

Innovation, Appropriate Technologies and Entrepreneurship for Global Sustainability Development: A Review Until the Early Twenty-first Century

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journals.sagepub.com/home/joe**Philippe Régnier¹**

Abstract

Appropriate technology and development have been disseminated globally as a concept and practice under various terminologies such as adaptive technology, accessible and cheap technology, community technology, low-cost technology, intermediary technology, and so on, especially for grassroots community development. Originating from Gandhi's anti-colonial campaigns and further expanded by Schumacher's ideas, the concept gained momentum with the rise of emerging economies such as Brazil, China, India and South Africa. These countries embraced appropriate technology, offering affordable, user-friendly solutions that matched local needs and resources, contrasting with capital-intensive methods. The digital revolution in the twenty-first century further diversified appropriate technology, permitting the widespread adoption of affordable and sustainable solutions across sectors and nations. This study also explores how emerging economies transitioned from being viewed as low-tech suppliers to becoming

¹University of Applied Sciences Western Switzerland (HES-SO), Delémont, Switzerland

Corresponding author:

Philippe Régnier, Full Professor, University of Applied Sciences Western Switzerland (HES-SO), Delémont, Switzerland.

E-mail: philippe.regnier@hefr.ch

innovators in high-tech spheres. These emerging economies have developed localised research and development centres, embraced open science and technology collaboration and engaged in reverse technology entrepreneurship by adapting and exporting technology-driven products to developing and developed countries. Furthermore, frugal innovation arises as a response to pressing sustainability challenges. It encourages simple, environmentally friendly designs that promote longevity and efficient resource practice. From its very beginnings and even more today, innovation in appropriate/frugal technologies has continued to make clear contributions to various forms of entrepreneurship for sustainable development. The study concludes that proper technology and frugal innovation are becoming global norms, endorsed by G7, G20 and United Nations member states, as they address economic and sustainable development goals, ultimately benefitting a broader spectrum of societies globally.

Keywords

Entrepreneurship, innovation, appropriate technology, sustainable development

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Introduction

Appropriate technology and development have been disseminated worldwide as a concept and practice since the 1970s–1980s, under various terminologies such as adaptive technology, accessible and cheap technology, community technology, low-cost technology, intermediary technology, etc., especially for grassroots community development. It has been originally inspired by India since the anti-colonial campaigns led by Gandhi, and down the road up to Prahalad and his 2005 famous book and slogan *The Fortune at the Bottom of the Pyramid*.

Since the late twentieth century, a rapid expansion of innovation and entrepreneurship capacities has taken place worldwide, including in developing and especially in so-called emerging countries. This phenomenon has been observed both in the formal and also the informal economy. Appropriate technology is generally viewed as accessible, affordable and user-friendly technology. It matches local community environments and

sustainable development needs, in particular where highly skilled human resources, technical and financial resources are limited or scarce. It contrasts with capital-intensive technology and high-tech investment and transfer strategies led so far by industrialised countries.

This introductory article provides to the reader a historical and analytical review of the origins and evolution of appropriate technology as a key concept initiated from the mid-twentieth century onwards. By the turn of the twenty-first century, both concept and practice of appropriate technology innovation and entrepreneurship have diversified further through wide digitalisation processes both in manufacturing and services. This diversification continues to evolve rapidly and tends to respond more and more to urgent calls for sustainable development and frugal growth aiming at a reconciliation of economic, societal and environmental objectives.

First, the article revisits the notion of 'Technology for the People' introduced by Gandhi and further expanded by Schumacher and his followers since the early 1970s. It led among other developments worldwide to the creation of the Development Lab at the Massachusetts Institute of Technology, still active globally today.

Secondly, it shows how wide applications of the appropriate technology concept has flourished further since the end of the twentieth century due to the rapid production and export-oriented rise of the so-called emerging economies such as Brazil, China, India, Mexico, South Africa and some other G20 member states. In addition, some large emerging countries, both geographically and demographically, gave inspiration to leading academia and private sector multinational firms to look into new business models and new marketing and technology tools to reach the so-called bottom of the social pyramid. At this bottom, stand large segments of populations categorised as low social classes and poor strata of domestic societies.

Thirdly, the very concept of appropriate technology has been renovated further with the coming of the digital revolution since the turn of the twenty-first century. This revolution implies a wide spectrum of applications both in manufacturing and services, which continue to expand globally and in all sectors.

Fourthly, innovations in appropriate/frugal technology and entrepreneurship also contribute to sustainable development in various directions to meet global challenges of the twenty-first century. Such innovations seem to go more and more transnational and bidirectional between industrialised countries and emerging economies.

From Gandhi to Prahalad, Twentieth–Twenty-first Centuries

Appropriate technology and its linkages with the very notion of international development are a global concept, which has not faded over time since its early and differentiated applications.

The promotion of appropriate technologies has been disseminated worldwide through various terminologies such as adaptive technology, community tech (Bakardjieva & Feenberg, 2002), indigenous tech (Sharma et al., 2009), low-cost tech (Viani et al., 2017), intermediary tech (Rahman et al., 2021) and various other definitions such as accessible technology and cheap technology, for example.

Yet, both the concept and implementation of appropriate technology are originally due to Gandhi's decolonisation struggles and anti-British textile industry domination. It was globally amplified since the late 1960s by Schumacher famous book *Small Is Beautiful: Economics as if People Mattered* (Schumacher, 1973). This book was based on Schumacher's local advisory experience in Burma and South/South-east Asia. For instance, in India, Schumacher was struck by the destructive effects of modern technology introduced by the United Kingdom on Indian traditional life modes. In his report to the Indian Planning Commission in 1962, he wrote:

It requires no lengthy argument to agree that India is 'long' in labor and 'short' in capital. It means that she requires a level of technology... that is likely to be very different from the current in the Western countries, which are 'long' in capital and 'short in labor...In short in India as well in other developing countries, the most primitive exists side by side with the most advanced...an artisan employing five rupees worth of tools, and workers minding machines worth fifty thousand rupees. (Mountjoy, 1971, p. 226)

Schumacher describes intermediary technology in his 1973 book as cheap enough to be accessible to local communities and to be applied on a mass scale without making excessive demands on the limited resources of a country. Appropriate technology is presented as combining smallness, simplicity and capital cheapness. Schumacher criticises the inability of most development aid projects to find appropriate solutions to key problems prevailing in developing countries such as poverty, vulnerability and lack of employment opportunities, especially in prevailing rural areas. In 1974, Schumacher further contributed and published on so-called Buddhist economics, which has inspired various Buddhist scholars

(such as in Thailand, for instance) interested in frugal economics and sustainable development till date. He underlined how developing countries were pressured by capital-intensive technologies imported from industrial countries, causing major sustainable development problems. In this context, appropriate technologies were presented as combining various advantages such as accessibility, frugality, simplicity and low-cost.

Until the late 1970s, appropriate technologies were applied by various organisations, including leading OECD development aid agencies, targeting the energy and environment sectors in developing countries. By 1980, there were about 1,000 international agencies, public departments and NGOs involved (Kaplinsky, 2011; Smith et al., 2014).

In the West and particularly the United States, some research and development (R&D) institutions were born downstream the first oil crisis, such as the National Center for Appropriate Technology, which focused on agriculture and sustainability. The Program for Appropriate Technology in Health (PATH) is another NGO active in appropriate technology areas such as diagnostics, drugs, vaccines, health care systems and services. Critics of appropriate technologies targeted the fear of keeping developing countries locked in low productivity and inefficient production activities if not charity. However, strong demonstrations of appropriate technology benefits led to the creation of the development lab at the prestigious Massachusetts Institute of Technology in Boston–Cambridge in 2002 with the core objective of fighting global poverty.

Genuine suggestions for appropriate technology innovation and entrepreneurship capacities at the lowest social strata of local societies have been re-formulated by Prahalad's world famous slogan and publication *The Fortune at the Bottom of the Pyramid* (2005), which did not target developing countries only, but also socio-economic initiatives from 'below' in developed economies as well. From his double affiliation at the University of Michigan Business School and the Indian Institute of Management, Ahmedabad, Prahalad underlines that poverty below USD 1 to 2 per day among billions of people cannot be addressed by classical development aid, but by new business and technology models aggregating micro-consumption capacities of densely populated low strata of societies both in developing and developed economies. In other words, the mass addition of micro-scale sales can raise big volumes of profits if private firms and public agencies can reach the bottom of the social pyramid. In India, for instance, over 400 million poor people can progressively access basic medicaments in both rural and urban areas through the introduction of mobile phones and light modes of medicine delivery able to reach remote areas.

Recent Contributions from Emerging Economies

Since the turn of the twenty-first century, the concept of appropriate technology has evolved and become multidirectional. In some cases, it corresponds to simple know-how to solve local problems (D-Lab, 2021a), and in some other cases to adequate engineering and entrepreneurial solutions addressing environmental and other societal issues (D-Lab, 2021b). This evolution mainly follows a rapid transformation of conceptual terminology and practice influenced by the rise of emerging economies since the 1990s.

Intermediary technologies have been and are still strongly promoted by G20 emerging economies such as Brazil, China, India, Mexico and South Africa primarily to feed their own domestic development according to less costly, more accessible and more employment intensive processes than technology transfers from OECD countries through foreign export inflows, foreign direct investment inflows and development aid programmes (Foster, 1999; Thwala, 2008).

In their turn, emerging economies have started to export such technologies and know-how for the benefit of other developing countries and even LDCs. As a consequence, the terminology of appropriate technology has been often replaced by more meaningful definitions such as alternate or adaptive tech, capital-saving tech, light engineering tech, labour-intensive tech, intermediary tech, bottom-up tech or even grass-roots or simplified innovation, to name a few (Agnilhotri, 2015; Prahalad & Hart, 1999, 2000; Utz & Dahlman, 2007).

Recent economic take off and industrialisation of emerging economies have led to a new distinction between hard and soft technologies developed with limited external collaboration, such as hardware in the case of China, and software in India. Based on rapid scientific and technological development especially in these two giant emerging countries, the concept of 'reverse technology' has even spread worldwide (Agnilhotri, 2015). It refers to cheap or simplified technology able to sell everywhere, including to OECD countries, due to a strong attractiveness among end consumers, whether companies or households and meeting low social class needs in particular. For instance, India and South Africa have become world pharma export leaders of low-cost generic drugs to both developing and OECD countries. Such a performance has enabled these two emerging economies to position themselves gradually in medical biotechnology. Other examples can be identified such as the low-cost Nano car produced by *Tata Motors* in India, or the world's cheapest USD 15 mobile phone *Nokia 1100* selling more than one million units per week during the years 2007–2010.

It seems that the variety of science and technology disruptive innovations and developments in emerging economies tend nowadays to address some socio-economic and even sustainable development objectives on all continents. OECD countries are not any more systematically well positioned to counterbalance this evolution by supplying their exclusive high cutting-edge technologies and services, which are not always adapted to solve fundamental problems in the emerging and developing world (Patnaik & Bhowmick, 2019).

Emerging Countries as Cheap Technology Providers

Like the early and so-called four Asian dragons (or tigers) during the 1970s–1980s (Hong Kong, Singapore, South Korea and Taiwan), the second generation of emerging economies has been commonly identified as cheap and labour-intensive producers of consumer goods, such as China since its early 1980s economic reforms, followed by India since her own reforms initiated since the early 1990s. Other emerging countries have also followed a similar but more modest path such as Brazil, Malaysia, Mexico, Nigeria, South Africa, Thailand and Turkey.

Such cheap products and/or services from emerging economies have often displaced home-made traditional, if not appropriate, technology and local community know-how in least developing countries, mostly in Africa, where a number of countries have remained major suppliers of commodities (agro-food, energy and minerals) in high demand, especially by Asian fast growing emerging economies.

In recent years, the cheap technology image of leading emerging economies, China in particular, has started to fade somewhat, due to their inroads in intermediary and even high-level technologies. Such evolution has also resulted from the rise of production costs (including salaries) and price inflation, especially in countries such as China, India, Turkey and some others.

Emerging Countries as Appropriate/Intermediary Technology Providers

Since the late 1990s onwards, emerging countries cannot be reduced any more to cheap and low-tech suppliers. They have also become innovation

providers to meet specific needs of various socio-economic segments of the population both domestically and in developing countries. This is particularly true for China but also for India. The 23 top-ranking Indian Institutes of Technology (IITs) for example have been assigned by federal directives since the 1950s onwards of a double mission: (i) to compete globally with similar OECD institutions, (ii) and also to address poverty alleviation and grassroots community development problems locally. This has been amplified in very recent years as IITs and other Indian leading academic institutions are allowed to receive direct funding from both domestic firms and foreign multinational affiliates on behalf of their compulsory 2% corporate social responsibility contributions imposed by the Indian federal authorities.

In addition, some leading emerging economies such as Brazil, China, India and South Africa have diversified into production—with appropriate/limited resources—of more capital—intensive products and even infrastructure equipment able to meet both domestic and external needs in the developing world at large. The new Chinese Silk Road strategy is a good illustration of such an evolution.

Since the turn of the century, emerging countries have also started to explore new innovation development frontiers to reach the so-called bottom of the social pyramid populated by 3 to 4 billion people worldwide living with less than USD 2 per day. As mentioned earlier in this article, this concept has been circulated worldwide by US/Indian Professor Prahalad and his famous book *The Fortune at the Bottom of the Pyramid* (2005). The objective is to create bottom-up innovative business models and technologies to serve the lowest strata of society. This type of strategy is designated in India by the concept of Jugaad, and in China by the concept of Zizhu Changxin (Radjou et al., 2012; Régnier et al., 2022). For instance, Indian domestic and foreign firms active in cosmetics or pharmaceuticals have started to explore how to distribute tiny supplies in distant rural areas with the combined support of mobile phones and light delivery transportation systems. Some other experiments promote for instance open access to technology and know-how, often combined with meso- or microcredit facilities, for enabling petty entrepreneurship to blossom with the support of accessible co-working and computer training centres locally.

This bottom-of-the-pyramid marketing approach in highly densely populated emerging economies such as Brazil, China, India, Indonesia, Nigeria or even entire continents such as Africa, is getting rising attention among OECD multinational firms. These corporations are increasingly exploring new business opportunities and potential markets considering

the saturation or slow growth of ageing OECD economies. For instance, in the pharmaceutical sector, most rural households cannot afford to buy a full box of medication in case of family illness but most of the time just a few pills. Similarly, young women cannot purchase full packs but only very tiny samples of cosmetics advertised on television. Therefore, foreign multinationals specialised in cosmetics or medicaments still have to team with large local corporations in emerging economies to be able to join complex value chains and to reach hundreds of millions of 'new' consumers at the bottom of the social pyramid. Such global-local corporate alliances are frequently operationalised through so-called global cities (about 120 ranked as such worldwide) like Hong Kong, Shanghai and Shenzhen in China; Delhi, Chennai and Mumbai in India; Mexico and San Paolo in Latin America; or Cairo, Casablanca and Johannesburg in Africa. Such global cities play key communication, business and applied research intermediation functions globally, regionally and sub-regionally on all continents.

Emerging Countries as Reverse Technology Providers

Emerging countries have also moved into simplified technology and the use of expired licences and intellectual property rights to supply equipment and consumer goods domestically, and also both in developing and developed economies. As already mentioned, India and South Africa have become world leaders in exports of generic medicines. China, India and some others have adopted strategies to provide cheap access to computers, laptops and mobile telephones. Some foreign multinational firms have started to realise a need to team with local firms to benefit from such new business opportunities, especially in densely populated emerging countries.

This trend is called as reverse technology entrepreneurship because it is not orchestrated as perceived by corporate headquarters but localised in developed economies. However, such projects may be successful or not. For instance, the Indian low-priced Nano car inspired as a simplified automotive by *Tata Motors* together with *Fiat* has not performed well despite its low price. It should have quite easily found a potential market, but it did not materialise significantly as the Nano was probably not attractive and secure enough for the Indian public. Recent moves by Chinese automotive corporations to promote and export small electrical

cars may become more successful both domestically and overseas. This development seems to worry European and North American automotive competitors in particular.

Such developments of reverse technologies by emerging economies have also started to produce unexpected and interesting spillover effects in OECD markets. For example, cheap computers and laptops exported by China can also reach various segments of low social strata and even middle classes in North America and Europe (The *Lenovo* laptop brand is not so cheap in Europe anymore). Indian and South African generic medicines can also reach 40 to 60 Million US citizens, who lack health insurance coverage, and other OECD publics, including insurance companies aiming to pay less for health treatments in case the corresponding generic medicines exist. In recent years, as mentioned above, Chinese electrical cars are expected to sell more and more in Europe because of their 20% to 30% lower pricing as compared with their European or Japanese competitors.

The reverse technology trend can also be initiated by industrialised economies vis-à-vis emerging ones. For instance, the US company *General Electric* has redesigned a portable electrocardiographic technology for the Indian market by using low-cost and localised inputs and fewer materials for a final price reduced from USD 10,000 in the United States to only USD 1,000 in India! But the story does not stop there, as these Indian simplified electrographic machines are also now sold in the United States (Pansera, 2013). This is also true for the Swiss multinational firm *Sulzer*, which has completely redesigned its agro-sector machines and tools during the last 10 years to meet the Indian market specifically, and efficiently reach other emerging countries in Asia and elsewhere accordingly.

Emerging Countries as New Appropriate High-tech Providers

Since the turn of the century, emerging countries have also started to innovate in high-tech spheres, China and India being in the lead. Some of these moves aim at competing with OECD economies, while some others illustrate the various transformations of the very concept of appropriate technology.

In leading emerging countries, a first evolution can be observed in the recent localisation of R&D centres by OECD multinational firms, and

even by some high-tech enterprises. Their objective is to develop their market presence locally and regionally with maximum proximity to existing and potential clients. This goal means to be able to supply adapted or even new products and services corresponding to local ecosystems and needs, which differ largely from those prevailing in developed countries. The investment in such R&D centres includes maintenance and repairing facilities, also closer geographically to end clients and more rapid in terms of delivery time.

A second evolution is linked to open science and technology sourced from developed countries. Such linkages foster new entrepreneurship capacities and innovations in emerging economies. More than once, conceptual science and technology applied research is conducted in OECD countries, but prototype testing, incubation and start-up creation are realised in emerging economies or through bilateral partnerships. The rapid rise of transnational academic, R&D and ICT distant collaborations in hard sciences and engineering are also new and lead to recent types of contributions. Highly talented students and young professionals develop new design thinking concepts and commercially oriented valorisation projects without the preoccupation of physical borders, rules and regulations among developed and emerging nations. Leading universities and engineering schools promote various types of mobility and partnership collaborations between West and East, especially in Asia, to foster innovation, prototyping, business incubation among students, instructors and external public-private supportive services. So-called globally born start-ups flourish downstream due to such processes, and serve various developed and emerging markets since inception or within a few years after their creation. This can be clearly observed between Asia and North America and between Asia and Europe (Falahat et al., 2018).

A third evolution consists of a rising number of mergers and acquisitions initiated by multinational corporations from emerging economies. This phenomenon is not new as it was already initiated by a significant number of M&As led by South Korean and Taiwanese firms in the 1980s and 1990s. It has been amplified by giant emerging economies, China and India in particular. The Chinese acquisition of the Swiss multinational firm *Syngenta*, with headquarters in Basel, as the largest acquisition in Europe so far by an emerging nation, shows how and how far a leading emerging actor such as China aims to control and redirect fertilisers and other chemicals for agriculture to promote easier access and sustainability development of the agro-food sector so vital to both domestic China and the developing South.

Global Moves into Appropriate/Frugal Innovation for Sustainable Development

As the twenty-first global society faces major sustainable development challenges, a rising number of industrialists and scientists tend to innovate by (re)-designing products and services through revisited business models in order to lower the use of natural and other resources and to produce in more affordable and applicable conditions for consumers (Albert, 2019; Woolridge, 2010). As noted earlier, generic medicines sell well not only in emerging and developing countries but also in OECD countries, and this type of market tends to contribute not only to the mobilisation of financial resources among local populations but also to decreased financial pressure on national health policies and systems (Keisler-Starkey & Bunch, 2021). In the example of low-cost production and sales of laptop and notebook computers, especially in China and India, but also elsewhere in developing countries, it enables pupils and students from modest family backgrounds to access education through distant learning tools.

Frugal innovation and engineering, as demonstrated in another article in this special issue, are not any more purely focused on economic and social objectives. It also aims at sustainable development reducing over-consumption and facilitating recycling processes instead of sourcing additional commodities and inputs. Frugal products are expected to reach extended life cycles through modularity and easy maintenance and repair, with reduced carbon footprint and use of limited resources. As Schumacher argued in 1973, when a greener future was not yet part of a global agenda, frugal innovation does not only target poverty reduction but a more simple, healthier and environmentally friendly mode of living, as Buddhist economics have already suggested for long. Schumacher himself wrote in 1973, 'Small-scale operations, no matter how numerous, are always less likely to be harmful to the natural environment than large-scale ones, simply because their individual force is small in relation to the recuperative forces of nature' (Schumacher, 1973, p. 31).

Conclusion

The concept and practice of appropriate technology have made substantial grassroot level contributions to various forms of sustainable entrepreneurship and development since their early inceptions initiated by Gandhi and Nehru in India during the 1940s–1950s.

Conceptually, the appropriate technology proposal was further echoed in the 1970s–1980s and again in the early twenty-first century by worldwide famous publications by Schumacher (1973) and Prahalad (2005), respectively. It was much amplified in academic circles both in industrial and developing countries ever since, ranging from IITs up to the Massachusetts Institute of Technology Development Lab (D-Lab, MIT) in collaboration with the US development aid agency and over 40 developing nations. In recent years, new contributions frequently labelled as frugal engineering and technology have inaugurated a wide global movement to address the pressing challenges of sustainable development.

In practice, innovation and appropriate technologies have led during the first phase (1950s–1970s) to various forms of local and community-oriented entrepreneurship initiatives in India and other decolonised countries, including sustainable development dimensions long before the very concept of sustainable development was properly introduced. With much labour and little capital in every sense of the term, development solutions were implemented to try to meet local basic needs and reduce community vulnerabilities. In the second phase (1980s–1990s), newly and so-called emerging countries, with China and India in the forefront followed by other G20 member states, have started to produce low-cost and intermediary tech products reaching simultaneously their vast domestic markets, other emerging and developing countries and even developed ones. Cheap/simplified notebooks, laptops, mobile phones or generic medicines in the pharma sector are good examples. In the third phase since the turn of the century, the digital revolution has enabled both industrial and emerging countries to disseminate accessible/appropriate/low-cost/simplified products and services in order not only traditional middle-class publics, but also the bottom of the social pyramid densely populated in the developing and emerging world in particular.

Looking at the mid-twenty-first-century horizon, appropriate technology or its substitute concepts such as frugal engineering seem gradually to become the new global norm and standard. Both G7 and G20 countries as well as UN member states call on multinational firms, large corporations and even technology-oriented small and medium enterprises to look into new business models and public–private partnerships as key contributions to frugal modes of production/consumption and sustainable development geared towards future generations of mankind.

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