The Economist

China's surveillance state

The tragedy of Keir Starmer

Jefferson rolls in his grave

Celebrity entrepreneurs

JULY 5TH–11TH 2025

Business

Photograph: Getty Images

Paramount Global reached a settlement with Donald Trump in his lawsuit against CBS News, which it owns. The president had claimed that CBS's "60 Minutes" programme had selectively edited an interview with Kamala Harris in a way that amounted to "substantial news distortion" in the run-up to last year's election. Many legal observers think the case would not have stood up in court, but Paramount has settled for $16m, to be paid to Mr Trump's future presidential library. It also relieves the pressure on the media giant's proposed merger with Skydance Media, which is being scrutinised by the Federal Communications Commission.

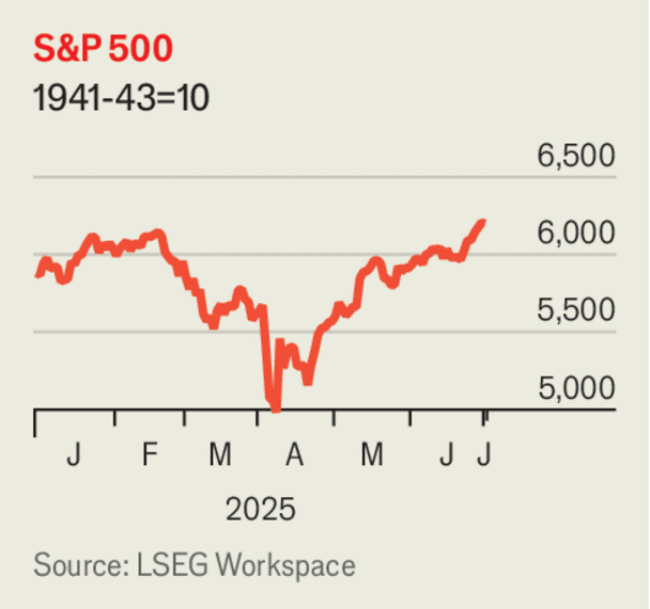

Chart: The Economist

The S&P 500 broke a new record, almost five months after reaching its previous peak before it slumped in April amid Donald Trump's trade wars. The index has risen by 25% from that trough. It is being boosted again by tech companies. Nvidia is closing in on a $4trn market value and Oracle's share price jumped to a new high after it announced a cloud-computing contract (said to be with OpenAI) worth $30bn a year, one of the biggest data-centre deals to date. But even Nike's stock has surged, by 15% in a day, amid signs that its turnaround plan is working.

The threat of further tariffs is a big factor that could derail markets. The American government is piling the pressure on countries, including India and Japan, that are hoping to reach a deal on trade and avoid a new round of duties that come into effect on July 9th. Canada dumped its digital-services tax that targeted big, mainly American, tech companies, after Mr Trump threatened to end negotiations with that country. Vietnam did reach a trade deal, but "reciprocal" tariffs of 20% will still be slapped on its goods.

The dollar edged up against other major currencies, after falling to three-year lows as investors assessed the fiscal impact of Mr Trump's tax-cutting jamboree in his "big, beautiful bill". The dollar has had its worst first-half of a year since 1973, falling by 11% against a basket of currencies.

The battle of the leggings

Lululemon launched a lawsuit against Costco for allegedly selling dupes of its yoga and leisure gear. The suit claims that Costco has unlawfully traded on Lululemon's goodwill, reputation and "sweat"

by selling knock-off versions of its patented designs, which include the Define jacket (as worn by Kate Middleton) and ABC pants (Barack Obama). Costco didn't comment.

Continuing its drive to reduce the layers of management across the company, Microsoft announced another 9,000 job cuts, or about 4% of its employees, which are in addition to the 6,000 it made public in May (those cuts were mostly in engineering and products). Microsoft says it is streamlining its workforce, but the job losses are also a signal to markets that it is trying to rein in costs as its spending on artificial intelligence balloons.

Tesla reported another drop in sales. It delivered 384,122 vehicles in the second quarter, down by 13.5% from the same three months last year. That follows a 13% decline in deliveries in the previous quarter. Tesla's sales have fallen sharply in Europe, and it faces cut-throat competition in China. Jim Farley, the boss of Ford, said this week that the growth of the electric-vehicle industry in China is "the most humbling thing I've ever seen".

Renault announced that its stake in Nissan will now "be treated as a financial asset measured at fair value through equity", and that the accounting change means it will book a €9.5bn ($11.2bn) loss on the stake in its earnings for the first half. The news comes as the French and Japanese carmakers continue to restructure their alliance, through which Renault will eventually reduce its holding in Nissan to 10%, from 36% today.

Bank of America, Goldman Sachs, JPMorgan Chase, Morgan Stanley and other American banks said they would raise their quarterly dividends to shareholders—Goldman by 33%—after passing the Federal Reserve's latest stress tests. All 22 banks that were assessed by the Fed to see how they would fare in a severely adverse economic scenario passed the evaluation.

The great Greggs invasion

The share price of Greggs dropped as fast as sinking dough, after the British purveyor of baked delicacies and sandwiches issued a profit warning. It blamed hot weather for reducing customer footfall in its shops. Despite introducing cooler goodies, such as iced caramelised biscuit lattes, Greggs is best known for its warmer treats, such as sausage rolls and steak bakes. Some analysts wonder if Greggs should still be rolling out quite as many new stores if sales are slowing. It has opened nearly 1,000 in a decade, taking its total to 2,600 across Britain.

Finance & economics
Xi Jinping wages war on price wars

Unfortunately for China's leader, his own policies are often to blame for them

Illustration: Alex Nabaum

When firms raise prices, "gouging" their customers, many governments complain. Some cannot resist intervening. But in today's China, the opposite is happening. In May the state reprimanded carmakers not for raising prices, but for cutting them. "There are no winners in this price war," it said, blithely ignoring the happy customers who can now buy a zippy electric car for less than $8,000.

Chart: The Economist

In wars, the methods are sometimes as shocking as the results. Many Chinese manufacturers sell cars cheaply to dealers, who resell them as "used" vehicles, even though they have zero miles on the clock. The ploy, perverse as it sounds, lets carmakers split their market, offering pre-owned but undriven vehicles to price-sensitive customers, and identical, higher-priced vehicles to everyone else. "This disguised method of reducing prices disrupts the market order," complains the People's Daily, an official newspaper. Carmaking is not the only part of the economy suffering: factory-gate prices fell year on year in May in 25 out of 30 major industries. In eight, including coal-mining and steelmaking, the drop was even steeper than for cars. Across China's vast industrial machine, average prices have now fallen for 32 months in a row (see chart).

Manufacturing investment, especially in high-tech ventures, has been a bright spot for China's struggling economy in recent years as it weathers a prolonged property crisis. But the rapid decline of industrial prices and profits has raised doubts about the sustainability of even this capital-expenditure boom. Industries such as electric cars, lithium-ion batteries and solar panels were supposed to be new engines of growth that would fill the yawning gap left by the property sector. Now they have also become engines of deflation.

The government has a new word for the problem: neijuan, or "involution". This has long referred to arms races between students or workers, for whom extra effort brings no additional reward, because

everyone else has to try harder, too. In the past year it has been applied to cut-throat competition between firms. It appeared in a statement from the Politburo, which comprises the 24 most powerful people in the ruling Communist Party, in July 2024. In December it reappeared in the conclusions of the Central Economic Work Conference, which sets the tone for economic policy. "'Involutionary' competition has caused great harm," said Qiushi, a party journal on July 1st, "and urgently needs to be effectively rectified."

Which industries are most involutionary? According to Zhao Wei of Shenwan Hongyuan, a Chinese securities firm, the problem most severely afflicts electrical machinery, steelmaking and products such as cement, ceramics and glass, where prices fell faster than the national average last year. These parts of the economy also suffer from unusual amounts of idle capacity. And, by his reckoning, another 15 industries, from cars to tobacco, show some involutionary tendencies, such as weak profit growth, rapid increases in debt, falling prices or low rates of capacity use.

Although the term "involution" is new, the problem is not. From 2012 to 2016 China suffered four and a half years of falling factory-gate prices. In response, Xi Jinping, China's ruler, introduced a policy called "supply-side structural reform". Its original aim was to raise prices and restore profitability, not by increasing demand, but by curbing supply. China had prepared two tables of food for only one table of guests, according to an unnamed source in the People's Daily. However hard the guests ate, they could not finish it all.

To clear the tables, China's planning agency imposed production quotas and capacity cuts on oversupplied industries such as steel. It sought mergers and acquisitions to reduce competition. Coal mines were instructed to operate for only 276 days a year. Officials also strictly enforced standards for energy efficiency and pollution, forcing older, dirtier plants to shut. The policy is considered a success. Steel prices and profit margins increased. Across industry as a whole, factory-gate prices stopped falling in September 2016 and rose by more than 7% in early 2017.

Factories floored

Is the government trying to repeat this trick? At a meeting on July 1st, Mr Xi promised to regulate "disorderly competition" and "promote the orderly withdrawal of backward production capacity". As well as rebuking carmakers for giving customers too good a deal, the government has told the solar-panel industry to exercise "self-discipline". At the end of last year, 33 panelmakers duly pledged to set a ceiling on production and a floor under prices. The government has also tried to prevent the "blind expansion" of steelmaking by insisting on the "three don'ts": don't produce anything without an order, don't sell at a loss and don't ship without sure payment. Local governments have also been told not to go too far in their efforts to promote investment or shield local champions from competition. According

to Thomas Gatley of Gavekal Dragonomics, a consultancy, listed firms on China's mainland (which number over 6,300) reported receiving 195bn yuan ($27bn) in subsidies last year, some 13% less than the year before.

These interventions are less bold than those of the 2010s. The campaign may be more tentative because many of its targets are different, says Robin Xing of Morgan Stanley, a bank. In 2015-17 the industries suffering from excess capacity were dominated by large state-owned enterprises. They were easy to boss about. And they were often the biggest winners from the eventual shake-out, emerging with a bigger share of a less crowded industry. The smaller enterprises squeezed out by production limits and pollution standards were often scrappy private firms, relying on cheaper, dirtier technologies.

Many industries now suffering from involution are led by less biddable private firms. Electric cars and solar panels, for example, are dominated by sophisticated commercial enterprises, using cutting-edge technology. Some of the industries, indeed, represent the new engines of growth for which the original supply-side reform was meant to make room. "New driving forces are being strengthened," said the anonymous sources interviewed by the People's Daily in 2016. But "if the old does not go, the new will not come".

Moreover, some excess capacity is an inevitable result of Mr Xi's desire to maintain China's industrial might. He wants to preserve manufacturing's share of China's output, whether or not anyone wants to buy it all. The problem is made worse by local governments scrambling to fulfil his wishes, thereby duplicating each other's efforts. At a symposium of economists and business leaders held last year, Mr Xi was warned that his call to cultivate "new productive forces" could result in involution, as each local government strove to ensure the cultivation happened on their patch.

Some of China's struggles with involution also reflect a persistent shortfall of demand in the economy. Consumer confidence is low; the household saving rate (more than 31% of disposable income) is high; and a smaller share of that saving is flowing into the property market. In the first five months of this year households spent less than half as much on new homes as they did in the same months of 2021.

Mr Xi's successful reforms a decade ago owed a lot to other policies that lifted demand. These included an expensive effort to replace so-called shantytowns in Chinese cities with modern flats. If the government could once again stabilise the property market, restore consumer confidence and lift spending, some of China's overcapacity problems might disappear. Others would be easier to bear. Rising prices in booming industries could offset deflationary pressures elsewhere, and hiring in sunrise sectors could ease the pain of firings in industries that overextended themselves. "Without a strong demand-side anchor, even the best-designed supply-side measures risk falling short of delivering

reflation," argues Mr Xing. Many Chinese industries have prepared two tables full of food. The government needs to invite more guests to the party.

Big, beautiful budgets: not just an American problem

Across the rich world, governments are splashing the cash. What could go wrong?

Illustration: Ricardo Tomás

LAST YEAR America ran a budget deficit of 7% of GDP. It may soon be even bigger. President Donald Trump's One Big Beautiful Bill Act, working its way through Congress, permanently extends tax cuts introduced in 2017, offers more to hospitality workers and old folk, and boosts payments to

poor children. The proposed legislation amounts to trillions of dollars of extra borrowing over the next decade.

Chart: The Economist

Mr Trump's showmanship attracts attention—but America is not alone. Governments across the rich world are increasingly profligate (see chart 1). This year France will run a deficit worth 6% of GDP; Britain's will be only a little smaller. The German government will borrow the equivalent of 3% of GDP. Canada's budget balance is also moving into the red. Jean-Baptiste Colbert, a bureaucrat under Louis XIV, remarked that the essence of tax policy involved "plucking as many feathers from the goose with the least hissing". Today's governments do not pluck the goose. Like producers of foie gras, they stuff it.

Governments have long run deficits. France, the land of foie gras, has not seen a surplus since 1974. And a government can simultaneously borrow money and become less indebted, if the economy grows faster than debt accumulates.

What is happening today, however, is unprecedented. Deficit levels would not be unusual if the economy were in recession. In fact, rich-world GDP is growing decently. The unemployment rate is near an all-time low. Corporations' profit growth is healthy. Meanwhile, borrowing costs have jumped. The average rich-world government, weighted by GDP, now borrows for ten years at a 3.7% annual interest rate, up from 1% during the covid-19 pandemic.

In these circumstances, textbooks would advise, at the very least, cutting your deficit. Today's governments prefer to double down. Many are promising to raise defence spending. Although that may be unavoidable, the same is not true of other decisions. In Japan political parties are offering fiscal sweeteners, ranging from cash handouts to consumption-tax cuts, ahead of an election to the upper house of parliament. The British government has been forced to reverse its plans to cut spending on disability benefits and on payments to old folk to help cover fuel bills. South Korea is cutting inheritance tax. Australia is cutting income tax.

Even once-prudent countries are getting in on the act. The German government is planning to borrow €800bn ($940bn) to invest in defence and infrastructure. "By German standards, this truly is 'whatever it takes' fiscal policy," say analysts at Deutsche Bank. Switzerland, which before the pandemic ran a significant budget surplus, now has a small one. Next year the country will introduce a 13th month of state-pension payments. The silver-haired folk enjoying a late lunch on the banks of the Rhine do not appear to be on the breadline. That does not matter, for these days everyone gets a handout.

Why are governments so spendthrift? During the pandemic politicians developed a habit of bailing out businesses and households. Inflation then spurred demands for payments to alleviate a "cost-of-living crisis". Today incumbents hope to ward off populists by throwing money around. When a politician suggests a cut, 24-hour news and social media ensure that everyone hears a sob story. Fiscal responsibility is more toxic than ever before.

Until recently, it was painless for governments to run loose fiscal policy. In 2021-23 nominal GDP was growing reasonably fast, inflation was high and interest rates were low. Under these conditions, the average rich-world government could run sizeable primary deficits (ie, before interest payments) and still cut their debt load. Some countries, such as Japan, could reduce their debt-to-GDP ratio even if they ran a primary deficit of 12% of GDP. As such, two-thirds of rich-world governments are less indebted today than five years ago. Japan's debt-to-GDP ratio has fallen by 24 percentage points. Greece's has fallen by 68 points.

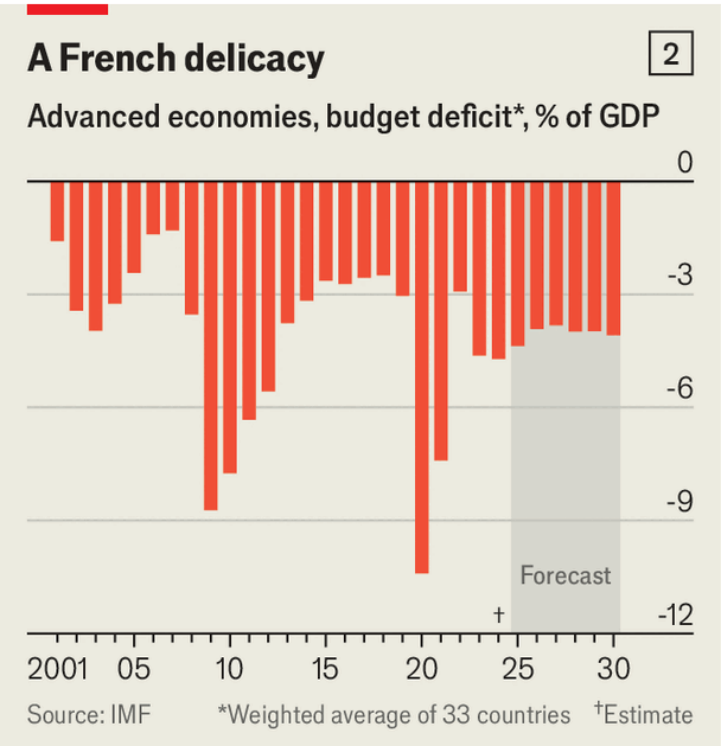

Chart: The Economist

Now growth and inflation are down, and interest rates are up. As a result, we calculate that, for the average rich country to cut its debt, it must balance its primary budget. For some, the fiscal arithmetic has radically altered. Italy's debt-reducing primary balance has swung from a deficit of 3.1% of GDP in 2023 to a surplus of 1.3% of GDP. The Italians are shrinking their budget deficit, but not by enough. With many other governments making even less progress, and a trade war promising a growth slowdown, rich-world public debt is likely to start rising (see chart 2).

This is bad timing. Demographers have known for decades that the mid-2020s would be the point at which baby-boomers would begin to retire in droves, prompting demand for health care and pensions to surge. In 2015 Britain's Office for Budget Responsibility, a watchdog, suggested that even under benign conditions, now was the point at which the government would struggle to avoid accumulating debt.

A demographic crunch and free-spending fiscal policies are therefore about to interact in unpleasant ways. No one can predict if or when investors will lose patience, forcing interest rates much higher. Yet there must be a limit to the debt binge. As any lover of foie gras knows, overfeeding even the greediest goose can cause its liver to explode.

Vanguard will soon crush fees for even more investors

Pity the firm's rivals

Admiral of the fleetPhotograph: Tracie Van Auken

The town of Malvern is a 45-minute drive north-west of Philadelphia. It has a population of 3,400 or so, and was the site of a minor drubbing for George Washington's continental army in 1777. It is, in many ways, a fairly unremarkable, affluent corner of the American north-east. But Malvern stands out in one way: it is home to $10trn in assets under management.

In 1975 Jack Bogle set up Vanguard in the town, launching the first index-tracking funds for ordinary savers soon after, with a focus on driving down the cost of investing. It worked. Today Vanguard manages both the world's largest mutual fund and its largest exchange-traded fund (ETF). The firm hosts 28% of American mutual-fund and exchange-traded-fund assets, a share that has climbed by seven percentage points in a decade. In America, though not around the world, Vanguard boasts as

many assets as BlackRock, Fidelity and State Street combined. Its devotion to low fees has given it a cult-like following. Some call themselves Bogleheads.

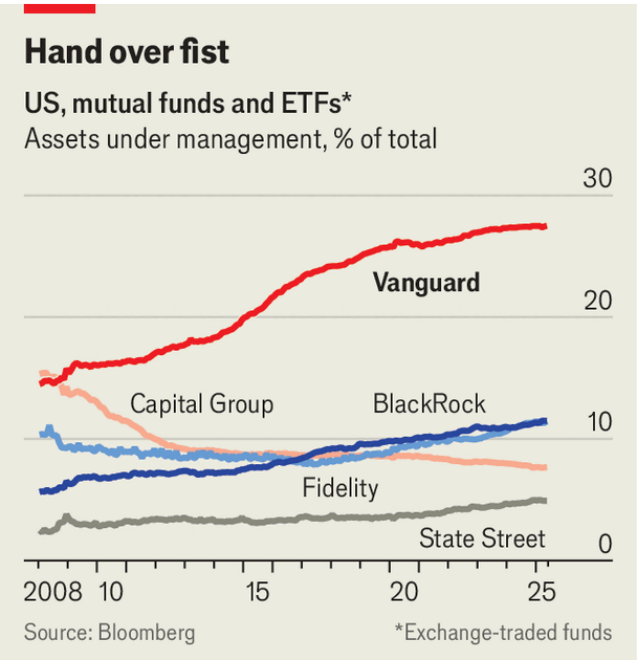

Chart: The Economist

On June 26th The Economist sat down for an interview with Salim Ramji, Vanguard's boss. Mr Ramji joined the firm a year ago from BlackRock, where he oversaw index investments, making him the first outsider to have led Vanguard. He aims to apply what he calls the "industrial logic" of Vanguard—lower fees combined with better returns—more thoroughly in advice, bonds, wealth management and even private markets. At the same time, he must navigate growing political scrutiny.

Vanguard is a strange financial firm. It is a kind of co-operative, owned by its funds, which are in turn owned by their investors. Rather than raising the value of the company, Vanguard focuses obsessively on driving down fees, forcing the rest of the industry to follow suit. This downward ratchet, the "Vanguard effect", has saved investors trillions of dollars since the firm's inception. On February 3rd Vangaurd announced that it would trim its average fee from 0.07% to 0.06%. BlackRock's share price fell by 5% on the same day.

Mr Ramji's focus on fixed-income markets is clear from Vanguard's new offerings. All of the six ETFs it has launched in America this year are bond funds. "The fixed-income market is twice the size of the equity market. It is far more inefficient than the equity market…It is far less understood," says Mr Ramji. Vanguard is renowned for passive, index-tracking investment, but he argues that some of its

best opportunities are in actively managed options, where there is more of a chance to bring down unreasonable fees.

Many of Vanguard's customers are heading into retirement, explaining its new focus on financial advice. In January the firm established a separate advice and wealth-management division, which now oversees a little under $1trn in assets. Vanguard is pitching its services at a less prosperous market than rivals. Mr Ramji notes that the median Vanguard client has assets with the firm of under $100,000. The goal, he says, is to "democratise advice, just as we have democratised investing".

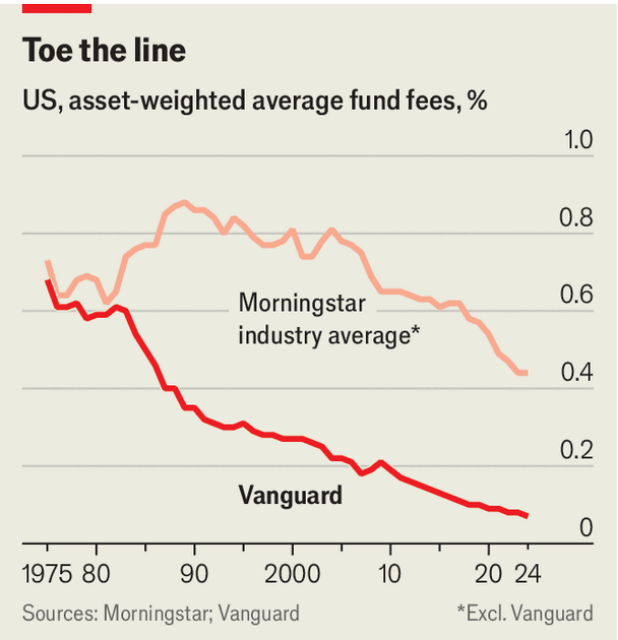

Chart: The Economist

In April Vanguard announced a tie-up with Blackstone, a private-markets giant, and Wellington, an asset-management firm. A month later the trio announced an "all-markets fund" blending public and private assets. "Private markets, if they are well designed, if they are well managed by the right kind of firm or firms, if they are well priced, can be additive from a risk-return point of view, for certain clients' portfolios," Mr Ramji argues. He recalls an old Bogle saying: rather than looking for a needle in a haystack, investors should simply buy the haystack. "Today the haystack includes private as well as public markets."

To purist Bogleheads some of this is close to heresy. Fees of any kind eat into returns. Private assets with higher fees and management costs are another drag. The die-hards will stick to bread-and-butter options: broad investments in stocks and bonds, with the lowest possible fees.

But the expansion into new markets matters for Vanguard. Athanasios Psarofagis of Bloomberg Intelligence, a research outfit, estimated that the firm, even before its recent cut in fees, accounted for just 9% of American ETF revenues—far behind BlackRock's 28%, even though the two manage a similar volume of assets. Unlike its profit-driven competitors, the firm has few high-fee options to fund investment.

One area of expense is technology upgrades, which are another priority for Mr Ramji. Some are unsexy. Vanguard has spent lots on cloud computing. At the end of last year, it announced a new technology-development office in Hyderabad, India. The next step, Mr Ramji says, will be AI-based assistance for clients, which should start to arrive next year.

Mr Ramji will have to oversee such changes while fighting off political attacks. The size of Vanguard means it has long faced criticism for its dominance of the market. More recently, it has been lumped in with other asset managers by Republican lawmakers, who believe the firms have pushed green dogma onto the American companies they own. The criticism is relatively flimsy: Vanguard left the Net Zero Asset Managers initiative in 2022, over two years before BlackRock and many of its rivals, who bailed out only after President Donald Trump was re-elected.

All the same, Vanguard faces a court case in Texas, along with BlackRock and State Street, filed by the state's Republican attorney-general and supported by a dozen other states. It accuses the firms of colluding to reduce production by coal miners. If it is successful, more could follow.

The company should be able to withstand even fierce shots across the bow. Employees are referred to as crew, owing to Bogle's obsession with the Royal Navy. The Malvern canteen is "the galley". Campus buildings—Defence, Goliath and Orion among them—are named after ships of the Napoleonic Wars. Vanguard itself is named after Horatio Nelson's flagship. Perhaps more importantly, the company shows no sign that it is faltering under bombardment. This year it has attracted 29% of American etf inflows, as well as 41% of those into stockmarket funds.

Bogle's ambition for Vanguard was as unique as its corporate culture. In his view, if a day came when his firm's market share began to tread water, putting its fee-cutting model in jeopardy, it would be a mark of success, for it would be proof that rival firms had been pushed into following Vanguard's lead. Mr Ramji takes inspiration from his illustrious predecessor, but in this sense he departs from Bogle's example. Vanguard's current boss wants his firm to rule the waves for a long time to come.

Inside Iran's war economy

Airstrikes and sanctions leave the country poor. They do little to halt its nuclear development

Photograph: Getty Images

Even before the bombs began to fall, Iran's economy was in a bad way. Six in ten working-age people were unemployed. Prices had risen by 35% in the past year. Some 18% of the population was living below the World Bank's poverty threshold. Despite exporting gas and oil, Iranian officials had to burn mazut, a low-grade refining byproduct, to keep the lights on. Binyamin Netanyahu, Israel's leader, then went after economic targets. Amid attacks on military bases and nuclear facilities, Israeli planes bombed at least two gas fields, a few oil fields and a car factory.

The idea behind the airstrikes was similar to the thinking behind international sanctions already applied to Iran. Hitting the economy will in time reduce the regime's tax revenues, which should be a blow to its nuclear ambitions. The problem is that the Islamic Revolutionary Guard Corps, the country's

security service, plays a crucial role in the development of Iran's nuclear programme. And the IRGC's financiers have nurtured a secretive commercial empire, which benefits from measures that hammer the wider economy.

Iran has long faced some of the world's toughest sanctions. Led by America, the West eased their severity after Iran agreed to wind down its nuclear programme in 2015, before once again tightening them when President Donald Trump withdrew from the agreement in 2018. The most recent measures were applied in response to Iran's support for Russia's war against Ukraine, and then after Mr Trump's return to the White House. Companies in the West are banned from buying Iranian oil, the country's biggest export, and from dealing with its banks.

In 2018, the last time that Iran allowed the IMF to inspect its finances, the country exported $46bn of oil, counting for around half its total exports. American officials think the share is closer to a third today. This year Iran is believed to be exporting 1.7m barrels a day (b/d), about the same as last year, even if production may have fallen during Israel's recent attacks.

Moreover, sanctions apply well beyond oil. A "blacklist" of targeted individuals, kept by America's Treasury, is thousands of people long. It grows every month. Western companies are banned from trade with counterparts in nearly every Iranian industry, including cars, metals, mining and textiles. Only farmers and pharma firms supplying Iran's population are exempt; they still face off-putting paperwork.

The result is that next to no business is done between the West and Iran. Iranian firms, cut off from the international banking system, which often settles transactions in dollars using SWIFT, a Europe-based payment system, must resort to subterfuge to pay trade partners even in China and Russia. This distorts Iran's economy, which is set to shrink by 1.6% in the next 12 months, according to the World Bank. Unable to export, new companies mostly sell services to the domestic market.

All of which inflicts a toll on the government's finances. In 2018 revenues from oil and taxation came to about 17% of GDP. Today they are worth 11%. Iran's fiscal deficit was roughly 3% of GDP in 2024. Unable to borrow from private creditors, policymakers have resorted to raiding the sovereign-wealth fund and printing cash. As a consequence, inflation is soaring.

Revolutionary commerce

A closer inspection of Iran's accounts reveals that little funding for Ayatollah Ali Khamenei, the country's supreme leader, or the IRGC, comes from official sources. Instead, they rely on their own financial empires. For its part, the IRGC has three sources of income. The first is a range of local

companies and foundations. Each of the organisation's five branches has control of an astonishing array of banks, factories and startups. Their portfolios include Persian Gulf Petrochemicals, Iran's biggest refiner of petrochemicals; Hara, a tunnelling business; and Bahman, once the manufacturer of Mazda cars in Iran.

Many fall under Khatam al-Anbiya, a conglomerate formed in 1990 to pool the IRGC's resources. It is now the country's biggest construction contractor. A Western official suggests Khatam is worth $50bn but, he adds, that is only a rough estimate because it holds stakes in so many smaller firms. He reckons that half of Iran's registered firms are owned, at least in part, by the security service.

Most of the IRGC's money, though, comes from abroad. Indeed, its second source of income is the oil trade. Historically a portion of Iran's budget has each year been allocated to the security service. But in recent years the treasury has been short of cash, so has offered oil in lieu. Before the war about 500,000 b/d of crude, equivalent to a quarter of Iran's exports, was going to the security service.

The IRGC then sells its oil via a fiendishly complex network of exchanges and shell companies. Buyers are mostly Chinese. According to American officials, the system is both cheaper and more adroit than that used by Iran's government.

Chart: The Economist

Security-service businesses also have a line in illicit imports and exports—their third source of income. America has long accused the IRGC of funnelling drugs that are destined for Europe from Afghanistan to the Middle East. The IRGC is also responsible for most of Iran's imported weapons, charging a premium for those it passes on to the armed forces. Within these shipments, it sneaks through cigarettes, consumer electronics and food, all of which fetch a high price among Iran's increasingly treat-starved population.

These varied sources of income leave Western policymakers with a headache. Iran's economy is suffering under sanctions. But if they tighten the screws in order to reduce tax revenues, the goods that the IRGC's smugglers import are worth even more. One official says that, since Mr Trump's most recent round of sanctions, other recipients of oil payments from the government have asked the IRGC to sell on their behalf, since the security service's network is so sophisticated.

Should Iran and Israel return to hostilities, Israeli generals might well target IRGC sites. The military locations they have already destroyed, which are suspected also to be nodes in the IRGC's distribution network, will carry a hefty repair bill. However, the recent history of oil sanctions has demonstrated that tighter restrictions do not prevent Iranian trade—they only temporarily slow shipments until exporters find a way around them (see chart). And as inflation spirals and shortages abound, the Iranian population will continue to pay the price for their security service's misadventures.

Tecnology

AI is helping to design proteins from scratch

They could treat diseases, test drugs and boost crop yields

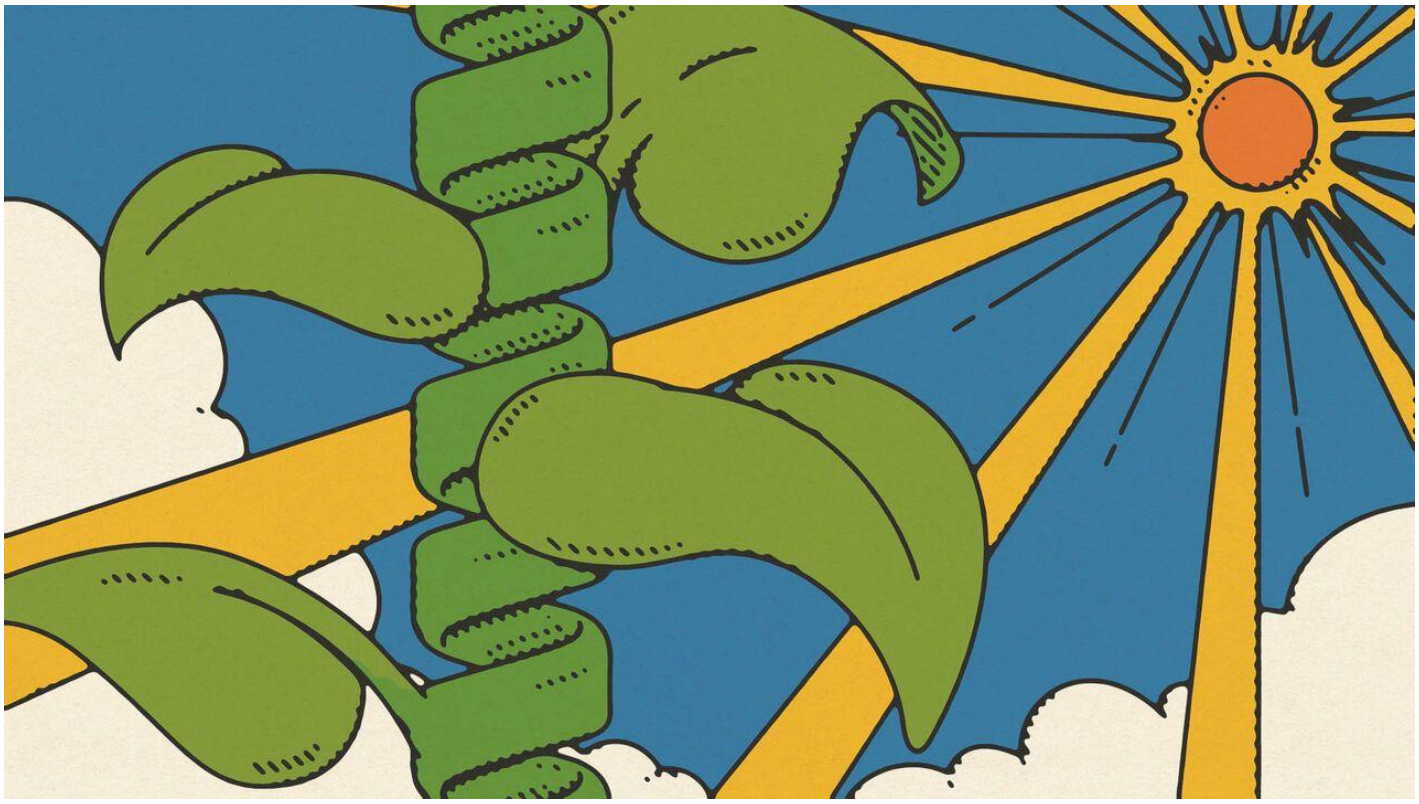

Illustration: Mike Haddad

Making biofuels is messy, inefficient and expensive. Vast quantities of crops such as maize and soyabeans must be grown, harvested and processed before their energy, accumulated slowly through natural photosynthesis, can be put to use. Nate Ennist of the Institute for Protein Design (IPD) at the University of Washington, in Seattle, thinks that synthetic proteins can boost the rate of return.

His target is the crops' photosynthetic machinery: first simplifying it as well as broadening its range, allowing it to make use of light beyond the red and blue that are naturally preferred. On longer

timescales, he and his colleagues plan to redesign the way the captured energy is employed, using it to generate hydrocarbons rather than sugar.

Tweaking proteins to do human bidding is nothing new. Enzymes and antibodies, for example, have long endured such outrages. But that is not what Dr Ennist is up to. Rather than modifying existing proteins, his versions are being designed from scratch, using artificial-intelligence (AI) models, to be optimised for the task at hand. To start with, they would be inserted into a suitable organism, such as a plant or bacterium, to do their thing there. But eventually they could, he hopes, operate independently and thus form the basis of a new type of solar cell—one that turns out petrol rather than electricity.

With this and other projects, ranging from artificial noses to covid-19 vaccines, the IPD, run by David Baker, joint winner of last year's Nobel prize for chemistry, is taking the much-hyped but under-delivering field of nanotechnology back to its roots. The future it once heralded of useful molecule-size factories has dwindled over the decades into a marketing gimmick for sunscreen ingredients and tennis-racket frames. Now, though, the original promise is back with a vengeance.

The new nanotech relies on three things. One is an ability to work out how a protein's structure affects its function (Dr Ennist is hunting ones capable of holding together the pairs of chlorophyll molecules that are the nub of photosynthesis in ways well-suited to capture light and transfer its energy to electrons). A second is to devise chains of amino acids (the building blocks of proteins) that would be expected to fold into the desired structure. And the third is to check computationally, before making them for real, that chains thus devised will indeed assume the target shape.

For the first of these tasks Dr Baker and his colleagues use RFdiffusion, an AI model they have developed to predict a protein's function from its structure. It does this in a similar manner to image-generating diffusion models, but with a training database of more than 200,000 natural proteins rather than photos and artwork.

For the second, their tool is ProteinMPNN, also trained in-house, which draws on databases of how amino acids interact with each other in protein chains and with other molecules that those chains encounter. And for the third they employ RoseTTAFold, a machine-learning model similar to software originally written by Dr Baker in the mid-1990s. So influential was this precursor that it inspired the creation of AlphaFold, a protein-folding AI model now backed by Alphabet's billions, and whose creators carried off the other half of the 2024 chemistry Nobel.

Once a design has been through this virtual mill, scientists can conjure it into existence by synthesising appropriate DNA and putting that into a bacterium or yeast. It can then be tested to see if it is truly up to the job.

Besides redesigning photosynthesis, groups at the IPD are working on a mind-bending array of other projects. These include circular protein fibres that could be linked up like mail armour to make novel fabrics; hybrid organic-inorganic materials (think snazzy versions of bone and mother-of-pearl); enzymes to digest hard-to-dispose-of plastics such as PET, thereby turning them into useful chemicals; and chip-based sensors that run molecules through protein pores to determine what they are. Technology of this kind already exists for DNA and its cousin RNA, but Dr Baker believes it can be applied to a far wider range of substances, creating devices that are, in essence, artificial noses. And these are just the non-medical applications.

All very well

In the field of health care, the opportunities are vast. The institute's covid vaccine, SKYCovione, for example, works by displaying synthetic copies of parts of the SARS-CoV-2 spike protein in a way that attracts the immune system's attention. IPD researchers have also created proteins they hope will transform the treatment of snake bites. These lock onto and neutralise venom molecules in the blood in the way that the antibodies now employed for that task do, but are smaller and easier to make.

Dr Baker and his colleagues have plans to attack Alzheimer's disease using a similar approach—making proteins that bind to the molecular precursors of the neuronal plaques and tangles found in the brains of those afflicted. And they hope to improve the field of gene editing with custom-targeted nucleases, the "Cas" part of the CRISPR-Cas complexes which are gene-editing's molecular scissors. These would be designed to bind to particular DNA sequences, increasing the range of DNA that can be edited and reducing the risk of off-target edits.

Where Dr Baker has led, others are following. Alphabet has two ongoing protein-design projects spearheaded by Sir Demis Hassabis, one of AlphaFold's Nobel-winning inventors. One, Isomorphic Labs, in London, is a spin-out that has contracts with the pharmaceutical firms Eli Lilly and Novartis to test candidate drug molecules' interactions with target proteins. The other is AlphaProteo, a system developed by Google DeepMind to design proteins to bind to specified targets.

Others are taking a slightly different tack. Profluent, in Emeryville, California and EvolutionaryScale, in New York, are building protein-design AI models that resemble not image-generating software, but large language models (LLMs) of the sort that power the world's chatbots. These firms' models treat

the amino-acid sequences in protein chains like the words in a piece of text—analysing relationships found in zillions of exemplars to design novel useful structures.

According to Ali Madani, Profluent's chief executive, the firm is particularly focused on creating new CRISPR-Cas gene-editing tools. Here, its USP is a curated database of around 5m CRISPR-Cas protein complexes on which its AI model has been trained in order to design new versions.

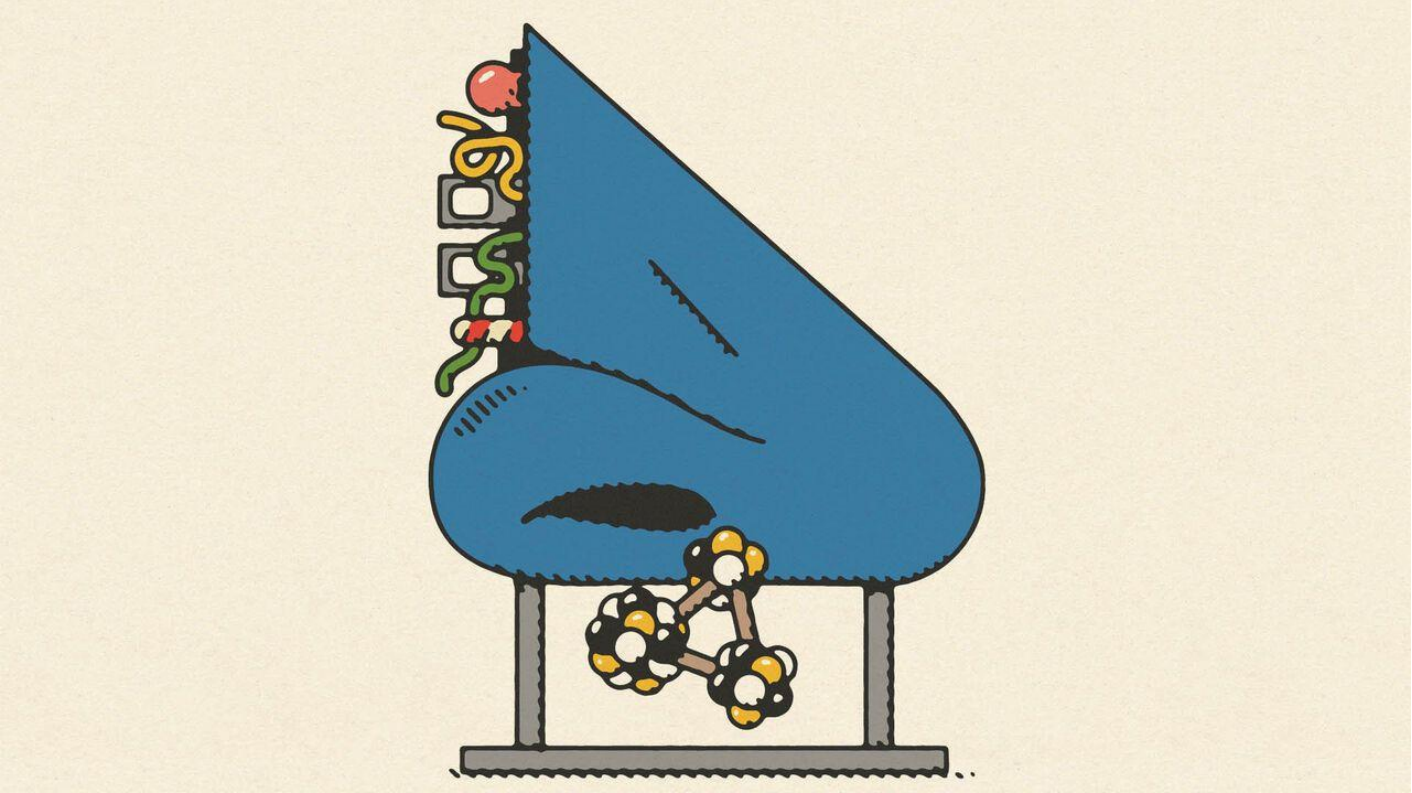

Illustration: Mike Haddad

EvolutionaryScale is pushing the LLM approach still further. Its version, ESM3, takes into account a protein's structure and function as well as its amino-acid sequence. And its training database is huge. Alex Rives, the firm's chief scientist, says it contains 2.8bn entries. He also talks of going beyond working with individual proteins and creating a first approximation to a virtual cell, within which these proteins interact with one another.

In EvolutionaryScale's case, the model itself is the product, to be licensed to firms that plan to make protein-based drugs and materials. But many of its peers are pursuing innovation themselves. The consequences of this new approach to nanotech are as yet only dimly discernible. Redesigning

photosynthesis, for example, would surely have consequences far beyond biofuels, particularly if the new approach could be made to work in existing plants. That, with due caveats for safety and customer acceptance, could boost crop yields. There is also huge scope for improvements in the yields of chemical processes: many enzymes are more efficient than conventional catalysts. And, as with any technology, less obvious breakthroughs may be possible, too.

One that excites Dr Baker is the idea of protein equivalents of the logic gates in silicon chips. These might be used to control gene expression in cells. In the longer term, he thinks, such gates could more easily be stacked in 3D arrays than their silicon counterparts, allowing for more compact designs. How that would work out in practice, who can say? One way or another, though, the curtain seems to have risen on nanotechnology's second act.