides better-paid jobs, on average, than service industries, is a big source of innovation, helps to reduce trade deficits and creates opportunities in the growing "clean" economy, such as recycling and green energy. These are all good reasons for a country to engage in it [8].

Despite China's rapid rise, the US remains a formidable production power. Its manufacturing output in dollar terms is now about the same as China's, but it achieves this with only 10% of the workforce deployed by China, says Susan Hockfield, president of the Massachusetts Institute of Technology [8].

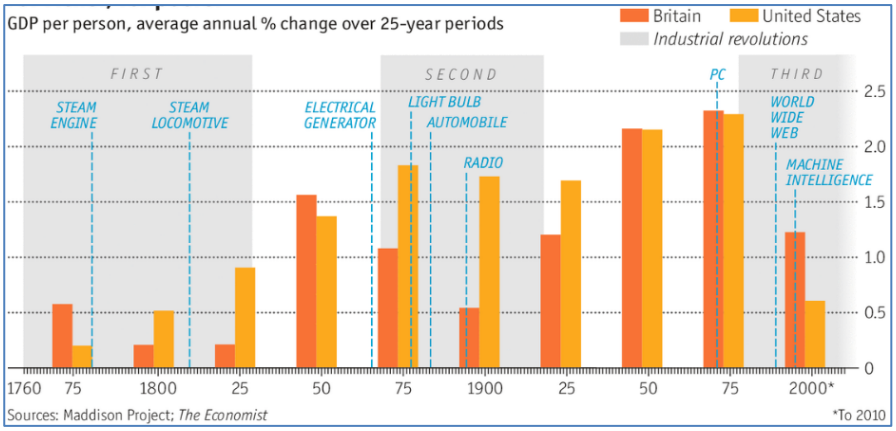
The "Hammering Man" catches a nostalgia for the kind of manufacturing employment, which in the developed world barely exists any more]. A factory floor today can seem deserted, whereas a nearby office block can be full of designers, engineers, IT specialists, accountants, logistics experts, marketing staff, customer-relations managers and other professionals. The definition of a manufacturing job is becoming increasingly blurred [8].

A lot of the jobs that do remain on the factory floor will require a high level of skill. Many people working in factories provide services that are crucial to manufacturing. "In the future more products will be sold on the basis of service," says Kumar Bhattacharyya, chairman of the Warwick Manufacturing Group at Warwick University. "If you sell a car with a ten-year warranty you need to make sure it will last for ten years and that you have the services in place to look after it" [8].

The revolution in manufacturing will affect not only how things are made, but where. The geography of supply chains will change. An engineer working in the middle of a desert who finds he lacks a certain tool no longer has to have it delivered from the nearest city. He can simply download the design and print it. The days when projects ground to a halt for want of a piece of kit, or when customers complained that they could no longer find spare parts for things they had bought, will one day seem quaint [9].

Factories used to move to low-wage countries to curb labour costs, but labour costs are growing less and less important. Offshore production is increasingly moving back to rich countries not because Chinese wages are rising, but because companies want to be closer to their customers so that they can respond more quickly to changes in demand. Some products are so sophisticated that it helps to have the designers and engineers in the same place [9].

More manufacturing work can be automated, and skilled design work accounts for a larger share of the value of trade, leading to what economists call "premature de-industrialisation" in developing countries. No longer can governments count on a growing industrial sector to absorb unskilled labour from rural areas. In both the rich and the emerging world, technology is creating opportunities for those previously held back by financial or geographical constraints, yet new work for those with modest skill levels is scarce compared with the jobs created in earlier technological revolutions (see chart, GDP per person) [10].



Manufacturing fetishism

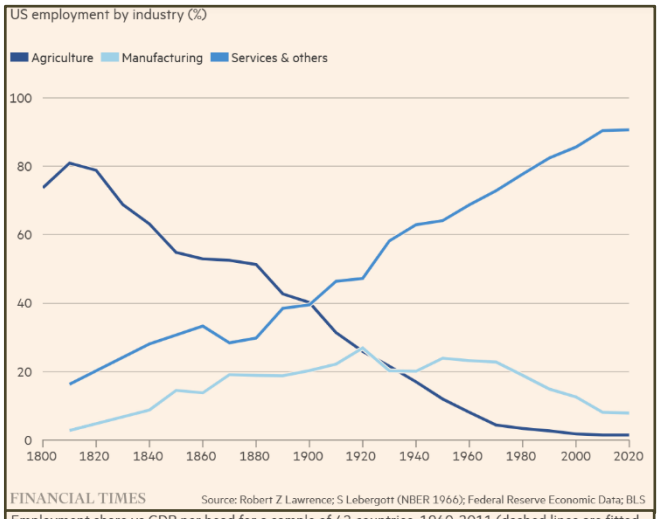
The notion of a fading economic sector arises from a big drop in US manufacturing employment. Some regions in the US were hit especially hard. From 1980 to 2005 the number of factory jobs fell by some 45%. Many, including President Trump, reckon that global trade, especially with China, is largely to blame. However, studies show that most past factory job losses were the result of investments in automation, which continue to pay off. US manufacturing has more than doubled output in real terms since the 1980s, to over $2trn in 2017 while the amount of labour required to produce those goods decreased (see charts, US manufacturing and output) [11].

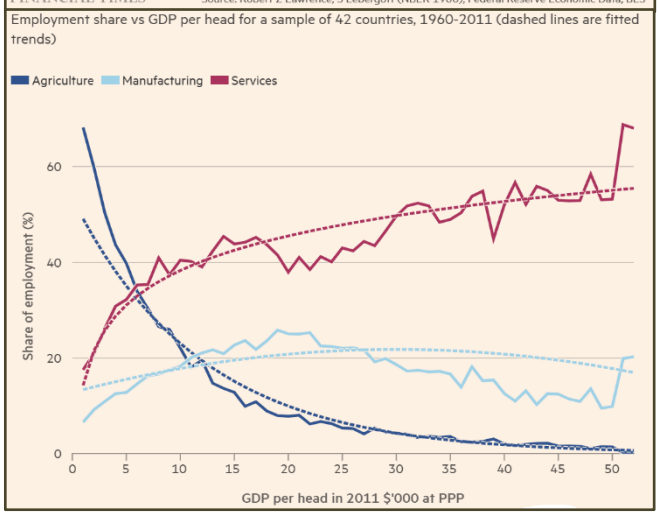
In 2020, the US employment shares of agriculture, manufacturing and services were 2%, 8% and 91%, respectively. The evolution of these shares describes the employment pattern of modern economies (see chart, US employment by industry). As countries become richer, whether they are big or small or run trade surpluses or deficits, it is what has happened.

What drives this evolution [12]? The answer is explained in terms of income elasticities of demand for the respective products, the elasticities of substitution, and the relative rates of growth of productivity. Income elasticities measure the proportional increase in demand for a category of goods or services relative to income. The elasticity of substitution measures the impact of changes in price on demand. What emerges is spillovers: what happens to a sector also depends on what happens in the other sectors [12].

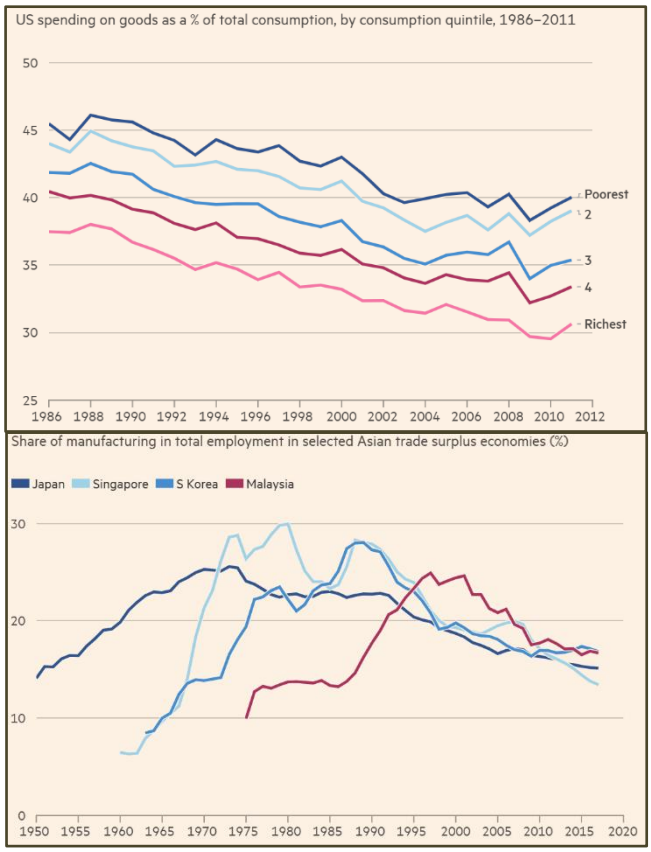
Consider the following simple and empirically-based assumptions. First, productivity grows fastest in agriculture, followed by manufacturing and then services. Second, income elasticities of demand are below one for agriculture, but above one for manufacturers and still higher for services. Third, the elasticities of substitution are all below one. This means that the proportion of income spent on a given broad category declines as it becomes relatively cheaper [12].

What happens is the pattern seen in the US and other high-income countries. Cheaper food and higher incomes shift spending towards manufactures and drives up the share of manufacturing employment. But the decline in the price of manufactures relative to services and the higher income elasticity of demand for services does the reverse (decreases the relative share of employment in manufacturing). As agricultural productivity increases it becomes too small to provide any further shifts that have a positive effect on manufacturing. The forces operating within manufacturing and services dominate (see chart, employment share vs GDP). Employment shares in manufacturing fall. The idea that this process is reversible through trade policy is ridiculous. In manufacturing, tasks tend to be repetitive, which is perfect for robots [12].





It is easier to blame the disappearance of US manufacturing jobs on China than on domestic consumers (see chart, consumption of goods) and automation. Even the Biden administrations Inflation Reduction Act merely delivered a further steady decline in manufacturing employment share of non-farm employment. Trump's tariffs will probably deliver no more than this. After all, rich Asian countries with trade surpluses in manufactures also have falling shares of jobs in that sector (see chart, share of employment in manufacturing of surplus countries) [12].



None of this is to say there are no important issues in production and trade in manufactures. Some manufactures are vital to national security (e.g., military equipment). The ability to produce some manufactures may also generate important externalities for the economy (e.g., pharmaceutical products). Even so, the idea that these are manifestly more important than in other sectors – software, for example – is nonsense. Equally, as the structure of the economy shifts, people need help in developing new skills. The absence of a market in the creation of human capital is a market failure that justifies intervention in labour markets. Fetishising manufacturing cannot restore the old labour force [12].

China's Graduation: Industrial Policy and SOEs

Made in China 2025

A plan called "Made in China 2025" issued by China's State Council in 2015 made clear the intention to become a global powerhouse in ten high-tech fields from artificial intelligence (AI) to aviation [13], a potential outcome of competition through industrial policy. China's industrial policy involves the use of tax, subsidies, trade policy measures and other programs to support, encourage investment and production in targeted sectors.

Since 2015 supporting plans and road maps published by government research agencies set out hundreds of market-share targets for Chinese firms, declaring, for instance, that 80% of electric or hybrid "new energy" vehicles sold in China must be domestically produced by 2025. Chinese officials, facing a worldwide backlash, downplayed those targets. Strictly-censored state media stopped using the term MIC2025. But the policy itself was not repealed. Speeches by party chiefs ring with calls for "self-reliance" and "indigenous innovation". Other Chinese technology sectors were encouraged to comply with a policy called "civil-military fusion", a national strategy backed by funds from opaque national-security budgets [13].

China's industrial policy has worked better than critics think, but the state-led model is creaking. Despite a truce in the US-China trade war in Dec 2019, China announced that the government would do more in 2020 to support strategic sectors, ranging from robotics to biomedicine. Having seen its vulnerability to US export controls, China became more determined to build up its domestic abilities [14].

In practice industrial policy is hard to get right. China is far from alone in deploying industrial policy, but it stands out for the sheer scale of its efforts. Since the 1980s it has produced dozens of plans and lavished public spending on sectors from solar power to film-making. The electricity and telecommunications sectors are natural candidates for government intervention, given the high cost of building power grids and phone networks, plus the benefits to society. But China has done more than build basic systems; it has also tried to reach the frontier of global innovation [14].

One tentative conclusion is that China's industrial policy works better when natural monopolies are involved. There is a clear role for a central authority with strong organising power to develop a power-transmission system or a high-speed rail network. Yet that same authority can stifle competition in sectors that need it. Alternatively, as often occurs in China, if lots of provincial governments try to foster their own champions, nominally in pursuit of national objectives, the outcome is extreme over-capacity, which undermines the targeted sector [14].

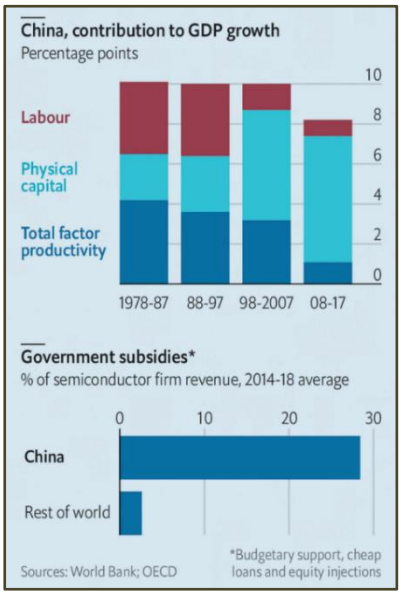
China's shipbuilding industry provides a textbook example. Panle Jia Barwick and Nahim Bin Zahur, both of Cornell University, and Myrto Kalouptsidi of Harvard University (2020) estimate in a paper that between 2006 and 2013 the government directed policy support worth 550bn yuan (roughly $80bn at the time) to shipbuilders. Most went as subsidies for entrants to the sector, attracting subpar firms. China became the world's biggest producer of ships. But the increase in net profits was just a fifth of the subsidies. Even the electricity sector, an ostensible success, is plagued by excess. A well-run power network should have back-up generating capacity equivalent to about 15% of peak load. The average among China's provinces is more than 90% [14].

That, though, is not the end of the story. Ultimately, the value of industrial policy is in its wider economic impact. Ernest Liu of Princeton University argues that state support is most effective when it targets those sectors that make the most essential inputs for others. Generally, these are upstream; turning raw materials into products used in a range of industries. Subsidies for them, even via state firms, can raise overall efficiency. As it happens, China has focused its support on the right sectors in Mr Liu's calculations, such as steelmaking and machinery. China, put bluntly, might never have become the economic power that it is today without ambitious industrial policy [14].

Mr Liu's model does not indicate when subsidies are too high, nor does it set out how best to design policies. There is evidence that China's heavy-handed intervention is becoming increasingly ineffective. Total factor productivity growth in China in recent years has been a third of what it was before the GFC (see chart, GDP growth). Productivity has also slowed in other countries, but the World Bank, in a book about Chinese innovation, notes that China's slowdown was unusually sharp [14].

After conducting extensive case studies of the vehicle and renewable-energy sectors, among others, the bank ascribes some of the blame to Chinese industrial policies that undermine fair competition. It argues that rather than targeting support at specific firms, China should shift to

more market-oriented policies. Even-handed regulations and incentives, which treat state firms no differently from private companies or foreign investors, would do more than lavish subsidies to promote entrepreneurship [14].



No government controls more of an economy worth controlling than China's does. Some 51,000 state-owned firms employ about 20m people and are collectively worth $29trn, according to analysis in 2017 by the OECD, a club of mainly rich countries. Many private Chinese firms claim that they receive no state support, and in strictly monetary terms that is often true, but free land from provincial governments and a side hustle in property management is the norm. The Communist Party's ability to ensure the successful deployment of a technology is not restricted to funding. The state hedges risk, squashes NIMBYism and pays for infrastructure [15].

But two other factors are taking over from raw state power as the motor of Chinese technological development. One is that companies occupy space in important supply chains in the world, giving them easy access to all sorts of technological know-how. As workshop to the world, China makes components for almost everything, understands how to assemble them, and is set up to bring together the right ones as quickly as possible. This geoepistemological advantage explains why the only successful smartphone companies founded since 2010. (They are all non-state firms.) Their success has spread to new markets based on similar components. The consumer-drone market is dominated by China because drones are basically phones with rotors [15].

Secondly, the size and particularities of the Chinese market have become spurs to innovation in their own right. WeChat and Alipay, which use QR codes to make payments with phones, emerged and took hold in China because payment cards were not yet established; as a result Chinese cities are becoming cashless. The Communist Party's need for social control has stimulated an entire industry of machine-learning technologies catering to the security services. The West does not like the applications to which China's AI companies—mostly, also, non-state firms—turn their algorithms, but there is no denying the scale of their ambition (though their success has some under-appreciated foundations) [15].

Not every peculiarity of the Chinese system is a benefit. State support is often doled out to firms or industries based on non-commercial factors. Ignorance and corruption mess things up; so does a thirst for prestige. In the crucial battleground of semiconductors, Beijing's investment policy is largely based on chasing after the highest-value sections of the supply chain by pumping money into Chinese versions of the foreign firms now commanding those heights [15].

Examining Chinese tech development reveals things not just about China, it illuminates global trends. A government able to shape and ignore public opinion can do things that governments forced to listen to the people—including vocal minorities—cannot. If China's technocrats want nuclear power and genetically modified organisms, they will get them [15].

Some trends are subtler. China's failure to catch up in technologies like internal-combustion engines, civil aviation and, to date, semiconductors shows how hard it is to make humanity's most complex mechanisms. The organisations which manage to do so depend on arcane insights and baroque procedures carefully nurtured by corporate hierarchies over decades. That even an economy as mighty as China's can scarcely catch up should give pause for reflection about the possibilities for innovation across so many sectors at the same time [15].

The potential for new technologies to enhance and project Chinese power, and the threat that poses to a global order led by the US, hangs over China's technological development. But China is grappling with an ageing population, environmental degradation and a slowing economy. The strengths and weaknesses of its attempts to solve these problems technologically will have lessons for other countries in similar straits, and for those which see China not just as a competitor but as an ever more sophisticated market [15].

For countries which wish to co-exist with China, its weaknesses reveal good places to invest in developing one's own capabilities. For those who wish to reduce or curtail Chinese technological power, knowing its strengths and vulnerabilities is vital [15].

The Belt and Road Initiative (BRI)

In 2013 China's president Xi first began talking about new silk roads under a scheme entitled: Silk Road Economic Belt and the 21st-Centruy Maritime Silk Road. In 2017, the BRI became the centerpiece of foreign policy when it was written into the Communist Party's constitution [16].

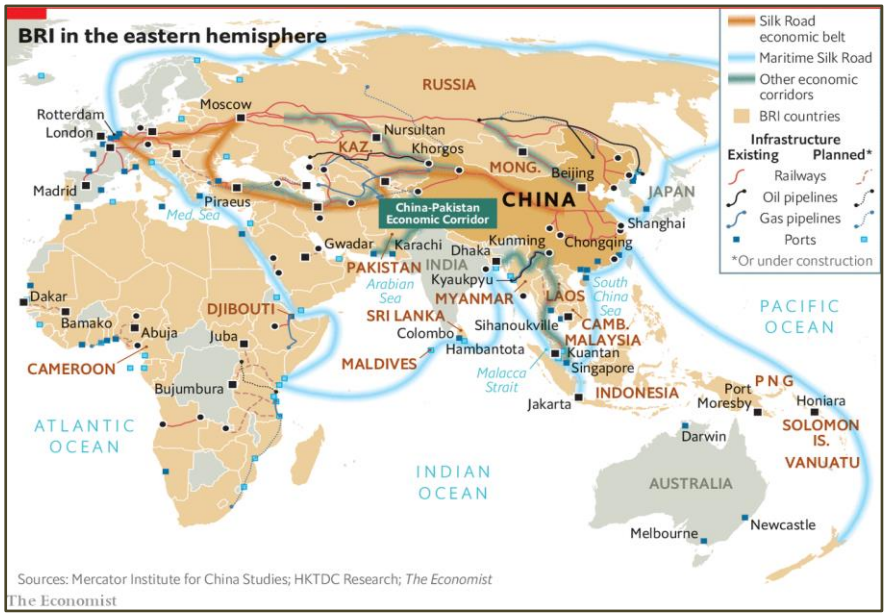
The BRI is an all-encompassing foreign policy – the "project of the century" as Xi called it. But what exactly is it? The World Bank gave an elemental definition of it: "the BRI is a China-led effort to improve connectivity and regional co-operation on a trans-continental scale through large-scale investments". That is a good summary as far as it goes, and helping poor countries build infrastructure is an important component. The global need for new infrastructure is immense. The Asian Development Bank (ADB) estimates that Asia alone needs to invest $26trn between 2016 and 2030, or $1.7trn a year, if it is to maintain economic growth, eradicate poverty and respond to climate change [16].

For China's leaders, it represents a prototype for an emerging geopolitical bloc at a time when the rules-based order was/is under shaky US management. It is a way to help knit together continents through improved infrastructure and a catch-all phrase to make anything China does abroad look unthreatening [16].

The BRI was launched in two speeches in 2013. The first, in Kazakhstan, presented the policy's overland component, the "Silk Road economic belt". It links China to Central, South-East and South Asia, and on to Europe. The word "belt" has that curious name to imply something more than mere transport, energy or other nodes. Rather, an interconnected network of infrastructure would grow into

something thicker: industrial zones and economic corridors with manufacturing, logistics, construction and more [16].

Soon after, Mr Xi presented the maritime component in the Indonesian capital, Jakarta. A "21st century maritime Silk Road", a network of port cities in the South China Sea, the Indian Ocean and the Mediterranean would tie China closer by sea to these regions. Mr Xi has unveiled further dimensions to the plan: a "polar Silk Road" to develop Arctic shipping routes; a "digital Silk Road" of undersea cables, 5G telecoms and cloud computing; and even a "space information corridor" to open up satellite- and space-launch capabilities (see map) [16].



The debates about the BRI began from the outset. At one level, it merely extended a trajectory China had followed for some time, meshing with its major resource suppliers worldwide, as well as its European markets. At another, it was a response to the GFC, which removed a large source of demand for Chinese goods. The lesson was that in future China had to make its own markets abroad. At a third level, it represented an internationalisation of Chinese industrial policy. Faced with overcapacity in steel, cement and more, a party-state whose legitimacy hangs on creating jobs and investment could hardly shut down capacity, as Western countries might do. Instead it must try to export it. Lastly, at a time when the West appeared to be stumbling, both in terms of growth and global leadership, here was a bend in the historical road with China's moment to be seized [16].

Strategic benefits might come from developing ports and cementing dominance in the global shipping industry. They could be stepping stones to China one day projecting naval power far from home—with big implications for Japan, South-East Asia, India and other countries that depend on the world's busiest sea lanes. By rolling out infrastructure across the Eurasian land mass, China becomes the indispensable power in an emerging supercontinent. Crucially, the state directs giant enterprises to do the national bidding, and state banking institutions to provide the financial firepower [16].

From the Party's perspective, cultivating political relationships, and what the party likes to call "people-to-people" ties, bends the world, bit by bit, to China's will. As Bruno Maçães, a former Portuguese foreign minister, puts it in "The Dawn of Eurasia", the spillover effects from infrastructure, trade and finance into politics, culture and security are not "a bug in the project", but its most fundamental feature [16].

The harshest criticism comes from the incumbent superpower, whose global dominance the project is challenging. Western critics argue that China applies dodgier lending criteria than do members of the Paris Club of major sovereign lenders. Nearly every major project meets bumps along the way. Out of sight, deals often get renegotiated, with lower interest rates and longer grace periods and repayment terms [16].

China knows flexibility serves its image best. It offers development money and diplomatic support not available elsewhere. If there is to be any US-led pushback, it must work by attraction, too, by offering developing countries better options than China does. The new connectivity must work well for client states [16].

Infrastructure Investment under BRI

Most Chinese investment has gone into commercial ports. The maritime push is led by a handful of giant state enterprises with close links to the Communist Party's leaders. China Communications Construction Company (CCCC) is the biggest company on the belt and road. COSCO, a shipping behemoth, is the world's third-biggest container line and has investments in 61 port terminals around the world. China Merchants, founded as a patriotic enterprise in 1872 to attract Chinese capital to take on Western shipping lines, manages 36 ports in 18 countries. Since 2010 well over $20bn of Chinese money has been poured into foreign ports [17].

One dimension is the "port-park-city" concept: a port is more likely to thrive with a hinterland in the form of industrial zones and a growing city. Another plan is for major ports to serve as regional hubs at which the biggest container ships can dock; their cargoes are then unloaded and dispatched on smaller vessels serving other regional ports [17].

In discussing BRI, China's president, Xi Jinping, peppered a speech with proverbs. "The ceaseless inflow of rivers makes the ocean deep," was one—a reference to how his scheme, involving huge spending on infrastructure in other countries, would promote the global flow of goods, capital and technology and with them, economic growth. Amid the pandemic, many BRI projects stalled as countries struggled to repay debts [18].

Mr Xi promised hundreds of billions of dollars in loans and grants for power plants, ports, railways, roads and other infrastructure in Africa, Latin America, South-East Asia, Central Asia and Europe (see chart Chinese investment and

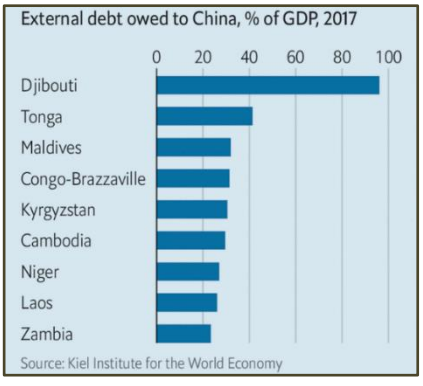
contracts). But because of covid-19, work on some projects came to a halt. A few were scrapped. Several that seemed of dubious worth even before the pandemic now look like white elephants. Many of the loans have been on the brink of technical default, as debtor countries sought to defer payments that are coming due [18].

Pakistan asked China for easier repayment terms on $30bn-worth of power projects. In April 2020 Tanzania's president, John Magufuli, said he would cancel a $10bn port project at Bagamoyo because it was signed (by his predecessor) with conditions that "only a drunkard" would accept—chiefly, that China would gain full control of the port with a 99-year lease. And in May, Nigerian legislators voted for a review of all of China's loans for Chinese projects amid concerns that financing may have been agreed on unfavourable terms. African leaders have called for emergency debt-forgiveness from sovereign creditors including China, which was owed about $8bn in 2020 in payments on about $145bn in loans to African countries, many involving BRI projects [18].

Many countries raised the cash for BRI projects by exporting commodities, but the pandemic slowed demand for them. The choice was whether to China should reduce the amount owed, as sovereign lenders sometimes do in response to a financial crisis or whether it should try to preserve as many loans and BRI projects as it can by delaying payments and extending terms (its typical approach)? Either way, experts said, a wave of defaults was inevitable [18].

In April 2020, amid debtors' growing calls for help, the G20, which includes China, broadly agreed to allow up to 73 countries to suspend debt-service payments totalling about $12bn-14bn until the end of 2020. But the devil is in the details. The G20 warned that applying for a suspension of debt-service payments could breach other terms to which a country may have agreed. Unlike members of the Paris Club of big sovereign lenders, who do not require collateral for their development loans, China's banks do for about 60% of their lending to developing countries, says Carmen Reinhart, the World Bank's incoming chief economist. In theory a country could apply for debt relief only to find that China could claim the rights to a mine, a port or money held in escrow. This is one reason why China's banks prefer to renegotiate sovereign loans bilaterally, and in secret. They have leverage, and can choose how to apply it [18].

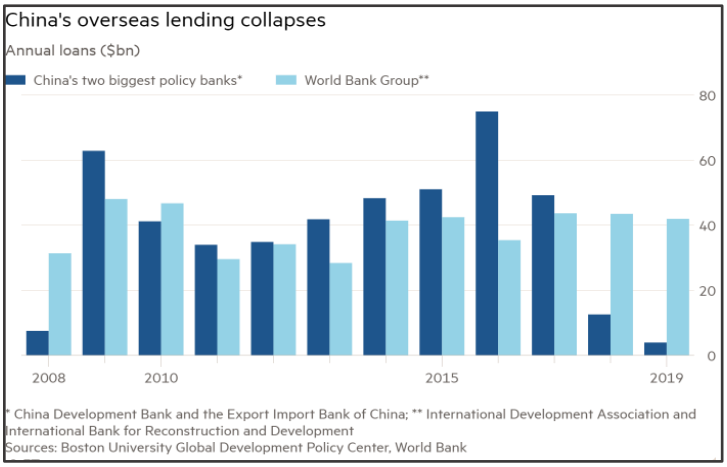
But this is where diplomatic risk looms large for China. Claiming assets from defaulting countries would create a furore. It would damage China's image in countries that the BRI was intended to help, and strengthen suspicions among Western hawks that China is using the BRI to saddle countries with debt (see chart external debt owed China) and thereby gain control of infrastructure that could help it strategically. "If they thought they were facing a backlash now, it would be really severe for them" if they were to seize collateral, says Scott Morris of the Centre for Global Development, a think-tank in Washington. China must tread warily, initiating fewer BRI projects [18].



If done right, without drowning countries in debt, BRI projects may yet provide a welcome boost to the global economy. Before the pandemic the World Bank estimated that BRI transport projects in Asia, including high-speed railways, would boost the GDP of participating countries by up to 3.4% overall. Some of those rail projects have stalled, and China is preoccupied with its own hard-hit economy. But Daniel Rosen of Rhodium Group, a research firm, argues that China's policy banks have ample capacity to maintain the present level of BRI lending. It just is not economically prudent for them do so, especially before a global recovery is on track [18].

When that happens, the BRI may revert to its original infrastructure development focus. And many countries in desperate need of better infrastructure will welcome this. They have few other options. In Nov 2020 the US, Japan and Australia announced an alternative to the BRI called the "Blue Dot Network" to fund infrastructure projects in the developing world. But, as with multilateral lenders such as the World Bank, the financial muscle behind it looks puny in comparison. The BRI has the best promise of meeting the glaring infrastructure gaps in the global economy. There is no global infrastructure surge without the BRI [18].

If China was unable or unwilling to provide sufficient relief to its borrowers, it could find itself at the centre of a debt crisis in developing markets. The data that describes China's predicament comes from researchers at Boston University who maintain an independent database on China's overseas development finance. They found that lending by the China Development Bank and the Export-Import Bank of China collapsed from a peak of $75bn in 2016 to just $4bn in 2019 (see chart, overseas lending collapses). The context around this is crucial. The two banks fall under the direct control of China's state council (cabinet), so they function as arms of the state. They provide the overwhelming majority of China's overseas development lending and the funds they disburse rival in scale those of the World Bank, the world's largest multilateral lender [19].



Between 2008 and 2019, the two Chinese banks lent $462bn, just short of the $467bn extended by the World Bank, according to the Boston University data. In some years, lending by the Chinese policy banks was almost equivalent to that by all six of the world's multilateral financial institutions — which along with the World Bank include the Asian Development Bank, the Inter-American Development Bank, the European Investment Bank, the European Bank for Reconstruction and Development and

the African Development Bank — put together. In global development finance, such a sharp scaling back of lending by the Chinese banks amounts to an earthquake. If it persists, it will exacerbate an infrastructure funding gap that in Asia alone already amounts to $907bn a year, according to Asian Development Bank estimates. In Africa and Latin America — where Chinese credit has also formed a big part of infrastructure financing — the gap between what is required and what is available is also expected to yawn wider [19].

Debt sustainability — or the ability of debtor countries to repay their loans — had to be part of any reassessment of the Belt and Road Initiative, says Kevin Gallagher, director of the Boston University Global Development Policy Center, which compiled the data on Chinese overseas lending. Debt renegotiations proliferated as the pandemic clobbered emerging economies in Africa and elsewhere. A report by Rhodium Group, a consultancy, says at least 18 processes of debt renegotiation with China took place in 2020 and 12 countries were in talks with Beijing as of the end of Sep 2020, covering $28bn in Chinese loans. Beijing appeared keen to pursue a soft touch, deferring interest payments and rescheduling loans. But the experience reinforced a growing sense of wariness that infused Mr Xi's big project. China is finding out, says Mr Hillman, that "risk runs both ways along the Belt and Road and the damage can return to Beijing" [19].

"Dual Circulation"

'Dual circulation' is China's retreat from overseas development finance which derived from structural policy shifts, according to Chinese analysts. "China is consolidating, absorbing and digesting the investments made in the past," says Wang Huiyao, an adviser to China's state council and president of the Center for China and Globalisation, a think-tank [19].

Yu Jie, senior research fellow on China at Chatham House, a UK think-tank, says Beijing's recently-adopted "dual circulation" policy represents a step change for China's relationship with the outside world. The policy, which was first mentioned at a meeting of the politburo in May 2020, places greater emphasis on China's domestic market — or internal circulation — and less on commerce with the outside world. "Volatile Sino-US relations and more restrictive access to overseas markets for Chinese companies have prompted a fundamental rethink of growth drivers by Beijing's top economic planners," says Ms Yu [19].

For years officials declared that China had to grow more innovative and more resilient. To a certain extent it achieved this naturally, as a result of its fast-paced economic development. But these goals took on far greater urgency as tensions with the US mounted. US restrictions on exports of critical components, notably semiconductors, shone a harsh light on the gaps in China's industrial abilities. Xi Jinping, China's leader, described the creation of fully domestic supply chains as a matter of national security [20].

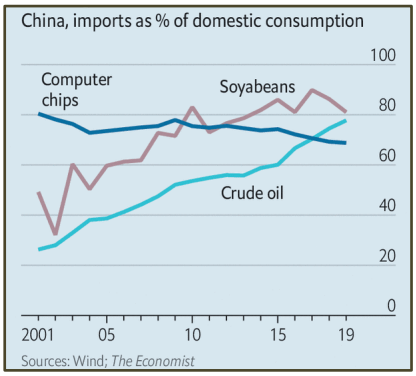
The question was how to build them. Chinese officials know that they cannot turn their backs on the world. Exports are still an important source of revenue for many firms. And China must attract technology and investment from abroad. Pushing too transparently for "indigenous innovation", a term once bandied about by the government, only makes foreigners wary. Striking the right balance is tough [20].

Enter the newest of China's big economic policies: the "dual-circulation" strategy. At its most basic it refers to keeping China open to the world (the "great international circulation"), while reinforcing its own market (the "great domestic circulation"). If that sounds rather vague, it was: the government had not spelled out the details. It had fast emerged as the most talked-about economic policy in China, with analysts and businesspeople jostling to put their spin on it. The strategy was at the heart of the five-year plan for 2021-25 [20].

The term "international circulation" was coined in 1988 by Wang Jian, a government researcher who argued that China should pursue an export-led growth strategy, plugging its vast pool of cheap labour into global production networks. Well into the early 2000s, this was a guiding principle for China's economic planners. Yet circumstances changed. Exports have shrunk as a share of GDP—from 36% in 2006 to 18% in 2019. The government repeatedly vowed to make consumption within China a bigger engine of growth. So scholars turned their attention more to the domestic kind of circulation [20].

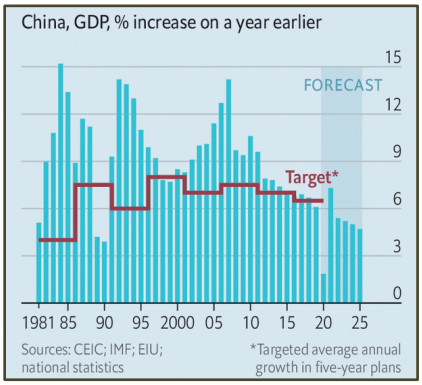
Some were tempted to dismiss this as just another way of phrasing the long-stated goal of rebalancing towards domestic demand. But Mr Xi comments on the economy were less about promoting consumption and more about bolstering China's defences. China needs "self-developed, controllable" supply chains, with at least one alternative source for vital products. Even more striking was his inversion of the idea of international circulation. Instead of talking about it in terms of the economic benefits China reaps from globalisation, he emphasised only the strategic purpose of opening China's doors to foreign firms, i.e., that making them more dependent on the Chinese market would deter foreign powers from putting pressure on the country. That combination—the pursuit both of economic self-reliance and of greater economic leverage over foreign countries—now describes much of what China is doing [20].

The party referred to a need to develop critical technologies at home. But other policies already in train suggest that China will prop up any high-tech sector threatened by global vicissitudes. In Aug 2020 tax breaks and loan support for semiconductor and software firms were announced. China currently produces about 30% of the chips it consumes (see chart, imports). Its goal is to reach 70% by 2025. Another focus is on green technology and renewable energy. That is not just for the sake of the environment (China pledged to halt the rise of its carbon emissions by 2030). Investment in such businesses will also limit China's thirst for imported oil [20].



In the past, when publishing outlines of five-year plans the party announced a goal for average annual GDP growth during the plan period (see chart, China GDP). For 2021-25 there was no such figure. China had good reason to abandon such targets. They lead to an overemphasis on investment in infrastructure and other short-term measures to boost growth, rather than on social policies such as those relating to health care or education which can promote growth but may take longer to show results. But de-emphasising targets may relate to the dual-circulation strategy in a way that the government left unspoken.

Making the economy less reliant on global supply chains could crimp its ability to grow [20].



Arguably China has been the world's main beneficiary of globalisation, which has enabled it to dominate ever-bigger segments of manufacturing. Turning inward could be costly. It may result in less foreign technology flowing into China, less of the competition that has spurred on Chinese firms, and more wasteful investment as the government throws money at favoured industries. Shaun Roache, an economist with S&P a credit-rating agency, forecasted China's average annual growth would be 4.6% in the 2020s. But he reckoned it could be about 3% if the drive for self-reliance was overdone. The country's "tolerance for slower growth may well be tested in the years ahead", he says. The party, ever fearful that a stagnating economy could trigger social unrest, may find it hard going [20].

Economies of Scale

Henry Ford launched his Model T in 1908, turning the car from a luxury into a mass-manufactured product. Ford's original factory used standardized parts and fitted them into vehicles as they travelled along a moving assembly line. By 1914 this cut the labour time needed to assemble a Model T from 12.5 hours to 93 minutes. Before long the factory complex became the centre of a vertically integrated empire, designed to produce everything required to make a car [21].

The Model T, however, soon became obsolete. The weakness of the Ford system was exposed: it is extremely expensive and slow to switch a giant factory from one product to another. Ford halted production, laying off 60,000 workers. After six months 15,000 machine tools had been replaced and 25,000 others rebuilt, so that the factory was ready to make the new Model A. As the switch from Model T to Model A plunged Ford into loss, Alfred P. Sloan, president of General Motors, presciently observed that carmakers would need to "adopt the 'laws' of Paris dressmakers". That meant bringing out new models more often [21].

The shortening of product cycles and the fickle nature of modern markets has duly seen manufacturing atomise into small, nimbler, more specialist factories. The original Ford factory lives on with just 6,000 workings making pick-up trucks [21].

Some see offshoring to low-wage countries, particularly in Asia, as the mega-factory's last hurrah. Yet long supply chains and distant plants are leaving producers vulnerable to rapid changes in their home markets, so production has been trickling back. Meanwhile, new materials and manufacturing methods, such as 3D printing, are demolishing the economics of scale that giant factories have relied on [21].

Economies of scale (EOS) run out at a certain point and the largest US firms may be beyond it. Some things only get bigger. Boats, planes, skyscrapers and shopping malls all have size records, which are routinely broken. Companies are operating at record scale, too. The trend towards growing ever larger is clear, whereas the economics of bigness are far murkier [22].

Container ships provide a good example of EOS. Greater size in container ships promises greater efficiency, as fixed costs are spread over higher output. Introduced in the late 1950s, the first ships could carry 480 20-foot equivalent (TEU) containers. By 2006 the biggest shifted 15,000 TEUs. Cost factors explain the rise: transport adds nothing to the final value of a good so cost minimisation is all-important. As shipping costs per container kept falling as ship sizes rose, container ships kept growing. A new range of 18,000 TEU ships was launched in 2013, the most efficient [22].

In buildings, however, the gains from scale may be running out. It is possible to exhaust the savings that come with size. Between 1931 and 2007 the record for the world's tallest building rose from 381 to 828 metres. As buildings get taller, the fixed cost of land per square metre of office space falls. Other height-related changes offset this saving. The wind force on a building rises exponentially with height, making design more complex and costly. Steve Watts and Neal Kalita of Davis Langdon, a consultancy, show that construction costs per square metre rise as a building gets taller.[4] In addition, the useable space per extra floor starts to fall as the central "core" of the building gets bigger. Most very tall buildings are at an inefficient scale, propelled skyward for reasons of prestige rather than efficiency. If developers focused on cost alone, they would opt for clusters of mid-rise buildings [22].

Where do firms lie on this spectrum? Firms have gotten bigger and the long-run trend tends toward bigger firms. A snapshot of the US economy shows huge dispersion in firm size: around a third of US workers are employed by one of the 6m small firms (fewer than 100 workers) with another third employed by one of the 980 large firms (more than 10,000 workers). Robert Lucas[5], U. of Chicago, documented how the average US firm size increased over a 70-year period (see left-hand chart) [22].

The world's biggest firms get bigger because (1) a firm gradually outdoes its rivals, or (2) more suddenly through mergers and acquisitions (M&A). M&A are important in explaining gigantism. Since 1990, the assets of the top 50 US firms rose from around 70% of US GDP to about 130% (right-hand chart). All top ten US firms were involved in at least one large M&A since the 1980s [22].

[4] Watts, S. & N. Kalita, "Tall buildings, a strategic design guide" and "The economics of high rise", Davis Langdon Tall Buildings Research.

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Do firms making boats or buildings seek out EOS, or are they too big to be efficient? One way to answer this question is to estimate how output levels influence the costs of production in a competitive industry. The "cost function", as it is known, can be tricky to establish because firms often have multiple inputs and outputs. Take farming[6]. Estimating a cost function requires complex information on how each farm's outputs (milk, meat and crops) and inputs (labour, energy, feed, capital) interact [22].

Once the cost function is pinned down, it can be used to identify EOS. A fall in average costs as a firm's size grows bigger suggests EOS exist for firms of that size. Results vary by industry. US dairy farms, for example, have gotten bigger but there are still EOS to exploit, especially among farms with fewer than 200 cattle. By contrast, rail-industry studies[7] show dwindling EOS over time as firms grow. Overall, estimated cost functions suggest the limits of scale may have been reached for some very large firms [22].

M&A studies support this.[8] The "winner's curse" describes the phenomenon of M&A destroying value for the shareholders of the firm taken over. McKinsey, a consultancy, finds that: close to two-thirds of managers overestimate the EOS a merger will deliver, inflating the benefits by more than 25%. Size can even drive costs up, if firms get too big to manage efficiently [22].

If size does not drive down costs, why do big firms keep expanding? One possibility is that they seek to boost profits not by driving down costs but by raising prices. Buying up rivals softens competition and enables firms to charge more. US antitrust regulators looked at past health-care M&As, and found that prices rose significantly after some deals. Another view is that M&A are driven by something other than profit. The "empire-building" theory holds that managers are out to increase the scale of their business whatever the cost in terms of creeping inefficiencies [22].

State safety nets can distort incentives, too. The three leading US car manufacturers grew through M&A: each of them employs over 50,000 workers, and the government balked at letting them fail during the crisis. Some firms may be growing not to lower costs but to receive the comfort of implicit state support. A Federal Reserve paper (2011) supported this conclusion, suggesting banks pay a premium for M&A if the tie-up gives them "too-big-to-fail" status. None of these reasons for operating at a vast size is benign. Antitrust authorities should be much more sceptical about M&As that claim to be justified because of EOS [22].

Luxury goods market

The global market for personal luxury goods, from handbags to haute couture and horology, grew by 4% in 2023. The past two decades have been remarkable for the industry. Global sales have tripled to nearly $400bn, thanks largely to a crazy rich Asias. The biggest beneficiaries of the boom are European companies. These account for around two-thirds of luxury-goods sales, according to Deloitte, a consultancy, and nine of the world's ten most valuable luxury brands, according to Kantar, a market-research firm. The industry remains a rare bright spot for Europe at a time when the continent seems as risk of fading into economic and technological irrelevance. Why has it been so immune to foreign competition [23]?

Just as Europe has lost techies to Silicon Valley, the US has lost top designers to European capitals. As Tom Ford noted, "if I was ever going to become a good designer, I had to leave America". But hobnobbing with other fashionistas is not the only advantage on offer in Europe. The continent is dotted with artisanal workshops that have for decades catered to the exacting standards of the luxury industry [23].

Over the decades the continent has developed specialized clusters of production, from watch-making in the Jura Arc of Switzerland to shoemaking in the Veneto region of Italy, where techniques are handed down over generations through specialist schools and coveted apprenticeships [23].

Europe's luxury champions deserve credit for pursing strategies that have reinforced their dominance of the industry. They have been steadily buying stakes in their suppliers, giving them a competitive edge through greater control of production. Vertical integration in the industry has stretched all the way back to alligator farms in Louisiana and sheep stations in Australia. It has also extended in the other direction, into distribution, with luxury firms increasingly opting to sell directly to shoppers through their own swanky stores, rather than entrusting the customer experience to others [23].

All that has required plenty of capital, which helps explain the parallel trend towards horizontal integration in the industry. LVMH now houses 75 luxury brands. Although these mostly operate autonomously, the model provides economics of scale in areas like marketing and the back-office function. It also gives the group the financial firepower to invest in prime real estate. In Jul 2023 LVMH bough the building on the Champs Elysees that houses ins Louis Vuitton flagship store. Swatch, which owns watch brands controls a portfolio of component suppliers, too. The conglomerate model also helps to lure in top talent by offering opportunities for designers and craftsmen to move between brands, noted Stefania Saviolo of Bocconi University. Could this simply be a case of external economies of scale [23]?

Does global competition weaken benefits of clusters?

Michael Porter from Harvard Business School argued that clusters help productivity, boost innovation and encourage new firms. Porter studied how firms' geographical proximity, their close competition with each other and the growth of specialised suppliers and production networks around them make a winning combination. Globalisation, however, makes this far less certain. More open trade and improved transport links mean that bunching together in a cluster no longer offers a strong defence against cheaper foreign rivals. As Italy's medium-sized industrial firms adapt to the threat from China, the benefit from being bunched together in a cluster seems to be weakening [24].

More than 100 clusters speckle the boot of Italy: tiles in Sassuolo, food machinery in Parma, sofas in Matera, footwear in Fermo and clothing in Treviso, to name some. Some owe their existence to local natural assets—e.g., marble is quarried in the mountains behind Carrara, others are the result of skills built up over successive generations. The packaging-machinery firms around Bologna grew out of the region's tradition of precision engineering, and around Belluno, where the first ever spectacles factory was built in 1878, is still home to a cluster of eyewear makers [24].

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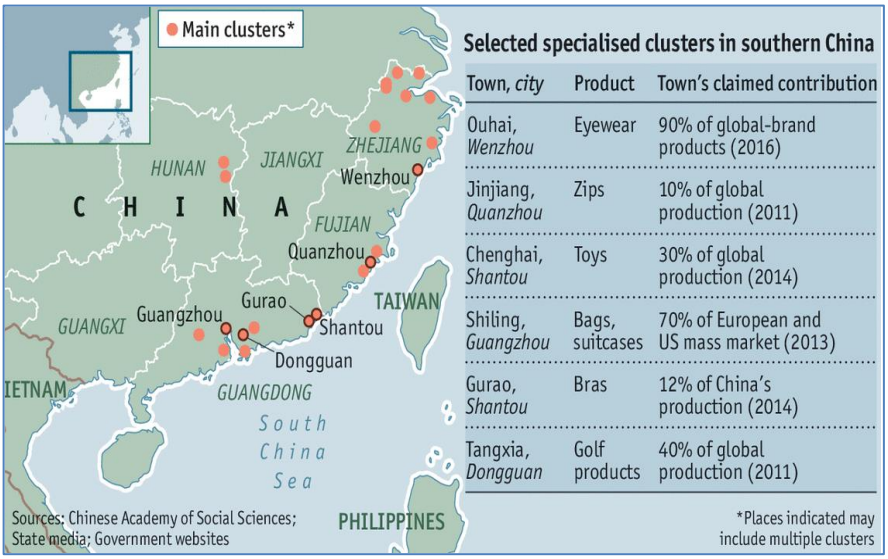
One cluster features the world's largest center for working brass, comprising 380 firms that together employ about 10,000 people making valves and taps and another 19,000 who work in small satellite firms involved in parts of the production process. Founded in 1951, Giacomini is a giant of the cluster with 850 employees who make brass valves, connectors and manifolds. However, quality certification, precision production and a catalogue of 6,000 products will not safeguard its future. "Germans saw us in the 1950s and 1960s as we now see Chinese products—low quality, low cost. The firm diversified into electronic controls and heating and air conditioning systems in the 1990s, a move away from its traditional business and the links to its cluster - increasingly less relevant to its future [24].



Selected specialised clusters in southern China

Town, *city*	Product	Town's claimed contribution
Ouhai, *Wenzhou*	Eyewear	90% of global-brand products (2016)
Jinjiang, *Quanzhou*	Zips	10% of global production (2011)
Chenghai, *Shantou*	Toys	30% of global production (2014)
Shiling, *Guangzhou*	Bags, suitcases	70% of European and US mass market (2013)
Gurao, *Shantou*	Bras	12% of China's production (2014)
Tangxia, *Dongguan*	Golf products	40% of global production (2011)

*Places indicated may include multiple clusters

Zucchetti, a tapmaker in Gozzano, changed strategy. It bought a maker of luxury baths and basins, and shifted production upmarket, with smaller production runs and a larger product range. Zucchetti's future performance depends less on being in the cluster than designing smart products and defending its brand. Competition is forcing firms to innovate, improve quality and build brands [24].

A jewellery cluster in Valenza hoped to protect its business by creating a group trademark and through peer pressure to keep skills in the cluster. Bruno Guarona, chairman of the jewellers' association, moaned about unfair competition from China, where labour regulations are lax and firms enjoy tariffs and duties that undercut those his members face. He accuses jewellers from Valenza who have moved production abroad, as "traitors who have committed a crime" [24].

Fragmentation of production and outsourcing abroad, clear signs that firms have become less competitive, weaken the networks on which clusters are built and may even destroy their competitive advantage, warns Rodolfo Helg, an economics professor at the University in Castellanza, which occupies the buildings that were once the town's large cotton mill. He believes successful clusters in the future would be very different from those of the past [24].

In several industries within China, the clustering of similar firms in the same place created a critical mass of good suppliers and workers with relevant skills. In 2016, niche one-product towns in China produced 63% of the world's shoes, 70% of its spectacles and 90% of its energy-saving lamps. China made 2.9 million bras, 60% of the world's total, according to Frost and Sullivan, a consultancy. Gurao, a town in the southern province of Guangdong that together with sever other towns make China the world's largest lingerie producer, produced some 350m bras and 430m vests and pairs of knickers a year for sale at home and abroad. Underwear accounted for 80% of the town's industrial output [25].

During the rapid economic growth starting in the 1980s, one-industry towns like Gurao and Chendian sprang up along China's eastern seaboard, often in what were once paddyfields. With investment from Hong Kong and Taiwan, and a huge influx of migrant labour from China's interior, they fuelled the country's export boom. In 2016, there were more than 500 such towns, making products such as buttons, ties, plastic shoes, car tyres, toys, Christmas decorations and toilets (see map, clusters) [25].

Officials in Gurao insist that the town can overcome its difficulties by upgrading its technology and using machines instead of people. But attractive the capital and skill to transform Gurao is becoming more difficult. Even China's largest underwear manufactur4ers had always found it hard to get long-term commitments from buyers. That made them reluctant to spend on research or technology. Some factories in Gurao are upgrading, for example, by making seamless laser-cut underwear and using new, more comfortable, materials to underwire bras, but most remain low-tech and labour-intensive [25].

Some of the one-product boomtowns could fade away, Leaving little behind but the concrete shells of employ factories and polluted soil. Gurao and other such places have generated extraordinary wealth in once dire-poor parts of the country. But to thrive in the future, they will need to look beyond the bare necessities [25].

https//www.economist.com/news/china/21697004-one-product-towns-fuelled-chinas-export-boom-many-are-now-trouble-bleak-times-bra-town
Video on one-product cluster towns in China (3.42 min)

Third industrial revolution is digitising manufacturing and transforming the way goods are made

The first industrial revolution began in the UK in the late 18th century, with the mechanisation of the textile industry. Tasks previously done by hand in hundreds of weavers' cottages were consolidated into a single cotton mill, and the factory was born. The second industrial revolution came in the early 20th century, when Henry Ford mastered the moving assembly line, ushering in mass production. These revolutions made people richer and more urban [9].

Old-style manufacturing involved taking many parts and screwing or welding them together. The factory of the past was based on cranking out zillions of identical products, making possible economies of scale which changed the economy—and society—in ways unimaginable at the time [9][10]. Ford famously said that car-buyers could have any colour they liked, as long as it was black [9].

A third revolution set off by advances in computing and information and communication technology (ICT) in the late 20th century, promised to deliver a mixture of social stress and economic transformation [9]. This change, making manufacturing go digital, is driven by a number of remarkable converging technologies: clever software,

novel materials, more dexterous robots, machine intelligence, new processes, notably 3-dimensional (3D) printing, and a whole range of web-based services. These technologies can deliver many innovations, e.g., unmanned vehicles; pilotless drones; machines that can instantly translate hundreds of languages; mobile technology that eliminates the distance between doctor and patient, teacher and student. Whether the digital revolution will bring mass job creation to make up for its mass job destruction remains to be seen [9][10].

Powerful, ubiquitous computing was made possible by the development of the integrated circuit in the 1950s. Under a rough rule of thumb known as Moore's law (after Gordon Moore, one of the founders of Intel, a chipmaker), the number of transistors that could be squeezed onto a chip has doubled every two years or so. This exponential growth resulted in ever smaller, better and cheaper electronic devices (today's smartphones carry vastly more processing power than the supercomputers of the 1960s). Though Moore's law has approached its end (because transistors are so small that shrinking them further is likely to push up their cost rather than reduce it), commercially available computing power continues to get cheaper. Google and Amazon are slashing the price of cloud computing to customers, and firms are getting better at making use of that computing power [9].

At the same time, hardware (from processors to cameras to sensors) continues to get better, smaller and cheaper, opening up opportunities for drones, robots and wearable computers. Innovation spills into new areas: in finance, for example, crypto-currencies like Bitcoin hint at new payment technologies, and in education the development of new and more effective online offerings may upend the business of higher education [9].

History suggests that society's adjustment to the changes will be slow and difficult. At the turn of the 20th century, writers conjured up visions of a dazzling technological future even as some large, rich economies were limping through a period of disappointing growth in output and productivity. As a new age of globalisation is hailed, then as now, political systems struggle to accommodate the demands of growing numbers of dissatisfied workers. Slow GDP growth rates at the start of the 21st century is testing governments beset by new demands for intervention, regulation and support [9].

The technology under this third revolution reverses the process of the earlier revolutions in manufacturing, i.e., making it as cheap to create single items as it does to mass produce them, thereby undermining EOS [9][10]. Future factories can focus on mass customisation. The cost of producing smaller batches of a wider variety, with products tailored precisely to each customer's need, is falling. The cost of setting up a 3D printing machine is becoming the same whether it makes one thing or as many things as can fit inside the machine [9].

It works like this. First, a blueprint of the design of an objected is uploaded onto a computer and its shape and colour is tinkered with using some software. The file is sent to a 3D printing machine, which builds a solid object gradually, either by depositing material from a nozzle, or selectively solidifying a thin layer of plastic or metal dust using tiny drops of glue or a tightly focused beam. A products is built by successively adding layers of material, one layer at a time, i.e., additive manufacturing [26].

Additive manufacturing has several cost advantages over the conventional manufacturing. First, it does not require a factory or even a large space (small items can be made by a machine the size of a desktop printer). Second, there are no production or assembly lines. Third, the 3D printer can run unattended. Forth, it reduces waste by requiring as little as one-tenth of the amount of material. Fifth, it allows the creation of parts in shapes that are too complex for a traditional factory using conventional techniques to achieve, resulting in new, much more efficient designs in aircraft wings or heat exchangers, for example; and enables the production of a single item quickly and cheaply—and then another one after the design has been refined. Hearing aids and high-tech parts of military jets are being printed in customised shapes [9][26].

Additive manufacturing is only one of many new breakthroughs shaping the factory of the future, and conventional production equipment is becoming smarter and more flexible, too. New production strategies standardize the parameters of certain components required to produce a final good. This enables a (car) manufacturer to produce all its differentiated products (e.g., an engine for cars) on the same production line. Eventually it should allow its factories in the US, Europe and China to produce locally whatever vehicle each market requires [27].

Before, 3D printers were used only for prototyping, mainly in the aerospace, medical and automotive industries. Once a design was finalised, a production line would be set up and parts would be manufactured and assembled using conventional methods. Now, finished items themselves are produced by 3D printers. Because each item is created individually, rather than from a single mould, each can be made slightly differently at almost no extra cost. Mass production gives way to mass customisation for all kinds of products [26].

By reducing the barriers to entry for manufacturing, 3D printing should also promote innovation. If a shape can be designed on a computer, it can be turned it into an object to see if there is a market for it. More can be printed, modifying the design using feedback from early users. This is a boon to inventors and start-ups, because trying out new products is less risky and expensive. Just as open-source programmers collaborate by sharing software code, engineers are already starting to collaborate on open-source designs for objects and hardware [26].

The materials used to make things are changing as well [10]. Earlier, the 3D printing process was possible only with certain materials (plastics, resins and metals) and with a precision of around a tenth of a millimeter [26]. New materials are lighter, stronger and more durable than the old ones. Carbon-fibre composites, for instance, are replacing steel and aluminium in products ranging from mountain bikes to areoplanes [9]. The large-scale use of carbon fibre began in aerospace. Both Airbus and Boeing aircraft use it extensively instead of aluminium. Not only is it lighter (about half the weight and just as strong as steel), there is also a big manufacturing advantage: large sections, like the main area of a wing, can be made in one go rather than being riveted together from lots of individual components [28].

Increasingly, new techniques let engineers shape objects at a tiny (nanotechnology) scale. Nanotechnology is already used to engineer some products with enhanced features, such as bandages that help heal cuts, engines that run more efficiently and crockery that cleans more easily [8].

Boston's biotechnology cluster consists of pharmaceutical firms, big and small, attracted in large part by the research carried out in the region's hospitals and universities. In the biological sciences the development of manufacturing capabilities is closely linked to that of the product, says Phillip Sharp, a Nobel prize-winner and co-founder of what is now called Biogen Idec, a Massachusetts-based biotechnology firm with annual revenues of $5 billion. What currently excites the industry, says Mr Sharp, is

nanotechnology, taking its name from the word for a billionth of a metre. When materials are measured at the nanoscale they often have unique properties, some of which can be used in beneficial ways [8].

Nanotechnology makes it possible to manufacture, on a tiny scale, new therapeutic substances carrying information on their surfaces that can be used to direct them to particular cells in the body. The drugs delivered by such substances could be valuable in treating diseases like cancer. They are being made in small quantities now, says Mr Sharp; the challenge will be to scale up those processes once clinical trials are completed. And that, too, he adds, will depend on both product and manufacturing innovation working together [8].

Making drugs for the most part remains an old-fashioned batch-manufacturing process. This involves assembling ingredients, often from different countries, processing them in a chemical plant into a batch of drug substance, then turning that substance into pills, liquids or creams in another factory, which might be in yet another country. All this involves a lot of moving around of drums and containers, and plenty of inventory sitting idle. It is time-consuming and expensive [8].

In a laboratory in Cambridge, Massachusetts, another way of making drugs is being developed. Raw materials are put into one end of a machine full of tubes, cogs, belts and electronics, and pills pop out of the other end. This pilot production line, a joint venture between MIT and Novartis, a giant Swiss-based drugs company, is pioneering a continuous manufacturing process for the pharmaceuticals industry. It is producing a copy of a standard Novartis drug, although not for use yet because the system is still five to ten years away from commercial operation. It relies on a combination of chemistry and engineering, speeding up some processes and slowing down others to make them work together [8].

The results are encouraging, says Stephen Sofen, the project's director. The number of discrete operations involved in producing the drug was cut from 22 to 13; the processing time (even excluding all the moving around of materials) shrunk from 300 hours to 40. Instead of testing each batch of material, every pill made is monitored to ensure it meets the required specification [8].

Continuous manufacturing could transform the pharmaceuticals industry. “Instead of a giant, purpose-built plant to supply the global market, you could imagine smaller, regionalised plants,” says Mr Sofen. Such factories could respond more rapidly to local demand, especially if a pandemic were to break out. The pilot line in Cambridge will fit into a shipping container, so it could be deployed anywhere. It can make 10m tablets a year, working around the clock. It might also be used to make customised doses of drugs for particular patients. Continuous manufacturing could make more treatments commercially viable [8].

Genetically engineered viruses are being developed to make items such as batteries. The internet allows ever more designers to collaborate on new products, so barriers to entry are falling. Ford needed heaps of capital to build his colossal River Rouge factory; his modern equivalent can start with little besides a laptop and a hunger to invent [9]. Like computing before it, 3D printing is spreading fast as the technology improves and costs fall. A basic 3D printer in 2011 cost less than a laser printer in 1985 [26][28].

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