Issue No. 29 University of Edinburgh Economics Magazine Autumn 2024

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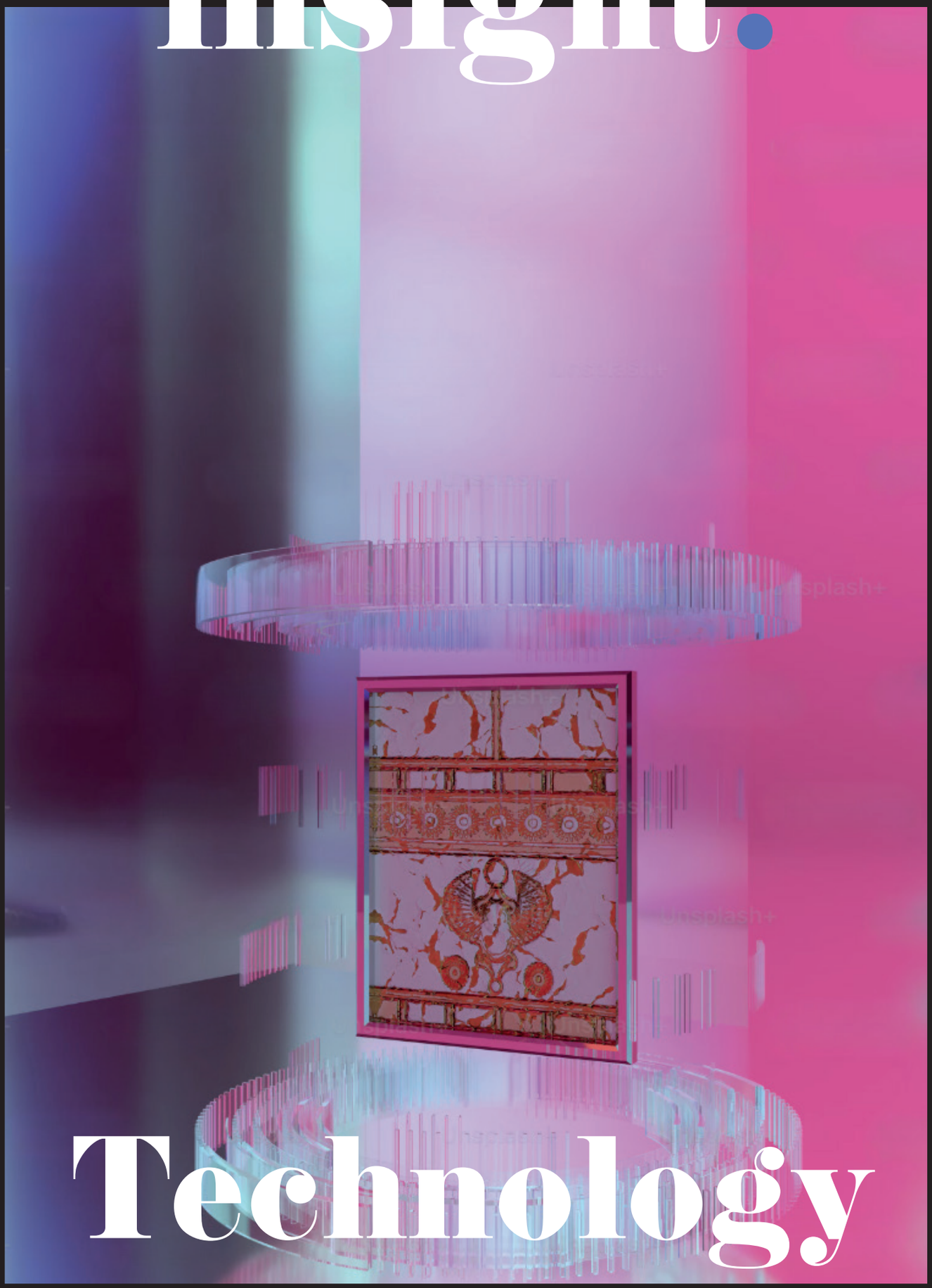

Technology

Letter from the Editor-in-Chief

Welcome to the 29th issue of Insight Magazine!

As technology continues to transform today's global economy, making it more dynamic and interdependent, new opportunities – as well as issues – arise. The practicality of technology often goes overlooked in classrooms; from artificial intelligence to climate technology and everything in between, we are delighted to have given students the chance to explore this exciting topic through an economics lens.

On behalf of Insight, I would like to take this opportunity to thank the School of Economics for their continued support of the magazine, without which this publication would not be possible. I'd like to extend a special thank you to our writers, editors, and producers for all their hard work in making this issue come to life.

I hope you enjoy this issue of Insight as much as we did working on it!

All the best,
Hannah Zuraimi
Hannah Zuraimi

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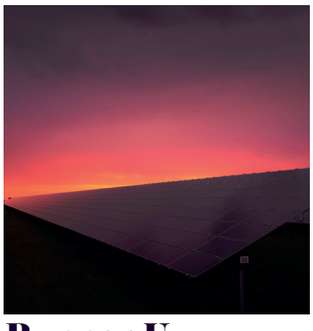

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Runner Up

Who's In Control?

Surveillance Capitalism: How Tech Companies Use Your Data

*As tech giants turn data into profit, **Taylor Cameron** reveals how control over personal information has slipped from the hands of individuals into those of corporations.*

"If people were deciders, they wouldn't take the deal; fortunately, they are not the deciders." This leaked statement from a Google executive is just one of many lines that expose the harsh truth of the internet today – that individuals do not decide how their data is used and collected.

This idea catalysed 'The Age of Surveillance Capitalism', Shoshana Zuboff's critically acclaimed book. In 2000, only 25% of information was stored digitally, but by 2013, that number had risen to 100%. Zuboff sought to understand why this change had occurred. From this, the concept of surveillance capitalism was born: behavioural signals left by users should be redefined as corporate assets and reappropriated into predictive value to be sold to advertisers. Google honed its search engine to do just this – and it worked. In 1999, Google had revenues of $220,000; by 2004, they had grown to $1.47 billion. Seeing this success, the model was soon adopted widely by the likes of Facebook and Amazon to garner higher profits.

A key reason this model was allowed to flourish was the Bush administration's decision to hand over control of the information highway to the private market. Prioritising industry growth and national security following 9/11, the administration removed barriers to data collection and corporate expansion. As the tech industry grew, it became increasingly difficult to regulate it, which aligned with government and security organisations' need for access to large pools of data. CIA's Chief Technology Officer, Gus Hunt, summarised this in 2013, outlining that the goal was to 'try to collect everything, and hang on to it forever'. In the same breath, he lauded the devoted work of conglomerates like Google for doing just this.

Even when faced with regulatory threats, tech giants find covert ways to sidestep consequences. Larry Page, founder of Google, was clear about his hiding strategy: there should be a purposeful imbalance of information access between users and corporations, leaving people unaware of how their data is being utilised. This asymmetry strips users of power and undermines democracy in digital spaces. To maintain control, these corporations shield themselves behind arduous lines of terms and conditions. With their platforms now integral to everyday life, the question of whether consent even exists in the first place is a poignant one.

To this day, large tech conglomerates commercialise our data and sell it to third parties, operating within minimal regulation to protect our privacy. Why does this matter so deeply? The biggest harm may be that these firms understand our preferences and behaviours better than we do ourselves, allowing them to implicitly shape our decision-making. For instance, the Cambridge Analytica scandal showcased how Facebook enabled firms to purchase data to further certain political agendas, particularly for the Republican Party in the 2016 US election. Considering the media's influence in shaping our worldview, these tools can be coercive, swaying public opinion and shifting influential narratives.

With the rise of wondrous technologies like Generative AI, Google Maps, and Alexa, there is a clear trade-off between convenience and privacy. Although these services make life easier, Zuboff argues that convenience in itself is a veil to hide exploitative business practices; that the real goal of these corporations is to extract our behavioural surplus. This trade-off became evident in 2010, when it was exposed that Google Street View cars were collecting key data from people's WiFi since 2007. Whilst Germany's data protection authority pushed back, Google faced a lack of repercussions – hinting at its endless power to evade.

It does not have to be like this.

In its inception, the internet was regarded by its users as a public good. Today, however, privacy seems to have been decoupled from people's rights. A decentralised internet could return control to individuals, allowing them to decide where their data goes and how it is used. In recent years, landmark progress has been made. In early 2024, Google was tried in the US for violating antitrust laws and consolidating its monopoly on search engines. In 2022, the EU introduced the Digital Services Act – a key piece of legislation, which Zuboff claims "declares that digital spaces belong to society". Yet, the fight does not end here. Ultimately, tying democracy to people's digital lives is crucial to ensure individuals have a say in how their data is used. In an age of information where the internet runs society, this is more important than ever. Only with bold action can users finally become the deciders.

Scrambling for Control: The Urgent Push to Regulate AI

Gabriel Pais Gaspar delves into the race to regulate artificial intelligence, examining whether global efforts can strike a balance between harnessing AI's transformative potential and guarding against its darker risks.

Ask Silicon Valley's titans who they fear most – Margrethe Vestager, the European Commissioner for Competition – might be their answer. The Commissioner has successfully taken up legal challenges against all sorts of monopolies, being famously very critical of the free market championed by libertarians, referring to it as 'the law of the jungle.' Her commitment to protecting consumers by intervening in markets has put her at odds with Big Tech. For example, we can thank Vestager for the regulation against Apple's iPhone jacks, implemented to avoid an unfair monopoly within these markets. She therefore can be accredited with protecting European consumers, and the wider world from the consequences of Adam Smith's free market.

Regulators on the Backfoot?

However, this regulatory success is being challenged by rapid innovations in artificial intelligence (AI). With computing power now doubling in record time, regulators find themselves behind in the race to regulate new technologies. Critically, this includes the prevention of the albeit fictional scenarios seen in 'Black Mirror' – a show that explores the darker sides of technology – where AI-driven creations push moral and ethical boundaries. Despite being fictional, these scenarios highlight real risks that, if left unregulated, could threaten the safety of our modern society.

Therefore, economists have argued for an international regulatory framework to ensure the advantageous use of these new technological innovations. This not only protects consumers, but also has the potential to demonstrate and encourage the safe use of AI across society. Ensuring the extraction of all the exciting benefits of new technology, such as personalised medical diagnoses and space exploration, whilst having sufficient safeguards in place to protect privacy, security, and societal well-being.

International Comparisons

Global regulators have begun implementing various strategies to regulate AI, but have received mixed results. The EU was the first to attempt to do so with its 144-page AI Act 2024, which states that starting in February 2025, AI models are to be assessed by the risk they pose to European consumers. Through this, the European Commission attempted to challenge the rise of dangerous bots and protect consumers' data when utilising advanced language models. However, business leaders across the continent have criticised the move as another form of European over-regulation, choking investment and innovation. In a continent grappling with significant demographic, climate, and economic challenges – underscored by Mario Draghi's report on EU competitiveness – there is a growing concern that Europe will be hiring 'lawyers while the rest of the world hires coders.' Alarmingly, Europe lacks tech firms with the same market significance as those based in Silicon Valley. This absence of major tech players raises concerns that over-regulation of the technology sector in Europe may exacerbate the old continent's competitiveness dilemma.

Surprisingly, the United States has become increasingly active within this field of law. Despite historically taking a lax approach to regulation, the Biden Administration has been increasingly hostile towards Silicon Valley's CEOs. However, California's own divisive AI safety bill demonstrated the challenges of regulating such a fast-paced market. It highlighted fears of barriers to entry, stifled innovation and monopolies facing regulators, and was ultimately vetoed.

The previous Sunak administration attempted to foster international cooperation towards regulation, but notably excluded China from their 2023 AI Safety Summit. As with all 21st century economic dilemmas, focusing solely on the West would be a mistake. The Chinese Communist Party has not hesitated from implementing its own regulatory policies. This has raised fears in the West about Chinese attempts to subvert Western firms and regulators, by imposing their own standards and promoting domestic innovations.

With ongoing instability in the U.S. presidency, political wrangling in the EU and rising trade tensions, the outlook for the technological sector is concerning. AI is likely to become a focal point in the growing divide between the West and East in the global economy.

The Need for a United Front

The need for an international, coordinated framework to govern AI is undeniable. After years of watching digital platforms run wild, governments now face a choice: to work together or fall behind. However, any global framework needs to be sustainable and growth-oriented, fostering innovation rather than stifling it. The right regulatory balance is not only crucial to protect consumers, but also to harness this new technology to address the multitude of crises faced today.

Intelligent Divide: The Precision of Segmentation

Mia Hutchins delivers a comprehensive overview of segmentation and the methods used by firms and governments to control it.

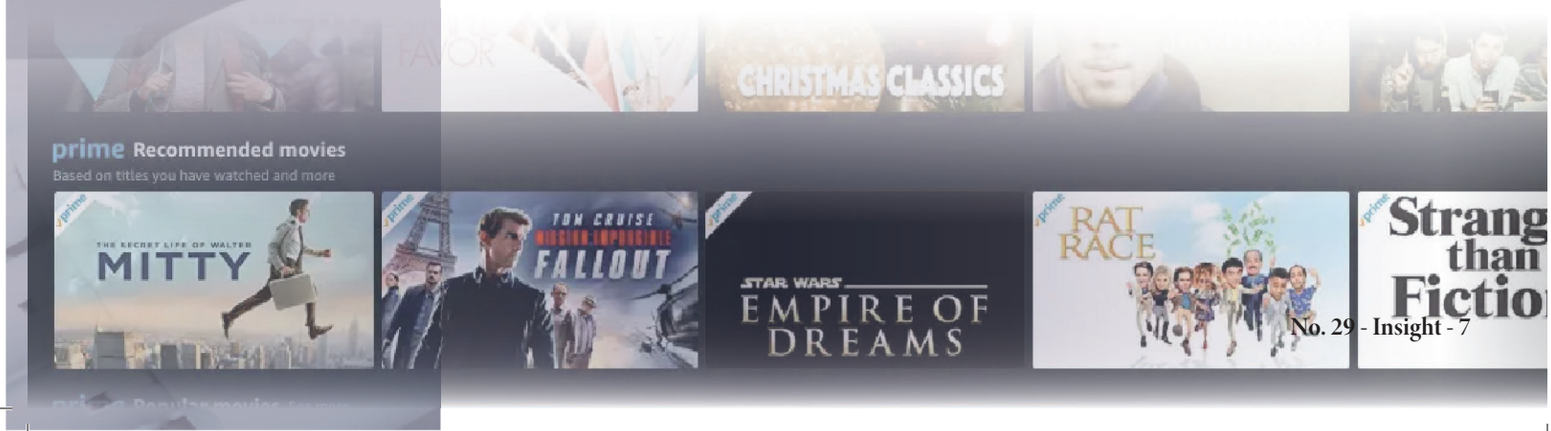
Artificial intelligence (AI) has been tracking our data for years. Only recently has tracking turned from targeting groups to targeting individuals. This is called segmentation – a process used by firms to maximise their profits by using 'third-party data', collected through cookies. Usually, firms split their consumers based on geographic location, demographics such as age and gender, psychologies, and, finally, behaviour (loyalty). Segmentation is completed using AI and therefore needs to be sense-checked before becoming directly human-interpretable. This raises the question of how reliable this data collection can actually be and who is gaining access to it. As a result, consumers are becoming increasingly aware of the need to protect their data.

Segmentation can provide consumers with many advantages, including more tailored product development to suit their specific needs. For example, 35% of all Amazon purchases in the last year were driven by personalised recommendations, and almost 80% of Netflix activity is chosen through the personal suggestions category on the consumer's account. Segmentation additionally provides a more efficient way for firms to allocate resources, allowing them to reduce costs and gain more profit as a result. Firms can invest time and money into the products that are more likely to be bought, thus elevating the quality of these products.

Despite these benefits, segmentation can sometimes lead to discrimination, especially in the case of geographic segmentation. More affluent areas are often more likely to be shown advertisements for higher quality products and better services, with lower-income locations excluded from these deals. In addition, firms can price-discriminate by geographical area. Firms assume that higher-income areas are more likely to have loyal customers, given these areas' residents' stable stream of higher income and hence, higher spending power. This means that firms release loyalty schemes and better deals to consumers in these areas, creating a discriminatory rift. For example, North Face – a high-end outdoor clothing company – uses a 'personal shop assistant' on their website which takes the location of the customer and finds products which would suit them. While this feature can benefit the consumer, it also allows them to fall victim to price discrimination due to their location.

Companies are starting to switch from using 'third-party data' to 'zero-party data'. This allows the consumer to opt in and to voluntarily give out their personal data, granting them more transparency and control. Simultaneously, it allows firms to gain access to more useful data. However, this method still allows companies to segment consumers based on data, giving the false impression of extra security to the consumers. As individual targeting replaces group-based targeting, consumers are becoming increasingly concerned with how their data is used. Recent studies show that over 31% of Americans use an ad blocker, and by 2025, Chrome aims to remove cookies entirely. This suggests that although zero-party data is a reasonable substitute to third-party data, it is unlikely to be a long-term solution.

To maintain privacy in the long term, further restrictions on advertising may be necessary. Already, European regulators have begun to call for a complete ban on advertisement targeting. Switching back to television advertisements and other non-targeted methods may be the only way forward. This would result in reduced profits for firms but would give consumers the safety of knowing how their data is used and allow for greater privacy.



Bitcoin: Digital Gold or Financial Wildcard?

*Examining Bitcoin's journey, **Shifa Ali** unpacks its double-edged sword. Could it become a beacon of economic freedom or a destabilising force?*

Bitcoin emerged in the wake of the 2008 global financial crisis, which exposed weaknesses in the banking system – over-centralisation, lack of transparency, and reliance on trusted middlemen. Beyond market value or appeal as a speculative asset, Bitcoin challenges traditional monetary theories and introduces new economic models. As digital currencies like Bitcoin gain traction, they are reshaping the economic landscape of the 21st century. Governments must decide: resist this transformation or adapt to a world where traditional money and digital currencies increasingly co-exist.

The Rise of Bitcoin

In 2008, an anonymous group under the pseudonym Satoshi Nakamoto, published a white paper titled 'Bitcoin: A Peer-to-Peer Electronic Cash System'. The paper introduced a vision for a decentralised digital currency enabling users to send and receive payments directly, bypassing traditional banks. Built on blockchain technology, it promised transaction integrity and security.

Since its beginnings in 2009, Bitcoin has evolved from a niche digital experiment to a global financial asset. Unlike fiat currencies, which derive their value from trust in an issuing authority, Bitcoin's worth stems from scarcity and market demand. With a fixed supply of 21 million coins, Bitcoin is inherently deflationary. This scarcity has drawn comparisons to commodities like gold, attracting investors eager for alternatives to traditional assets. But Bitcoin's impact extends beyond speculative investment; it is transforming how value is stored, transferred, and perceived, especially in regions where traditional financial systems fall short.

Empowering Economies in Crises

In a world marked by financial borders, restrictions, and checkpoints, Bitcoin offers a new kind of access. For millions of people living in conflictzones or under oppressive regimes, traditional financial systems are often out of reach. Bitcoin, decentralised and borderless, has become a 'checkpoint that's always open', enabling individuals to access the global economy despite their location or restrictions.

For instance, Bitcoin has offered an economic lifeline for Palestinians in particular. Amid ongoing conflict and severe financial constraints, Bitcoin provides an alternative to traditional banking systems, enabling direct and affordable cross-border transactions. The ease of using Bitcoin for remittances, which account for approximately 15% of Palestine's GDP, helps reduce the costs and delays tied to traditional money transfer services. In times of war, Bitcoin has proven to be a crucial financial tool, offering a degree of stability and independence for households grappling with economic and political pressures.

The decentralised nature of Bitcoin also offers protection against economic instability. In countries

experiencing hyperinflation such as Zimbabwe, cryptocurrencies have become a viable alternative for storing value. With inflation rates exceeding 200%, the Zimbabwean dollar continues to lose purchasing power, prompting many to seek refuge in Bitcoin as a hedge against currency depreciation. Unlike fiat currencies, which central banks can inflate by increasing money supply, Bitcoin's fixed supply inherently guards against inflation. This capacity to hedge against inflation makes digital currencies especially appealing in volatile economic environments, challenging central banks' dominance over monetary systems.

A Threat to Financial Stability

For governments, Bitcoin poses an even bigger threat: it operates outside their control. Decentralisation makes them difficult to regulate – this opens doors to tax evasion and money laundering. As Bitcoin facilitates the movement of assets offshore and conceals earnings, governments face the risk of losing vital tax revenue. This could weaken public finances, jeopardising essential investments in infrastructure, healthcare, and education. Over time, this threatens not only economic stability but also shifts a heavier financial burden onto law-abiding taxpayers, heightening inequality.

Sensing this threat, China has taken a leading role in addressing the risks. Banning cryptocurrency trading due to concerns over financial stability, China sought to prevent the creation of a parallel, uncontrolled financial system that could challenge its centralised authority. The government cited Bitcoin's extreme volatility, which saw prices swing from nearly $65,000 in April 2021 to $30,000 just two months later. Such fluctuations make Bitcoin unreliable as a medium of exchange, with businesses and consumers wary of a currency that may lose significant value overnight.

Crossroads

In a world grappling with technological transformation, Bitcoin stands at crossroads: a pioneering asset reshaping financial access, or a volatile disruptor to established systems. Ultimately, Bitcoin's future hinges on whether societies can integrate its advantages while managing its inherent risks. If it evolves from an unpredictable asset into a stable store of value, Bitcoin might indeed achieve its moniker as 'digital gold'. Until then, it remains a financial wildcard, symbolic of both the possibilities and uncertainties of the digital age.

Climate Technology

Making Clean Energy Transitions Work with Economic Forecasts and Practical Technology Solutions

Jinyue Liu explores the future of climate technology adoption through the lens of existing policies and complexity economics models.

Technology plays a key role in the transition to greener energy – it lowers production costs, increases supply, and reduces prices. Moore's Law and Wright's Law can be used to predict the pace of technological development and estimate how costs will decrease, enabling cost-benefit analyses for the next 20 to 50 years.

Moore's Law and Wright's Law: Predicting Cost Declines

Wright's Law states that each time the cumulative production of a product doubles, the cost per unit decreases at a constant rate, a trend seen across industries as production scales and efficiency improves. Similarly, Moore's Law, relating specifically to the IT industry, predicts that the number of transistors on a microchip doubles roughly every two years, increasing computing power and efficiency while lowering costs. Together, these laws illustrate how technological advancements drive down costs and enhance performance as production scales up.

Reviewing the evolution of energy technologies since 1880 reveals the gradual rise in the use of oil and natural gas, which overtook biomass by 1955 and matched coal by 1980. This contrasts with the rapid rise of nuclear energy in the 1960s, which then plateaued. The most significant trend has been the exponential growth in solar PV in recent decades, transitioning from niche to mass markets. These renewables have exponentially increased deployment of solar photovoltaic panels and decreased costs, positioning them to challenge fossil fuel dominance within the next decade.

In 2018, American economist William Nordhaus was awarded the Nobel Prize for his model forecasting renewable energy costs. His model calculates the "optimal" path of renewable energy transition to maximise utility for a typical household while meeting climate change mitigation targets. It includes two additional functions that measure both the cost of reducing emissions and the projected economic cost of global warming based on total emissions.

The expected increase in future costs to corporations, governments and individuals, due to climate change pressures is misaligned with the decreasing investments governments are making to reduce emissions annually.

By contrast, scientist J. Doyne Farmer and his team propose a more feasible solution than Nordhaus by prioritising future cost savings through early action. Building on Nordhaus' research, Farmer argues that addressing energy-related emissions could save substantial costs, implying that transitioning to sustainable energy sources is essential. Citing World War II as an example, Farmer and his team show how rapid production scaling and efficiency improvements reduce costs. This principle underpins their approach, suggesting that scaling and efficiency work together to drive down costs.

Transition Scenarios: Fast, Slow, and No Transition

Farmer's team created hypothetical scenarios representing different futures – Fast, Slow, and No Transition – to assess the different cost probabilities of each. Instead of looking at past examples to find the "best" strategy, Farmer demonstrates that if current trends in reducing energy costs continue for another decade, a green-energy transition could be achieved quickly and affordably. Farmer's team observed that technology deployment often follows an S-curve, where initial growth is slow, but rapidly increases as the technology reaches about 5-10% of the market, often replacing older technologies. This model explains the rapid growth in solar, wind, and battery technologies, which now supply 12% of global power. As renewables expand, S-curves and learning rates will be essential for predicting the pace and impact of the energy transition.

In the Fast Transition scenario, renewable technologies grow at current rates, replacing fossil fuels within two decades. Farmer's team also examined a nuclear scenario, in which fossil fuels are replaced with nuclear power - though at a much higher cost, of $15 trillion more than a No Transition scenario and $27 trillion more than the Fast Transition scenario. The No Transition Scenario describes an energy system that stays in its current form, with each energy source growing proportionally at a 2% rate, implying a continued reliance on fossil fuels indefinitely.

This scenario closely resembles what are now termed 'worst-case' scenarios, previously known as business as usual' scenarios. High transition costs have reduced enthusiasm for rapid action, despite evidence suggesting it would be economically beneficial.Farmer's analysis could guide governments to act more cost-effectively in supporting the green energy transition.

For example, government subsidies could help technologies following Wright's Law move forward on the S-curve and reduce costs over time. However, this does not apply to all technologies;fossil fuels and nuclear power, for example, do not follow Wright's Law.

Challenges and Barriers to the Green Energy Transition

A key question is whether production scales up because costs decline or whether costs decline as production scales up, stimulating demand. In 2023, China led global solar panel production, manufacturing 541 GW – 83% of the world's supply. Over the past year, production costs for solarmodules in China decreased by 42%, reaching $0.15 per watt, givin Chinese manufacturers a significant cost advantage over international competitors.

Policymakers need to understand this dynamic to allocate funds effectively. For instance, providing compensation to households for installing solar panels can encourage renewable energy adoption and support sustainable growth. Wright's Law supports the idea that costs fall as cumulative production increases, underscoring the mportance of this relationship. Since the 2010s, falling technology costs have led governments to reduce fiscal support for renewables, assuming their role in stimulating the transition was complete. However, transitioning to greener energy requires extensive changes across sectors like transportation, construction, and agriculture.

This transition is further complicated by renewable energy and fossil fuel supply chains, which are deeply intertwined. Generally, the energy supply chain is divided into upstream energy suppliers), midstream (production), and downstream (sales and consumption.This chain starts with resource extraction and moves through storage, transportation, production, and ultimately sale and consumption, forming interconnected upstream and downstream value exchanges where upstream delivers to downstream and downstream provides feedback to upstream.

Moreover, the Kyoto Protocol – an international treaty adopted in 1997 and enacted in 2005 – highlights these challenges. Although aiming to legally bind developed countries to reduce emissions, the enactment of this treaty led to free-riding problems, in which some nations benefited from other nations reducing their emissions without reducing their own emissions, such as the United States.

Rapidly developing countries, where emissions continued to rise, lacked comparable commitments which hindered the protocol's effectiveness and resulted in a disappoining 50% increase in global CO2 emissions, far from the intended 5% reduction target.

Therefore, global climate challenges require coordinated action. Summits like COP play a vital role by increasing pressure on governments to commit to meaningful policies. Strengthening international forums can foster more substantial agreements and provide a platform for sharing strategies and financial support between countries at different stages of development. This global forum can also support innovative funding mechanisms, including for technologies like carbon capture, which require significant upfront investment.

These complexity economics models, grounded in data, require substantial investment in computing technologies. Major barriers include vested fossil-fuel interests and resistance to grid expansion. While data-driven methods are useful, they address only part of the problem. Comprehensive models are necessary for countries and businesses to plan strategies for thriving in the new economy. With these models, we can better balance profitability and sustainability, which poses long-term environmental resilience over short-term gains.

Can We Eliminate These Barriers?

Farmer's Climate Policy Laboratory uses a modular approach, dividing climate change solutions into eight testable areas, such as the interactions between industries and households. Combined, these models offer a detailed view of the green-energy transition. These complexity economics models, grounded in data, require substantial investment in computing technologies. Major barriers include vested fossil-fuel interests and resistance to grid expansion. While data-driven methods are useful, they address only part of the problem. Comprehensive models are necessary for countries and businesses to plan strategies for thriving in the new economy. With these models, we can better balance profitability and sustainability, which poses long-term environmental resilience over short-term gains.

Scientific experts, policymakers, and financial investors have shaped global climate plans, leading to widespread electrification, which shifts energy reliance from fossil fuels to electricity. Regardless of differing opinions, the shift to renewable energy is happening and will continue to shape the future. Addressing each issue step-by-step is key to a successful transition. This approach to climate technology has the potential not only to help save our planet but also to create a sustainable future.

Digging Deep in the Green Revolution

Despite a surge into climate technology, a crucial investment gap in critical minerals persists. ***Thomas McKillop*** *investigates the causes and impacts of this gap, which could risk derailing global decarbonisation targets.*

Innovation-hungry investors have poured funds into climate technology over the past decade. In 2022 alone, $1.3 trillion was allocated to renewable power systems, battery storage, and electric vehicles. With the International Energy Agency (IEA) forecasting a 700% increase in battery demand by 2035, the appetite for climate technology assets shows no signs of abating.

The Critical Minerals Conundrum

Despite this acceleration, a lack of focus on downstream companies has left a widening funding gap for critical minerals miners – those responsible for extracting lithium, copper, iron ore, cobalt, and nickel. Underinvestment in this sector reveals a core weakness in the climate investment model, one that threatens to bring global shortages of these essential minerals.

The IEA has projected an $800 billion deficit in critical minerals investment – necessary to avert catastrophic supply chain disruptions and meet 2040 climate goals. Ambitious targets for decarbonising industries, power grids, and particularly automotive manufacturing hinge on a steady supply of raw materials – yet data indicates shortages of at least 1,000 metric tonnes of nickel and cobalt by 2050. With soaring demand downstream, ambitions to scale up the climate technology sector may be undermined by inadequate capacity in the critical minerals industry.

Investor Disillusionment

Critical minerals mining faces a fundamental ethical trade-off. Unlike sectors driving the energy transition, which have benefited from sustainability-driven investments, mining's reputation for environmental harm, community displacement, and labour exploitation deters many ESG-focused investors. The reluctance to invest has led to fewer funds for an industry essential to green technology. One might assume that booming demand for battery metals would attract investors eager to capitalise on the transition to a green economy, however; memories of past investment missteps in mining linger.

Since 2014, mining companies and investors have had a rocky relationship, especially following a period of cooling Chinese economic growth that toppled leveraged mining bets. By 2013, the top 40 mining firms had committed $130 billion in capital expenditure for new projects. But as commodity prices fell amid a slowdown in China, leading miners were forced to write down billions, eroding investor trust. Although mining profits eventually recovered, distrust remains.

Some analysts see opportunity in this wariness. Mining industry missteps have resulted in valuation gaps between mineral extraction firms and their downstream customers. The average price-to-earnings ratio for major mining firms sits over 10 points below the 18.5x of the S&P 500, despite demand surges not only for battery metals but also iron ore – a critical component of the 170 million tonnes of steel needed to support the renewable energy industry.

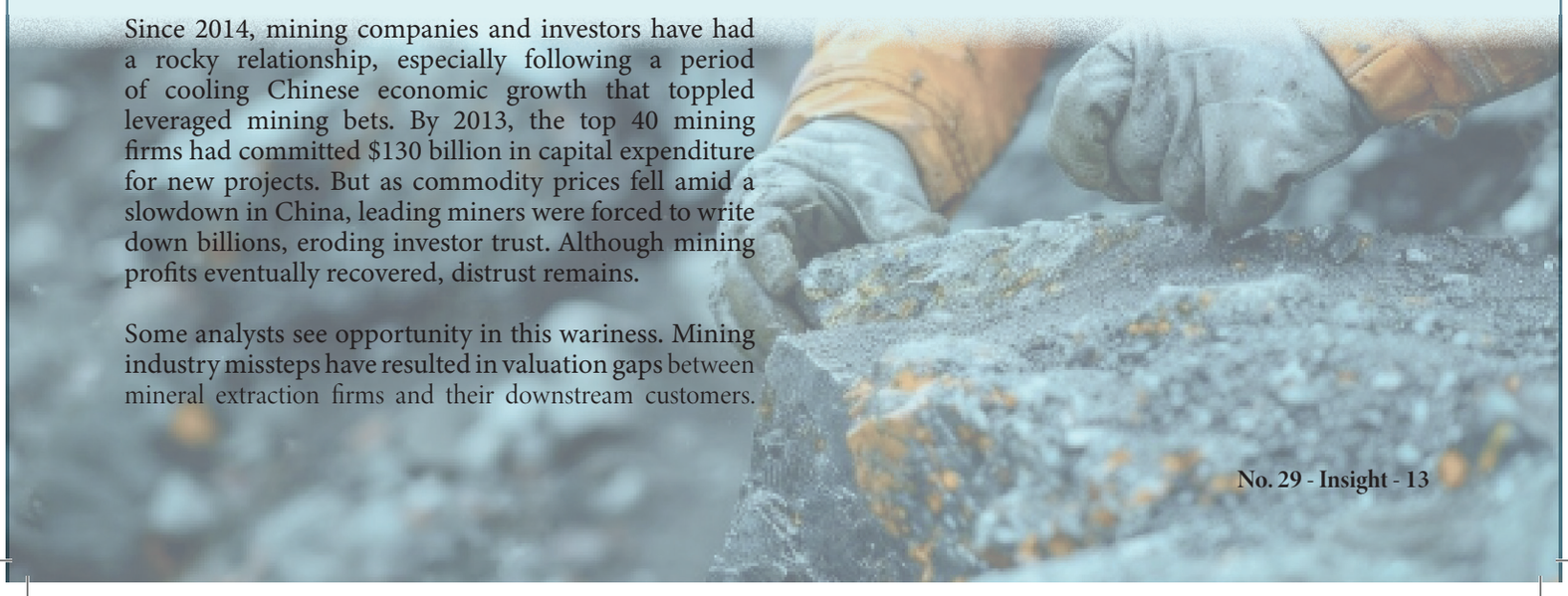
Beyond surging demand, mining firms are also exploring downstream integration, particularly in the United States. New business models feature onsite mineral processing and nearby value-added production, allowing mining companies to capture up to 39% of battery production revenue. Many are also considering onsite battery recycling, which could expand revenue further.

A Risky Renewable Future?

Yet, market miscalculations may be compounded by challenges within the industry itself. Lengthy permitting processes, political risks, environmental opposition, and rising operational costs all deter long-term commitments. Even industry giants are cautious – Rio Tinto recently abandoned a $2.4 billion lithium project in Serbia following widespread protests.

Western governments are increasingly aware of the need for stable critical minerals supply chains, partly to reduce reliance on China, the world's leading critical minerals exporter. Former UK Deputy Prime Minister Dominic Raab noted the strategic importance of minerals by comparing them to oil, observing that while China controls over 80% of certain minerals, no country holds more than 15% of global oil supply. As economies transition to renewables, dependence on Chinese mineral supplies poses a mounting security risk.

The climate technology industry shows no signs of slowing, nor should it; however, an unresolved shortage in critical minerals may represent an insurmountable barrier to its long-term success. Without a shift in the attitudes of investors, policymakers, and civil society towards mining, the grand ambitions of a renewable future risk drifting further out of reach.



Case Studies

Indian EdTech's Double-Edged AI Sword

Meenakshi Mani explores how AI-driven EdTech is reshaping India's education landscape, raising questions about equality, data privacy, and the influence of Silicon Valley on the nation's classrooms.

In India, K-12 schools vary widely in resources and infrastructure. Some schools benefit from robotics labs and air-conditioned classrooms, while others, particularly in rural areas, struggle to provide students with basic amenities like reliable electricity and access to toilets. While progress has been made in bridging these gaps, educational inequity remains the biggest challenge for India's K-12 education system – one that technology companies increasingly claim can be solved with the help of Artificial Intelligence (AI).

India's burgeoning EdTech industry generated over $4 billion in 2022. EdTech products have found huge success in India, where six of the world's 28 EdTech unicorns – privately held EdTech companies valued at over $1 billion – are Indian. The influence of AI can be seen in the first page of India's National Education Policy (NEP) of 2020, which states the need to build a 'skilled workforce', equipped to tackle rapidly advancing fields of machine learning and AI. While the NEP also emphasises socio-emotional learning, encouraging interest in the arts, and shaping ethical individuals, it is clear that a primary concern of policymakers is ensuring that the Indian education system pivots towards a future job market that is reshaped by AI technologies.

> **"India currently lacks adequate regulations to protect students and parents who are the subject of myriad AI interventions by tech corporations, and to sufficiently address issues of child data privacy, ownership, and consent."**

Like many policies before it, the NEP justifies this economic focus as the primary means of addressing inequalities experienced by socio-economically disadvantaged groups that are disproportionately from rural regions and marginalised communities. While the notion of education primarily serving as a pipeline into the economy has long been the subject of critique and contention, the stark reality of the inequalities experienced in India – home to 167 billionaires while 47% of the population lives on less than $3/day – has reinforced this view of education as the ultimate pathway to economic stability. The technology sector has been apt in capitalising on this belief to position themselves as saviours of a broken education system and to promote AI initiatives and products that universally promise success in children's educational journeys.

The Silicon Valley-fication of Indian Education

The Indian central and state governments play a significant role in facilitating the intervention of tech companies within the education space. State governments across the country have contracted with EdTech companies to implement solutions in government schools to address issues of educational access and inequity. These solutions, largely marketed as incorporating state-of-the-art AI, are often backed by Silicon Valley giants like Google, Amazon, and Microsoft.

India's K-12 education system is heavily geared towards examination performance, a legacy of the colonial era when culturally-rooted learning was replaced with exam-oriented teaching aimed at assessing suitability for roles within the British Empire. A majority of AI EdTech developments in India largely reinforce these methods, concentrating on tutoring, assessment, and test preparation. Innovation, when presented, involves equating pedagogy to gamification, where children interact with technology-mediated content, often by themselves, and are subsequently assessed on their knowledge. These gamified curricula may engage students and help them understand concepts better through interactive and visual means. However, they hardly challenge the overarching design of the educational system that continues to prioritise assessment styles that reward rote learning.

Other tech initiatives have involved promoting specific types of curriculum. Amazon, for example, is funding personalised computer-science and AI education in Indian government schools. There is a whole network of actors – tech corporations, NGO's, consulting firms – who are involved in this large-scale roll-out of AI EdTech into government schools. The end result is a patchwork quilt of initiatives and products: students may take up an Amazon curriculum on a Monday, learn through an NGO's EdTech app on a Tuesday, a Google-driven initiative on a Wednesday, and so on. While it could be argued that these initiatives provide valuable skills to students and attempt to bridge the digital divide, they also underscore the growing influence of large corporations in shaping Indian education and labour markets. This raises concern about whether such programmes truly prioritise students' long-term well-being or the company's interests.

Trade-offs and False Promises

Technology companies have a vested interest in engaging with schools, particularly government schools, as they provide easy access to vast swathes of student data. Data is

the new oil. A struggling government school is more likely to welcome data-hungry AI EdTech products, especially when given for free. Technology encourages advancement, and these schools desperately need it. However, what are the terms of use for these products? What does a daily-wage labourer in a rural village understand about consenting to their child's data being used for training a machine-learning model? And what happens five years down the line when tech corporations have entrenched themselves in school functioning and decide they will no longer offer their services for free? India currently lacks adequate regulations to protect students and parents who are the subject of myriad AI interventions by tech corporations, and to sufficiently address issues of child data privacy, ownership, and consent.

Although advertised as a mechanism to level the playing field, in many ways, AI is unsuccessful in achieving higher educational equality. EdTech products are costly, often affordable only to middle-class or affluent families. In an attempt to address financial, infrastructural and educational disparities, companies often create different tiers of products: advanced, feature-rich solutions for private schools that can afford them, and offline, foundational tools to help students in government schools catch up in low-resource settings. This combined with issues of infrastructure, access, and AI literacy, only serve to exacerbate existing inequalities between government schools and private counterparts, often along the lines of income, caste, and region. This matters in a country where government schools constitute nearly 70% of K-12 schools and serve over 50% of the country's K-12 student population.

This is not to say that there are no benefits to these products. For a child from a migrant community who enters school for the first time at age 11, AI EdTech can quickly assess their learning level and provide a suitable curriculum, even if that curriculum is that of Grade 1. This is not something an average teacher at a government school would be able to support. There is also important EdTech work being done in early childhood education, where companies have found innovative ways to engage young children in rural areas with meaningful materials. The NEP's directive to make textbooks available in various Indian languages along with advances in home-grown Indic large language models mean that more students will have access to learning in their mother tongues, helping reduce the high drop-out rates observed after middle-school.

While AI EdTech has its benefits when applied thoughtfully, its large-scale rollout often reinforces standardisation in its methods, restricting true creativity. There is also an implicit assumption that being continuously assessed and staying 'on track' within a new AI-driven education system will somehow ensure every child an equal chance at a high-quality of life. However, without tackling existing systems of oppression and injustice, all AI systems do is reinforce old patterns in the Indian education system, perpetuating a quantification-driven, zero-sum game of winners and losers. Indian AI EdTech, in its current envisioned forms, do not necessarily change the inherent orientation of the Indian education system towards examination performances, which eventually carve out economic futures of millions of students.

Technology-owned Public Good?

Today, AI-driven education in India is designed not just by Indian EdTech companies, but often under the influence – overt and covert – of Silicon Valley players. It would seem that the NEP's directive to teach students to 'learn how to learn' has meant a reimagining of education through a tech-focused lens, promoting visions that are inextricably bound to tech utopias that valorise certain forms of knowledge and creativity. In a country where Indian-born Silicon Valley leaders like Sundar Pichai are venerated, there is a risk of the education system being unilaterally shaped by the tech sector primarily towards producing the next generation of coders, considered the sole architects of a 'better tomorrow'. Meanwhile, scholars warn of an inequality vortex driven by the growing influence of a purely tech-oriented workforce in cities worldwide.

"Without tackling existing systems of oppression and injustice, all AI systems do is reinforce old patterns in the Indian education system, perpetuating a quantification- driven, zero-sum game of winners and losers."

Who should have power over the education of hundreds of millions of children? The fallout from Byju's collapse – India's most well-known and once the world's most valuable EdTech company – is still felt nationwide, leaving the most vulnerable students stranded with outdated, tablet-based learning tools and no teacher support. This serves as a reminder to re-evaluate the tradeoffs being made when a public good as important as education is increasingly provisioned by the tech sector. While AI might complement educational provisions, it is not fully clear whether it will help, or worsen, issues of educational equity. In the meantime, caution must be exercised in ceding power over the educational futures of the 250+ million K-12 aged children in India to the tech industry, and a deeper, democratic discussion is required to understand the implications of doing so.

Energising West Africa: The Promise of Solar Photovoltaics in Overcoming Energy Poverty

Satvik Singla examines the potential for solar photovoltaic technology to revolutionise West Africa's energy sector and foster economic growth across the region.

West Africa is currently grappling with one of the lowest electrification rates in the world, with 220 million people (47% of the total population) living without access to electricity. The region also faces some of the highest electricity prices globally, experiencing an average of USD 0.35 per kilowatt-hour (kWh) and highs of USD 0.66 in certain countries. Despite these challenges, West Africa has vast renewable energy potential, with 1,956 gigawatts available from solar and an additional 106 gigawatts from wind. However, the region's energy supply remains heavily reliant on fossil fuels. For example, oil and gas in Nigeria account for almost 80% of electricity generation. This energy poverty stifles economic growth, reduces productivity, and limits industrial development. In response to these challenges, renewable energy solutions, especially solar photovoltaics (PV), are crucial to unlock the region's economic potential.

A Ray of Hope

Considering that much of West Africa's abundant solar energy potential remains untapped due to infrastructure and cost barriers, the recent technological breakthrough in solar PV is a ray of hope for the region's energy security. Recent innovations such as the ultra-thin solar cells developed by Oxford scientists, can now deliver energy conversion efficiencies exceeding 27% – a significant leap towards energy transition. One of the most critical metrics considered when determining energy efficiency is the Levelized Cost of Energy (LCOE), which measures a generator's average net present cost of electricity generation over its lifetime. Currently, the LCOE for solar PV is estimated at USD 0.05 to 0.10 per kWh, which is considerably lower than the cost of electricity generated from fossil fuels.

Researchers from LUT University in Finland suggest solar PV could meet up to 85% of West Africa's energy demand by 2050, offering a promising future.

The Economic and Environmental Benefits

The renewable energy sector can generate thousands of jobs across the value chain, from manufacturing to installation, while also attracting foreign investment to further boost economic growth. This transition would enhance energy security, reducing dependence on costly fossil fuel imports and positioning West Africa as a renewable energy hub. Environmentally, solar energy significantly lowers carbon emissions, which is crucial for a region particularly vulnerable to climate change. With minimal historical emissions, West Africa's solar energy adoption could set a precedent for global climate mitigation, helping the region adapt to extreme weather patterns while promoting sustainability.

The 'California Duck Curve' and Grid Stability

Despite solar PVs' promise to address West Africa's energy crisis, the reality is more complex. The California Duck Curve underscores the challenge of balancing energy supply and demand with high solar PV adoption. As the generation of solar energy peaks during the day and drops at night, a sharp demand for conventional power emerges in the evening, creating a steep "ramp". This phenomenon, first observed in California, should be of significant consideration for West Africa's energy transition. Despite the increasing installations of solar PV, fossil fuels may still be needed to stabilise the region's grid during evening demand surges, due to inadequate energy storage and fragmented grid infrastructure.
This highlights the urgent need for West Africa to improve its grid infrastructure and provide adequate training to transmission operators to ensure a smooth energy transition.

Strengthening Regional Cooperation

Energy regulation and cooperation are other essential aspects for successfully achieving energy transition and energy security for West Africa. To address these issues, the Economic Community of West African States (ECOWAS) has used multiple initiatives to implement key policies to promote energy cooperation and cross-border trade. For instance, the West African Power Pool (WAPP) initiative aims to create a unified regional electricity market, facilitating seamless power exchange across borders by linking national grids. However, challenges persist; there are legal discrepancies among member states, incompatible grid infrastructures, and political hesitation in adopting regional standards. Only a few countries have fully complied with the ECOWAS Energy Protocol, delaying progress towards a fully integrated energy market, which would have amplified the impact of solar PV systems, allowing for efficient solar energy distribution across West Africa. Improved cooperation enhances the potential of solar PVs, enabling West Africa to harness its solar resources to meet regional demand and improve energy security.

Ultimately, innovations in solar technology, including ultra-thin solar cells and emerging energy storage solutions, are key to making solar PV a cost-effective, reliable power source. Moving forward, coordinated regional policies, enhanced grid infrastructure, and international investment are essential for West Africa to establish itself as a future renewable energy hub.

Tradition and Modernity in Mongolia: Environmental Degradation

*In this crucial period of digitalisation, **Mahrukh Khurshid** traces Mongolia's transition from Communist to Capitalist policies, exploring the relationship between the nation's nomadic heritage and modernisation.*

Mongolia's recent history has been host to a number of contrasting policies on climate activism and environmental conservation. Interestingly, environmental degradation was present in Mongolia both before and after the collapse of the USSR, despite the nation following opposing political-economic ideologies across this period. This article outlines this history and explores these policies' lasting effects on Mongolia in light of the digital revolution, before addressing new approaches to prevent climate change. Ultimately, the fundamental question for Mongolia looks to be whether they can expect to continue balancing a nomadic way of life with the contemporary proliferation of technology, or if it will eventually succumb to the tide of digitalisation, as other nations have.

Communist policies (1921-1990)

As a satellite state of the USSR, Mongolia followed the intensely compressed policy of rapid industrialisation to fuel the Soviet economy, which has led to long-term economic harm, still felt by Mongolians today.

The Communist state pursued rapid industrialisation by building coal-burning power plants in the capital, Ulaanbaatar, developing national infrastructure in the form of roads and railways, and establishing open-pit mining operations, such as the construction of the Erdenet Mine in 1974 to exploit mineral resources like copper and molybdenum ore. These initiatives led to significant environmental damage, particularly through surges in air and land pollution.

The institution of negdels (collectives) eliminated most private ownership of animals, and herders instead received wages to tend to their allocated animals and land. Resources were sometimes allocated according to environmental carrying capacity; negdel leaders regulated the proportion of sheep to goats in herds, as goats eat plants down to their roots, thereby razing grasslands and hindering reseeding. Despite their authoritarian nature, negdel leaders provided basic healthcare, education, and transport to help nomads gather supplies to support themselves and their herds.

Though this demonstrates that the Communist regime was somewhat concerned for the wellbeing of the people and environment, these considerations were ultimately overshadowed by the pursuit of rapid industrialisation to support the Soviet economy. The resulting environmental damage might have been countered by Mongolia's transition to laissez-faire economics after the USSR's collapse, had the people known more about capitalism's institutions and practices. Instead, the transition entailed unregulated corruption and profiteering, which further exacerbated environmental degradation.

Capitalist policies (1990-current)

The collapse of the USSR left Mongolia without its most important trading partner, forcing it to turn to the pro-privatisation IMF and World Bank for aid. These institutions feared a regression to Communism, and so instantaneously transformed Mongolia into a mostly unregulated economy (which was known as "shock therapy"), resulting in environmental harm to a similar degree.

Shock therapy led to an unfair distribution of resources, particularly of animals and vehicles. The well-connected benefited, whilst the majority lacked sufficient resources for even subsistence farming. This greatly augmented wealth inequality and drove many to abandon their nomadic lifestyles and move to Ulaanbaatar for work in the technological sector. This movement from rural to urban areas relates to the broader context of urbanisation, which has accompanied the technological revolution in Mongolia.

Moreover, capitalist policies effectively withdrew government support from the people, leaving many herders without transport to access supplies. The reversal of infrastructure policy left many rural areas

without adequate roads, forcing nomads to drive vehicles directly on the steppe, further degrading the land. Herders began moving closer to towns for better connectivity, resulting in more localised and less nomadic lifestyles. This shift exacerbated desertification as herds depleted grasslands in concentrated areas. The situation worsened with the relaxation of government regulations on livestock ratios; previously, the proportion of sheep to goats in herds was maintained at 8:1, a balance that preserved both grasslands and animals. The ratio has since dropped to 1:1, resulting in vast stretches of overgrazed, exhausted land.

Another significant strain on Mongolia's resources is the development of its mining sector. Mongolia is rich in mineral resources like copper, uranium, and gold; the government's 'Gold' programme initiated large-scale mining in 1993. However, the rapid growth of mining coupled with the increase in mines located near river headwaters have deprived local herders of their most essential resource: clean water, already naturally scarce in steppe grasslands. As a result, hazardous mining practices are a primary concern for Mongolia's environmentalists.

Overall, desertification, land exhaustion, and resource depletion have contributed significantly to climate change. Herders face increasingly severe zuds – harsh winters – that often decimate entire herds, compounding the instability of nomadic life and leaving many hungry and destitute.

Privatisation has brought rural industry to the brink of collapse. Without government aid, an increasing number of herders have moved to urban areas, threatening the nomadic features of Mongolia's civilisation and worsening the country's environmental damage.

The government's single-minded focus on economic growth exacerbates these issues. Regulations on hunting rare and endangered species have recently been relaxed to boost tourism revenue. For instance, when Donald Trump illegally killed an argali sheep in 2019, the Mongolian government issued him a licence after the fact. This suggests that the government prioritises economic growth over environmental protection, a stance that mirrors that of the Communist state.

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A Cause for Hope

There are steps being taken to counteract environmental destruction. To address water scarcity caused by unsafe mining practices, the government passed the 'Law on the Prohibition of Mining Operations at Headwaters of Rivers, Protected Zones of Water Reservoirs and Forested Areas' in 2009, which bans mining in areas critical for water and biodiversity protection.

To support this law, the International Union for Conservation of Nature proposed an awareness project about the importance of reducing mining impacts. This includes an education programme in schools in eastern Mongolia, a plantation programme for sea buckthorn trees, and a workshop for local and international stakeholders to better understand the adverse effects of mining.

Both the Mongolian Parliament and international organisations have shown interest in preserving Mongolia's environment. Many Mongolians are also keen on balancing tradition with modern technology, contrasting with the approach taken by other industrialised countries. They have integrated three main technologies into their otherwise nomadic lifestyles: mobile phones, solar LEDs, and motorcycles.

Nearly all nomadic households have solar LEDs, which allow for extended evenings and make cooking more convenient. Most people own mobile phones, though cell service is limited in some areas, and one often needs to travel to get a signal. This justifies the need for motorcycles, which are inexpensive to run and also useful for obtaining supplies from nearby towns. These technologies do not threaten or impede the nomadic lifestyle; nomads can still pack up their possessions within an hour, and motorcycles facilitate their travels.

Evidently, Mongolians have managed to integrate technology into their nomadic lifestyle fairly seamlessly. This is not the cause of severe environmental harm, as the widespread use of solar panels largely offsets nomads' already minor carbon footprint. Rather, government economic policy has driven much of the ecological destruction, particularly through the over-exploitation of mineral resources, grasslands, and clean water.

Overall, as government policy increasingly emphasises technology, Mongolia's nomadic population faces an uncertain future. Many young nomads are moving to Ulaanbaatar to work in sectors like AI rather than becoming herders like their ancestors. Whether Mongolia can sustain its balance of tradition and modernity, or if its culture and traditions will eventually succumb to the digital revolution, remains to be seen.

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