INTERNATIONAL STUDIES CENTER

JOURNAL

No. 2/2025 | August 2025

Appropriate Technology for the Digital Age
How Accessible AI Can Close the North-South Development Gap

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Artificial Intelligence (AI) has garnered increasing scholarly attention for its capacity to reshape global development trajectories as a general-purpose technology, comparable to past breakthrough innovations like the internet, personal computers, the steam engine, and electricity. Generative AI, in particular, has extended automation into creative and cognitive domains previously considered resistant to substitution, boosting productivity in areas such as agriculture, education, healthcare, and climate change mitigation. Nonetheless, these benefits are accompanied by serious risks. The new innovation may exacerbate inequality by displacing workers and concentrating wealth among those with technological control. AI can also accelerate environmental degradation due to its intensive resource consumption. Crucially, these risks and benefits are not evenly distributed. Many developing countries are particularly vulnerable to the disruptive impacts of AI, while simultaneously lacking the necessary capacities to fully harness its advantages.

Whether AI promotes inclusive development or exacerbates global disparities largely depends on its design, governance, and deployment. Without inclusive governance and deliberate safeguards, AI development risks catering to the narrow commercial or geopolitical interests of a few, thereby sidelining

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the broader social and environmental considerations for the majority. The current AI landscape is primarily dominated by companies in the Global North, particularly in the US, with leading firms such as OpenAI, Google, Meta, and Microsoft[2]. This concentration of technological power raises multiple ethical issues, including unequal access and the alignment of innovation with the priorities of high-income countries, continuing the long-standing trend in technological development[3]. Against this backdrop, *DeepSeek*, a Chinese AI firm launched in early 2025, reportedly offers capabilities comparable to those of OpenAI's latest model, but at a fraction of the cost and with much lower energy use, fostering hopes that AI technology can be more democratised and appropriate for developing economies[4]. While it holds true that China is the world's second-largest economy with an advanced innovation system, it still encounters developmental challenges common to many developing nations. As a result, China's endogenous innovations, designed for its local context and demands, are often more applicable to the Global South countries[5].

Drawing upon the *Appropriate Technology* theory, this paper argues that DeepSeek represents a potentially more inclusive pathway for AI development, one that considers the needs and capabilities of developing countries. Realising this potential, however, requires two key conditions: first, enhanced capabilities in developing nations to adopt and adapt this transformative innovation; and second, global AI governance that ensures the ethical use of AI, prioritising social and environmental needs over profit and geopolitical gains. The paper proceeds in five sections. Section 1 explores the dual potential of AI to advance or hinder global development, with a focus on preexisting disparities that lead to the unequal distribution of its benefits and harms. Section 2 introduces the Appropriate Technology theory as the analytical framework, highlighting that technology is not always universally applicable and there are considerations for developing

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[2] Pascale Davies, 'Which Country Is Leading the AI Race?', Euronews, 2025, https://www.euronews.com/next/2025/04/08/which-country-is-winning-the-race-to-be-the-worlds-ai-leader.

[3] Raphael Kaplinsky. 'Schumacher Meets Schumpeter: Appropriate Technology below the Radar'. Research Policy 40, no. 2 (March 2011): 193–203. https://doi.org/10.1016/j.respol.2010.10.003.

[4] David Krause, 'DeepSeek and FinTech: The Democratization of AI and Its Global Implications', 2025, https://doi.org/10.2139/ssrn.5116322; David Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1: Implications for Sustainable Development', SSRN Scholarly Paper (Rochester, NY, 2 February 2025), https://doi.org/10.2139/ssrn.5120918.

[5] Xiaolan Fu, *Innovation under the Radar: The Nature and Sources of Innovation in Africa* (Cambridge: Cambridge University Press, 2020), https://doi.org/10.1017/9781316869482.

economies to reap the benefits of innovations. Section 3 applies this lens to DeepSeek, examining how South-South technological diffusion might offer a more suitable pathway for the Global South. Section 4 outlines the main obstacles to this pathway, including structural limitations in developing countries and the growing risks of US-China geopolitical tensions. It calls for stronger local capacities and inclusive global AI governance. The final section synthesises these insights and concludes the paper.

1. The Developmental Impacts of AI: Promises and Perils

AI development originated in the mid-20th century, led by pioneers such as Alan Turing and John McCarthy. Initially confined within academic research due to limited computational resources, AI advanced significantly with the advent of microcomputers in the 1980s and was further accelerated by breakthroughs in machine learning and the explosion of big data in the 21st century[6]. These developments facilitated the design of more complex algorithms and their practical applications, drawing greater attention from both the industry and government sectors. The rise of open-source platforms has made powerful AI tools accessible to anyone with an internet connection, fostering innovation and collaboration globally. Recent breakthroughs in Generative AI, especially those using large language models, have pushed AI into tasks once thought too complex for automation. Generative AI can produce original content such as text, images, or audio based on training data[7]. Unlike traditional conversational AI, which simulates dialogue, it can generate complete, creative outputs in real-time. Tools like OpenAI's ChatGPT have popularised Generative AI by generating realistic language and imagery from natural language prompts, reshaping communication, and content production[8].

AI exemplifies Schumpeter's definition of innovation as *"creative destruction",* a process in which new ideas and technologies replace older ones, creating new economic opportunities but also disrupting

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[6] Costa, Carlos J., Manuela Aparicio, Sofia Aparicio, and Joao Tiago Aparicio. 'The Democratization of Artificial Intelligence: Theoretical Framework'. Applied Sciences 14, no. 18 (12 September 2024): 8236. https://doi.org/10.3390/app14188236.
[7] Ömer Aydın and Enis Karaarslan, 'Is ChatGPT Leading Generative AI? What Is Beyond Expectations?', SSRN Scholarly Paper (Rochester, NY, 29 January 2023), https://doi.org/10.2139/ssrn.4341500.
[8] Brady D. Lund et al., 'ChatGPT and a New Academic Reality: Artificial Intelligence-Written Research Papers and the Ethics of the Large Language Models in Scholarly Publishing', *Journal of the Association for Information Science and Technology* 74, no. 5 (2023): 570–81, https://doi.org/10.1002/asi.24750.

existing industries[9]. With its transformative potential, AI is estimated to enable 134 of 169 targets across all Sustainable Development Goals (SDGs)[10]. However, these gains are not automatic. Without inclusive governance and ethical considerations, AI may widen global inequalities and cause environmental harm, disproportionately affecting already vulnerable lower-income economies.

1.1 AI's Promises for Sustainable Development

AI holds considerable promise across economic, social, and environmental dimensions. Economically, Generative AI alone could contribute significantly to the global economy, with estimates suggesting a potential economic impact of up to US$4.4 trillion, stemming from labour productivity, automation, and the acceleration of innovation[11]. While it is true that AI may displace certain jobs, particularly clerical roles, technology-driven job creation is still expected to outpace these losses. A report from the World Economic Forum projects that up to 97 million new jobs could emerge globally, especially in digital services, green technology, and cybersecurity[12].

Socially, AI enhances productivity in delivering essential services, such as education and healthcare. In education, for example, AI can facilitate personalised learning by adapting content to individual needs, including those of students with special educational requirements. Intelligent tutoring systems powered by large language models allow real-time feedback and adaptive tasks, helping to close learning gaps and promote educational equity[13]. In healthcare, AI is transforming diagnostics and

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[9] Joseph A Schumpeter. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Harvard Economic Studies; v. 46. Cambridge, Mass: Harvard University Press, 1934.

[10] Vinuesa, Ricardo, Hossein Azizpour, Iolanda Leite, Madeline Balaam, Virginia Dignum, Sami Domisch, Anna Felländer, Simone Daniela Langhans, Max Tegmark, and Francesco Fuso Nerini. 'The Role of Artificial Intelligence in Achieving the Sustainable Development Goals'. Nature Communications 11, no. 1 (13 January 2020): 233. https://doi.org/10.1038/s41467-019-14108-y.

[11] McKinsey, 'The Economic Potential of Generative AI: The next Productivity Frontier.', 2023, https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/the%20economic%20potential%20of%20generative%20ai%20the%20next%20productivity%20frontier/the-economic-potential-of-generative-ai-the-next-productivity-frontier.pdf.

[12] World Economic Forum. 'The Future of Jobs Report'. World Economic Forum, 2020. https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.

[13] Yoshija Walter, 'Embracing the Future of Artificial Intelligence in the Classroom: The Relevance of AI Literacy, Prompt Engineering, and Critical Thinking in Modern Education', *International Journal of Educational Technology in Higher Education* 21, no. 1 (26 February 2024): 15, https://doi.org/10.1186/s41239-024-00448-3.

streamlining workflows. For instance, AI applications in diabetic retinopathy have reduced image preparation time by 90%, decreasing patient waiting times and improving hospital efficiency[14].

Environmentally, AI can also contribute to climate action through diverse applications. It improves renewable energy forecasting, automates electricity grids, and monitors emissions with high precision[15]. In agriculture, AI can reduce fertiliser use, enhance water efficiency, and increase crop yields[16]. A study shows that the use of AI in Californian vineyards resulted in a 25% increase in yield and 20% water savings. It also supports waste reduction and circular economy by optimising supply chains and automating sorting processes[17]. Through sensors and remote sensing, AI can track threats in fragile ecosystems, predict natural disasters, and detect biodiversity stress. It can also reduce its own environmental footprint by using edge computing, locating data centres in regions powered by renewable energy, and incorporating AI-driven cooling systems[18].

1.2 AI's Perils of Inequalities and Environmental Harm

Despite its promising trajectories, AI presents a range of risks that may hinder its developmental impacts. Economically, while AI improves task-level productivity, its broader impact remains modest. Acemoglu estimates that Generative AI will increase total factor productivity by only 0.66% over a decade. The benefits tend to accrue to capital owners and high-skilled workers, exacerbating income inequality for those with limited access to AI and, more broadly, education[19]. Globally, around 40% of jobs are at risk of automation, particularly in advanced economies. Although low-income countries face lower exposure (around 26%), their limited capacity to absorb technological change raises concerns about deepening income

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[14] Junaid Bajwa et al., 'Artificial Intelligence in Healthcare: Transforming the Practice of Medicine', *Future Healthcare Journal* 8, no. 2 (July 2021): e188–94, https://doi.org/10.7861/fhj.2021-0095.
[15] David Mhlanga. 'AI War Between China and America and the Rise of DeepSeek-R1: Implications for Sustainable Development'. SSRN Scholarly Paper. Rochester, NY, 2 February 2025. https://doi.org/10.2139/ssrn.5120918.
[16] Jeffrey Ding, 'Deciphering China's AI Dream: The Context, Components, Capabilities, and Consequences of China's Strategy to Lead the World in AI' (Centre for the Governance of AI, 2018), https://cdn.governance.ai/Deciphering_Chinas_AI-Dream.pdf.
[17] Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1'.
[18] Amir Lebdioui, Angel Melguizo, and Victor Muñoz, 'Artificial Intelligence, Biodiversity and Energy: From a Resource-Intensive to a Symbiotic Tech' (Technology, Industrialisation and Development (TIDE) Centre, 2025).
[19] Daron Acemoglu, *The Simple Macroeconomics of AI*, NBER Working Paper Series No. W32487 (Cambridge, Mass: National Bureau of Economic Research, 2024).

disparities across countries[20].

Socially, AI may amplify existing inequalities beyond income. AI-driven job creation does not necessarily yield positive welfare outcomes. Some new tasks, such as generating disinformation, enabling surveillance, or automating cyberattacks, may carry negative social value. In such cases, AI could theoretically increase GDP while reducing overall well-being; for example, a 2% GDP gain may coincide with a -0.72% decline in welfare[21]. Algorithmic systems also risk reproducing biases in hiring, education, healthcare, and policing, disproportionately harming women, minorities, rural communities, and other marginalised groups[22]. In education, AI tools may standardise thought and marginalise traditional knowledge systems, particularly in culturally diverse or under-resourced settings[23]. Besides, in contexts without transparency or democratic oversight, AI can be misused to manipulate behaviour, fuelling nationalism, discrimination, and election interference, often without individuals' knowledge or consent[24].

Environmentally, AI is highly resource-intensive, requiring the extraction of minerals and rare earths for semiconductor production, as well as extensive water and energy consumption, and carbon emissions from innovation development and operations. Training a single large language model in 2022 emitted 25 times more CO_2 than a return flight from New York to San Francisco and consumed energy equivalent to powering an American home for 41 years[25]. GPT-3 required approximately 700,000 litres of

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[20] Mauro Cazzaniga, Florence Jaumotte, Longji Li, Giovanni Melina, Augustus J Panton, Carlo Pizzinelli, and Marina M Tavares. 'Gen-AI: Artificial Intelligence and the Future of Work'. Staff Discussion Notes. IMF, 2024.
[21] Daron Acemoglu, *The Simple Macroeconomics of AI*, NBER Working Paper Series No. W32487 (Cambridge, Mass: National Bureau of Economic Research, 2024).
[22] Pawel Gmyrek, Janine Berg, and David Bescond, 'Generative AI and Jobs: A Global Analysis of Potential Effects on Job Quantity and Quality', SSRN Scholarly Paper (Rochester, NY, 21 August 2023), https://doi.org/10.2139/ssrn.4584219.
[23] Weng Marc Lim, Asanka Gunasekara, Jessica Leigh Pallant, Jason Ian Pallant, and Ekaterina Pechenkina. 'Generative AI and the Future of Education: Ragnarök or Reformation? A Paradoxical Perspective from Management Educators'. The International Journal of Management Education 21, no. 2 (1 July 2023): 100790. https://doi.org/10.1016/j.ijme.2023.100790.
[24] Ricardo Vinuesa, Hossein Azizpour, Iolanda Leite, Madeline Balaam, Virginia Dignum, Sami Domisch, Anna Felländer, Simone Daniela Langhans, Max Tegmark, and Francesco Fuso Nerini. 'The Role of Artificial Intelligence in Achieving the Sustainable Development Goals'. Nature Communications 11, no. 1 (13 January 2020): 233. https://doi.org/10.1038/s41467-019-14108-y.
[25] Alexandra Sasha Luccioni, Sylvain Viguier, and Anne-Laure Ligozat, 'Estimating the Carbon Footprint of BLOOM, a 176B Parameter Language Model' (arXiv, 3 November 2022), https://doi.org/10.48550/arXiv.2211.02001.

water for training and consumes around 500 ml per 10-50 responses[26]. By 2027, global AI-related water use could reach 4.2-6.6 billion cubic metres, almost half of the UK's annual withdrawal[27]. The rising consumption is anticipated to rapidly continue, with global investment in data centres projected to exceed US$200 billion by 2028. As of 2025, the US leads with 5,426 data centres, far surpassing Germany (529), the UK (523), and China (449), the only developing country among the top five[28]. These trends highlight the unequal geographic concentration of AI infrastructure and the environmental burden it imposes, particularly on low-income countries that contribute merely 10% of global emissions but face the most severe climate impacts[29].

1.3 Preexisting Global Disparities

Most concerningly, the economic, social, and environmental risks associated with AI are unevenly distributed, with developing countries, already vulnerable to multiple forms of disruption, being the least prepared to manage them. AI models are predominantly developed in the Global North and often tailored to high-income contexts, making them poorly suited to the social, economic, and infrastructural conditions of the Global South. Many low- and middle-income countries face barriers such as inadequate digital infrastructure, high implementation costs, and limited institutional capacity, all of which hinder effective adoption and innovation[30].

At present, advanced economies dominate AI investment and innovation. In 2024, US-based institutions produced 40 notable AI models, compared to 15 from China and just 3 from Europe[31]. While

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[26] Pengfei Li, Jianyi Yang, Mohammad A. Islam, and Shaolei Ren. 'Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models', 6 April 2023. https://arxiv.org/abs/2304.03271v5.

[27] Josh Lepawsky, 'Climate Change Induced Water Stress and Future Semiconductor Supply Chain Risk', *iScience* 27, no. 2 (16 February 2024): 108791, https://doi.org/10.1016/j.isci.2024.108791.

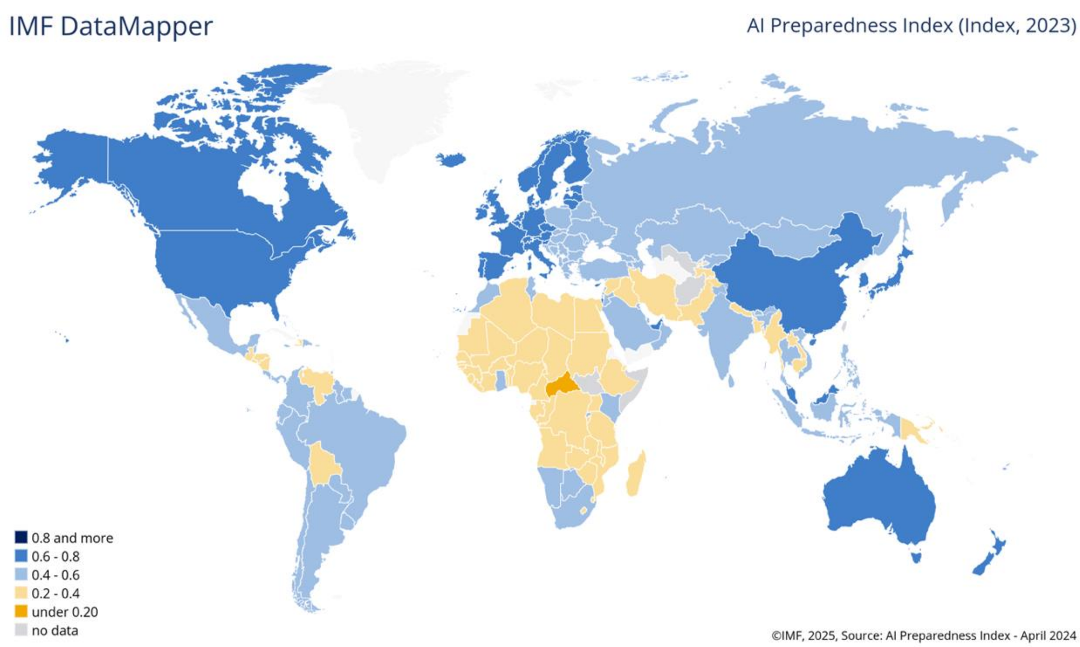
[28] Statista, 'Data Centers Worldwide by Country 2025', Statista, 2025, https://www.statista.com/statistics/1228433/data-centers-worldwide-by-country/.

[29] Ruma Bhargawa and Megha Bhargava, 'The Climate Crisis Disproportionately Hits the Poor. How Can We Protect Them?', *World Economic Forum* (blog), 13 January 2023, https://www.weforum.org/stories/2023/01/climate-crisis-poor-davos2023/.

[30] Nishith Reddy Mannuru, Nishith Reddy, Sakib Shahriar, Zoë A Teel, Ting Wang, Brady D Lund, Solomon Tijani, Chalermchai Oak Pohboon, et al. 'Artificial Intelligence in Developing Countries: The Impact of Generative Artificial Intelligence (AI) Technologies for Development'. Information Development, 14 September 2023, 02666669231200628. https://doi.org/10.1177/02666669231200628.

[31] Nestor Maslej et al., 'The AI Index 2025 Annual Report' (AI Index Steering Committee, Institute for Human-Centered AI, Stanford University, 2025).

China ranks among the world's top 30 most innovative nations, it is an outlier as the only non-high-income country[32]. The global landscape of AI readiness is deeply unequal. The global digital divide reflects this inequality: only 27% of people in low-income countries have internet access, compared to 93% in high-income countries[33]. Broadband remains unaffordable in many parts of the Global South, with costs reaching up to 31% of monthly income, far exceeding the UN's target of 2%[34]. The IMF's AI Preparedness Index, which assesses 174 countries based on digital infrastructure, human capital, innovation capacity, and regulatory frameworks, reveals that most developing countries significantly lag behind high-income nations, posing a major barrier to inclusive AI adoption[35].



Source: IMF

[32] WIPO, 'Global Innovation Index 2024: Switzerland, Sweden, US, Singapore, UK Top Ranking; China, Türkiye, India, Viet Nam, Philippines Among Fastest 10-Year Risers; Dark Clouds for Innovation Investments', 2024, https://www.wipo.int/pressroom/en/articles/2024/article_0013.html.
[33] World Bank, 'Individuals Using the Internet (% of Population)', World Bank Open Data, 2025, https://data.worldbank.org.
[34] ITU, 'The Affordability of ICT Services 2023' (International Telecommunication Union, 2024), https://www.itu.int/en/ITU-D/Statistics/Documents/publications/prices2023/ICTPriceBrief2023.pdf.
[35] IMF, 'AI Preparedness Index (AIPI)', International Monetary Fund, 2025, https://www.imf.org/external/datamapper/AI_PI@AIPI.

These preexisting disparities give rise to two major risks. First, they reduce the ability of developing countries to adopt, adapt, and regulate AI technologies, increasing their vulnerability to technological dependence and marginalisation. Second, AI-driven automation threatens labour-intensive sectors such as textiles, electronics, and IT services, which form the backbone of many developing economies. As demand for offshore labour declines, traditional development models based on export-led growth and service outsourcing face growing disruption[36]. Most Global Southern countries also lack the fiscal and institutional capacity to manage job displacement or invest in large-scale reskilling. With high levels of informal employment and weak social protection systems, the spread of AI could worsen poverty[37]. Countries least prepared for AI are also the most exposed to climate change and food insecurity, compounding their vulnerability and deepening existing global inequalities[38].

Although AI holds considerable promise, its benefits are conditional. Without equitable access, inclusive design, and governance frameworks that ensure AI is socially just, environmentally sustainable, and contextually appropriate, it may reinforce existing global inequalities rather than alleviate them[39]. The following section turns to Appropriate Technology theory to examine why it is essential that technological solutions to development align with the specific needs, capacities, and contexts of the communities they are intended to serve.

2. Appropriate Technology: Origins and Modern Application

In discussions of technology for development, it is essential to consider not just whether technology is used, but which technology to use. Appropriate Technology (AT) theory challenges the assumption that technologies, especially those developed in the Global North, are universally applicable. Given differences

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[36] Cazzaniga et al., 'Gen-AI: Artificial Intelligence and the Future of Work'.
[37] Philip Schellekens and David Skilling. 'Three Reasons Why AI May Widen Global Inequality'. Center For Global Development, 2024. https://www.cgdev.org/blog/three-reasons-why-ai-may-widen-global-inequality.
[38] Ruma Bhargawa and Megha Bhargava. 'The Climate Crisis Disproportionately Hits the Poor. How Can We Protect Them?' World Economic Forum (blog), 13 January 2023. https://www.weforum.org/stories/2023/01/climate-crisis-poor-davos2023/.
[39] Ian Bremmer and Mustafa Suleyman, 'Building Blocks for AI Governance', *IMF* (blog), 2023, https://www.imf.org/en/Publications/fandd/issues/2023/12/POV-building-blocks-for-AI-governance-Bremmer-Suleyman; Lebdioui, Melguizo, and Muñoz, 'Artificial Intelligence, Biodiversity and Energy: From a Resource-Intensive to a Symbiotic Tech'; Sirimanne and Fu, 'Will AI Close or Widen the Development Gap?'

in infrastructure, resources, and institutional capacity, some technologies are poorly suited to the contexts of the Global South. When mismatched, they can hinder development and exacerbate inequalities. AT instead promotes context-appropriate solutions that are economically viable, socially inclusive, and environmentally sustainable. It prioritises local resource availability, skill levels, and cultural practices over universal scalability or technical complexity[40]. While initially framed as a moral critique of industrial capitalism, AT is increasingly viewed as a practical strategy for promoting inclusive and sustainable innovation, particularly as capabilities and demands in the Global South expand[41].

2.1 The Historical Rise and Fall of Appropriate Technology

The concept of AT emerged as a movement in the mid-20th century to criticise neoclassical economic models, which assume ideal conditions, such as full access to technology, perfect market pricing, and the absence of environmental or scale constraints, under which countries have infinite technological choice and would adopt technologies that align with their resource endowments. In theory, low-income countries would therefore adopt labour-intensive methods, while high-income countries would opt for capital-intensive systems[42]. However, many economists challenged these premises. For instance, Eckaus argued that the range of economically efficient technologies was limited, dominated by capital-intensive methods developed in high-wage economies, making them unsuitable for the needs of low-income countries[43]. Stewart highlighted the structural fixity between process and product technologies. Capital-intensive methods were often tied to proprietary production systems designed for affluent markets, limiting their adaptability and accessibility elsewhere[44]. The Sussex Manifesto expanded these critiques by identifying how scientific and technological investment was geographically concentrated in rich countries,

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[40] E. F. Schumacher, *Small Is Beautiful: A Study of Economics as If People Mattered* (London: Blond and Briggs, 1973); Frances Stewart, 'Macro-Policies for Appropriate Technology: An Introductory Classification', *International Labour Review* 122, no. 3 (May 1983): 279.
[41] Raphael Kaplinsky, 'Schumacher Meets Schumpeter: Appropriate Technology below the Radar', *Research Policy* 40, no. 2 (March 2011): 193–203, https://doi.org/10.1016/j.respol.2010.10.003.
[42] Kaplinsky, 'Schumacher Meets Schumpeter'.
[43] R. S. Eckaus, 'Appropriate Technology: The Movement Has Only A Few Clothes On', *Issues in Science and Technology* 3, no. 2 (1987): 62–71.
[44] Frances Stewart. 'Macro-Policies for Appropriate Technology: An Introductory Classification'. International Labour Review 122, no. 3 (May 1983): 279.

leading to institutional mismatches, brain drain, and underinvestment in domestic innovation systems in poorer nations[45].

It was within this intellectual milieu that the AT movement emerged, most prominently articulated by Schumacher, who criticised the prevailing industrial development model as an *"idolatry of gigantism"* that values growth and centralisation over human well-being and environmental sustainability. He proposed *"intermediate technology"* that bridges the gap between outdated tools and overly complex systems, making them more accessible, affordable, and locally relevant. Schumacher argued that technological progress is not inherently beneficial; its value depends on how well it aligns with local needs, values, and constraints. Technologies designed for affluent markets, if transferred uncritically to low-income contexts, can alienate workers, degrade the environment, and deepen inequality[46].

The AT movement gained traction in the 1970s, particularly among grassroots organisations, NGOs, and environmental groups. Despite its ethical appeal, however, AT struggled to achieve mainstream adoption. Kaplinsky argued that Schumacher's approach, rooted in moral critique rather than economic strategy, limited the integration of AT into national development policies. Three key constraints hindered its uptake: a lack of entrepreneurial capacity in low-income countries, weak innovation systems dominated by institutions from the Global North, and low effective demand, as poor consumers often could not afford AT products. Moreover, scientific and policy elites in the Global South sometimes viewed AT as backwards-looking, fearing it would lock their countries into low-productivity paths[47].

2.3 Contemporary AT Application and Technology Transfer

In the 21st century, AT has experienced a revival under new terms such as *"frugal innovation," "inclusive innovation,"* and *"pro-poor technology".* Emerging economies, such as China and India, have become major hubs for innovation, driven by low production costs, large domestic markets, and a pragmatic

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[45] H. W. Singer, Sussex Group, Institute of Development Studies, and United Nations Advisory Committee on the Application of Science and Technology to Development. The Sussex Manifesto: Science and Technology to Developing Countries during the Second Development Decade. IDS Reprints 101. Brighton: Institute of Development Studies at the University of Sussex, 1970.
[46] Schumacher, *Small Is Beautiful.*
[47] Kaplinsky, 'Schumacher Meets Schumpeter'.

orientation toward scalable, low-cost, and robust technologies[48]. This reflects a growing convergence between market-driven innovation and development-focused goals. Kaplinsky credited this change to several geographical and structural shifts. First, both state-led and private R&D efforts in the Global South have matured, reducing dependence on innovation from high-income countries. Second, infrastructural constraints and lower wage levels have spurred the development of labour-intensive, context-sensitive technologies. Third, consumer expectations in these markets, less shaped by stringent environmental or labour standards, allow for more flexible approaches to innovation[49]. Ruttan's theory of induced technical change helps explain this evolution. He identified market demand, relative factor prices, and firm-level learning trajectories as drivers for technical change. Historically, these forces produced capital-intensive technologies better suited to the Global North. Today, however, similar forces are driving innovation more relevant to low-income producers and consumers[50].

Yet, for many low-income countries, developing local innovations is often prohibitively costly and risky due to limited resources and capabilities. As technological capability building is cumulative and path-dependent, technology transfer offers a more practical route to innovation[51]. However, successful transfer depends not only on access but also on absorptive capacity—the ability to identify, assimilate, and apply external knowledge in ways that suit local needs[52]. The rise of innovations from other developing countries has eased the identification and acquisition of appropriate technologies, as these are often more affordable and better aligned with similar socio-economic conditions, enabling smoother diffusion[53]. Nonetheless, effective adoption requires robust institutional conditions, including open trade and investment policies,

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[48] Ming Zeng and Peter J. Williamson, *Dragons at Your Door: How Chinese Cost Innovation Is Disrupting Global Competition* (Boston, Mass: Harvard Business School Press, 2007).
[49] Kaplinsky, 'Schumacher Meets Schumpeter'.
[50] Vernon W. Ruttan. Technology, Growth, and Development: An Induced Innovation Perspective. New York; Oxford University Press, 2001.
[51] Xiaolan Fu, Carlo Pietrobelli, and Luc Soete, 'The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-Up', *World Development* 39, no. 7 (July 2011): 1204–12, https://doi.org/10.1016/j.worlddev.2010.05.009.
[52] Wesley M. Cohen and Daniel A. Levinthal, 'Innovation and Learning: The Two Faces of R & D', *The Economic Journal* 99, no. 397 (1989): 569–96, https://doi.org/10.2307/2233763.
[53] Fu, *Innovation under the Radar*.

sound legal frameworks, strong local-foreign linkages, and sustained investment in education and human capital[54].

The developmental value of technologies like AI thus depends not only on suitable technical features but also on the readiness of local ecosystems. In many developing countries, this means addressing critical gaps in digital infrastructure, education, regulation, and data sovereignty[55]. Appropriate AI cannot rely on assumptions that one model fits all. It must be intentionally designed, governed, and shared in ways that are not only technically effective but also socially inclusive and environmentally responsible. In this light, the emergence of DeepSeek, a Chinese AI model that claims high performance with lower energy and cost, raises important questions about whether such systems can serve as viable models of inclusive and appropriate AI for low-resource environments.

3. The Rise of DeepSeek: Appropriate AI from the Global South?

The introduction of DeepSeek, a Generative AI model developed in China, marks a significant turning point in global AI development. In contrast to earlier Chinese innovations that often lagged behind their Western competitors[56], DeepSeek achieves performance comparable to leading systems such as OpenAI's GPT-4, but at a fraction of the cost and resource demands. Developed in under two months for less than US$ 6 million, compared to GPT-4's estimated US$ 100 million, and operating on one-tenth the computational power[57], DeepSeek offers a compelling model of cost-efficiency and energy-conscious design. These characteristics make it particularly appealing for countries in the Global South, where high costs and limited infrastructure have traditionally inhibited AI adoption[58].

A defining feature of DeepSeek is its open-source architecture. By making its model architecture

[54] Fu et al.,'The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies'.
[55] Schellekens and Skilling, 'Three Reasons Why AI May Widen Global Inequality'.
[56] Alex He, 'DeepSeek and China's AI Innovation in US-China Tech Competition', *Centre for International Governance Innovation*, 2025, https://www.cigionline.org/articles/deepseek-and-chinas-ai-innovation-in-us-china-tech-competition/.
[57] Reuters, 'DeepSeek's Low-Cost AI Spotlights Billions Spent by US Tech', 2025, https://www.reuters.com/technology/artificial-intelligence/big-tech-faces-heat-chinas-deepseek-sows-doubts-billion-dollar-spending-2025-01-27/.
[58] Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1'.

and training methods publicly available, DeepSeek lowers entry barriers for small firms, academic institutions, and governments[59]. This enables greater innovation from developing countries, as users can adapt the model to local needs, for example, in personalised finance, fraud detection, or education[60]. In contrast to proprietary models like OpenAI's, which restrict access and modification, DeepSeek can be deployed and fine-tuned on relatively modest hardware, making it more accessible in low-resource settings[61]. Beyond accessibility, DeepSeek also introduces architectural innovations such as multi-head latent attention and mixture-of-experts design, enhancing performance without incurring high computational costs. Its recent iterations reportedly outperform Meta's LLaMA 3.1 and match the capabilities of GPT-4 and Claude 3.5[62]. These developments challenge the prevailing notion that cutting-edge AI must be expensive and capital-intensive.

According to Kaplinsky, AT can originate from four sources: adapting underused existing technologies, upgrading traditional techniques (*upscaling*), simplifying advanced systems for low-resource contexts (*downscaling*), or designing entirely new solutions for specific needs[63]. DeepSeek combines both upscaling and downscaling by refining existing generative AI models to improve efficiency while reducing costs. This approach challenges the dominant *"bigger is better"* paradigm in Silicon Valley[64] and echoes Schumacher's notion that *"small is beautiful,"* but does so without sacrificing technological advancement.

While DeepSeek offers a promising model for developing countries to follow, it is important to recognise that China is a sui generis case with its own unique innovation ecosystem that cannot be easily replicated elsewhere. Its innovation capacity far exceeds that of most Global South nations. Unlike the decentralised, market-driven model of the West, China's AI strategy is state-led, backed by substantial

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[59] Krause, 'DeepSeek and FinTech'.
[60] Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1'.
[61] Costa et al., 'The Democratization of Artificial Intelligence'.
[62] Bertin Martens, 'How DeepSeek Has Changed Artificial Intelligence and What It Means for Europe', *Bruegel*, Policy Brief, 2025, https://www.bruegel.org/sites/default/files/2025-03/PB%2012%202025.pdf.
[63] Raphael Kaplinsky, *The Economies of Small: Appropriate Technology in a Changing World*. London: IT Publications in association with Appropriate Technology International, 1990.
[64] Krause, 'DeepSeek and FinTech'.

public investment in R&D, supercomputing infrastructure, and national laboratories[65]. In 2022 alone, China allocated over US$12 billion to AI development[66]. The country also benefits from weaker data privacy regulations, which allow extensive data access, facilitating rapid model training[67]. While these advantages have enabled progress in sectors such as autonomous vehicles, healthcare, and public surveillance, they also raise ethical concerns. China's record on data security, state surveillance, and digital authoritarianism, exemplified by China's social credit system and predictive policing, complicates the global legitimacy of Chinese AI technology[68]. These concerns are intensified by ongoing US-China tensions, which may limit the international reach of models like DeepSeek[69].

Despite its limitations, DeepSeek's affordability and accessibility offer developing countries a chance to participate in AI innovation on more equitable terms. With appropriate safeguards, it could serve as a model for low-cost, inclusive AI development. However, its openness also poses risks. Without strong governance frameworks, open-source AI can be misused for surveillance or discrimination. To fully benefit from DeepSeek, developing countries must first address key prerequisites, including infrastructure, skills, and regulatory capacity. Realising its potential, therefore, requires coordinated efforts across different levels, a challenge discussed in the next section.

4. Towards Appropriate AI: Constraints and Considerations

The emergence of open-source, cost-effective, and energy-efficient models such as DeepSeek highlights the potential for AI to become more accessible and inclusive for developing countries. However, realising the promise of AI as Appropriate Technology for the Global South requires confronting two major challenges: persistent structural inequalities and the intensifying Sino-US geopolitical tensions.

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[65] Ding, 'Deciphering China's AI Dream: The Context, Components, Capabilities, and Consequences of China's Strategy to Lead the World in AI'.
[66] Chris Miller, *Chip War: The Fight for the World's Most Critical Technology* (London: Simon & Schuster, 2022).
[67] Rogier Creemers, 'China's Social Credit System: An Evolving Practice of Control', SSRN Scholarly Paper (Rochester, NY, 9 May 2018), https://doi.org/10.2139/ssrn.3175792.
[68] Steven Feldstein, 'The Global Expansion of AI Surveillance' (Carnegie Endowment for International Peace, 2019), https://carnegie-production-assets.s3.amazonaws.com/static/files/files__WP-Feldstein-AISurveillance_final1.pdf.
[69] Reuters, 'DeepSeek's Low-Cost AI Spotlights Billions Spent by US Tech'.

While the widespread AI adoption can improve productivity and deliver macroeconomic benefits, if adoption remains concentrated in a few high-tech industries, structural frictions may undermine these gains, leading to lower overall growth and greater inequality, a pattern described as *"Baumol's growth disease*[70]*."* Bridging the digital divide is therefore essential to ensuring inclusive outcomes. As discussed in Section 1, many developing countries face significant gaps in digital infrastructure, human capital, innovation capacity, and regulatory frameworks. These gaps limit their ability to adopt, adapt, and govern AI effectively. Although models like DeepSeek reduce technical and financial barriers and offer more adaptable AI tools for developing contexts, technical diffusion alone is not enough. Their effective use depends on local absorptive capacity. Building this capacity requires coordinated national policy. First, investments in digital infrastructure and reliable electricity are essential. Without them, with policies prioritising affordability, reliability, and inclusivity. India's *"Digital India"* initiative, which connected over 600,000 villages to high-speed broadband[71], and Kenya's investment in geothermal energy, now supplying over 40% of its electricity[72], illustrate how strategic infrastructure development can support digital transformation.

Second, education and skills development are vital. Expanding STEM education, vocational training, and AI literacy can equip workforces for emerging industries. Vietnam's integration of AI into the national education strategy reflects proactive planning for future labour market[73]. Preparing for job displacement is equally important. Programmes like Singapore's *"SkillsFuture"* demonstrate how governments can support reskilling and ensure inclusive transitions[74]. Fostering local innovation is equally

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[70] Francesco Filippucci, Peter Gal, and Matthias Schief. 'Miracle or Myth? Assessing the Macroeconomic Productivity Gains from Artificial Intelligence'. OECD Artificial Intelligence Papers. 29th ed. OECD Artificial Intelligence Papers, 22 November 2024. https://doi.org/10.1787/b524a072-en.
[71] Klaus Schwab, 'Entering the Intelligent Age without a Digital Divide', *World Economic Forum* (blog), 25 September 2024, https://www.weforum.org/stories/2024/09/intelligent-age-ai-edison-alliance-digital-divide/.
[72] Lisa Dutiro, 'The Rise of Alternative Energy in Africa: Geothermal Power Generation', *DLA Piper Africa*, 17 November 2019, https://www.dlapiperafrica.com/en/africa-wide/insights/africa-connected/issue-03/the-rise-of-alternative-energy-sources-in-africa.html.
[73] Bénédicte Rispal, 'Vietnam, National Strategy on Research and Development and Application of AI (2021-2030)', *OECD* (blog), 2021, https://oecd.ai/en/wonk/documents/vietnam-national-strategy-on-rd-and-application-of-ai-2021-2030.
[74] Soon-Joo Gog, Edwin Tan, and Kelsie Tan, 'Future-Skilling the Workforce: SkillsFuture Movement in Singapore', in *Creating the University of the Future: A Global View on Future Skills and Future Higher Education*, ed. Ulf-Daniel

important. Homegrown AI applications tailored to regional challenges are often more effective than imported technologies. Rwanda's grassroots programmes in coding and AI training highlight the importance of inclusive innovation ecosystems[75]. Finally, international collaboration remains important. Partnerships with advanced economies and participation in frameworks like the *"Global Digital Compact"* can support knowledge exchange and promote inclusive global AI governance[76].

Escalating geopolitical tensions pose significant risks to the inclusive development of AI. The technology has become a strategic domain shaping global military power, digital governance, and industrial competitiveness. Technological decoupling, illustrated by US export controls and China's pursuit of self-sufficiency, threatens to fragment the global AI landscape. The development of DeepSeek amid US sanctions reflects China's growing technological autonomy, but also raises concerns over its use in surveillance, data extraction, and authoritarian governance.

The US and China represent two distinct models of AI development. China's approach is state-led, coordinated through national strategies aimed at achieving global AI leadership by 2030[77]. State-backed firms such as Huawei, Baidu, Alibaba, and Tencent work closely with the government, benefiting from vast datasets and regulatory support. AI is deployed in areas such as predictive policing, social credit systems, and military modernisation [78]. In contrast, the US model is decentralised and market-driven, with firms like Google, Microsoft, and OpenAI leading innovation. Nevertheless, it increasingly supports military applications, as seen in federal initiatives such as the National Artificial Intelligence Initiative Act[79] and the Joint Artificial Intelligence Centre[80]. This strategic competition has security implications. Data centres,

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Ehlers and Laura Eigbrecht (Wiesbaden: Springer Fachmedien, 2024), 515–28, https://doi.org/10.1007/978-3-658-42948-5_26.

[75] MINICT, 'MINICT Launches the Second Edition of Coding Bootcamp', Ministry of ICT and Innovation, Rwanda, 31 January 2025, https://www.minict.gov.rw/news-detail/minict-launches-the-second-edition-of-coding-bootcamp.

[76] UN, 'Global Digital Compact', 2025, https://www.un.org/global-digital-compact/en.

[77] Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1'.

[78] Ding, 'Deciphering China's AI Dream'.

[79] National Artificial Intelligence Initiative Act of 2020, H.R.6216, 116th Congress (2020), https://www.congress.gov/bill/116th-congress/house-bill/6216

[80] Terri Moon Cronk, 'Joint Artificial Intelligence Center Has Substantially Grown to Aid The Warfighter', 18 November 2020, https://www.defense.gov/News/News-Stories/Article/Article/2418970/joint-artificial-intelligence-center-has-substantially-grown-to-aid-the-warfigh/

which power AI models, have become targets for cyber threats and espionage[81]. Rising calls for "sovereign AI" and data localisation reflect growing concerns about national resilience, often at the expense of economic efficiency[82].

In the absence of robust global regulatory frameworks, these dynamics risk diverting AI development away from global public goods and toward narrow national interests. Without shared standards for transparency, accountability, and ethical use, AI could deepen surveillance practices, algorithmic discrimination, and environmental harm from energy-intensive training. There is an urgent need for international governance to ensure AI contributes to inclusive and ethical development. Such frameworks should establish global ethical standards, regulate AI applications in defence and cybersecurity, and enhance accessibility for developing countries. Institutions like the UN must lead efforts to promote principles of data sovereignty, algorithmic fairness, and equitable access.

Governance must extend beyond improving access to shaping institutional norms, preventing misuse, and aligning innovation with public interest goals, such as healthcare, education, and climate resilience. Appropriate AI cannot be achieved through design or deployment alone. It requires rethinking institutional incentives, addressing geopolitical asymmetries, and ensuring that the benefits of AI are equitably distributed. Only through coordinated national and international action can AI be governed as a global public good that advances sustainable and inclusive development.

5. Conclusion

The development of DeepSeek signals a shift in the global AI landscape. As a low-cost, energy-efficient, and open-source alternative to proprietary models, it challenges the belief that cutting-edge AI must be high-cost and resource-intensive. Interpreted through the lens of AT, DeepSeek reflects core

[81] Jared Cohen, 'The Next AI Debate Is About Geopolitics', *Foreign Policy* (blog), 27 May 2025, https://foreignpolicy.com/2024/10/28/ai-geopolitics-data-center-buildout-infrastructure/.
[82] Helena Vieira, 'The Global Pursuit of Sovereign AI Is Becoming the 21st Century's Arms Race', *LSE Business Review - Social Sciences for Business, Markets, and Enterprises* (blog), 27 January 2025, https://blogs.lse.ac.uk/businessreview/2025/01/27/the-global-pursuit-of-sovereign-ai-is-becoming-the-21st-centurys-arms-race/.

principles of accessibility, contextual relevance, and scalability, demonstrating that *"appropriate"* does not mean low-tech or less capable, but rather fit-for-purpose[83].

This matters because the benefits and harms of AI are unevenly distributed. While AI holds promise for advancing health, education, and climate resilience, it also risks deepening inequality and environmental harm, especially in countries lacking digital infrastructure, institutional capacity, or skilled labour[84]. DeepSeek offers a potential model for democratising access to AI, but its success in the Global South depends on national absorptive capacity, the ability to adopt, adapt, and govern technology effectively[85]. Yet, structural barriers and intensifying geopolitical rivalry, particularly between the US and China, threaten to fragment global AI development. While China's state-led ecosystem enabled DeepSeek, concerns over data privacy, surveillance, and digital authoritarianism may limit its legitimacy abroad[86].

Achieving the potential of Appropriate AI requires coordinated action. Developing countries must invest in infrastructure, digital skills, and regulation. Internationally, shared principles for ethical and inclusive AI governance are essential. DeepSeek showcases the potential of AI that is relevant, affordable, and tailored to the needs of developing countries. The future of AI hinges on political decisions regarding equity, access, and global solidarity. For AI to support sustainable and inclusive development, it must be treated as a public good: designed with local contexts in mind, governed transparently, and made available to all.

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[83] Kaplinsky, *The Economies of Small: Appropriate Technology in a Changing World*.
[84] Mannuru et al., 'Artificial Intelligence in Developing Countries'.
[85] Cohen and Levinthal, 'Innovation and Learning'; Filippucci et al., 'Miracle or Myth?'
[86] He, 'DeepSeek and China's AI Innovation in US-China Tech Competition'; Mhlanga, 'AI War Between China and America and the Rise of DeepSeek-R1'.