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BEYOND CATCH-UP: THE END OF BUSINESS AS USUAL FOR INDUSTRIAL DEVELOPMENT

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Executive Summary

The current global growth paradigm, which has historically driven economic expansion and poverty reduction, is no longer sustainable, signalling the end of Business as Usual for industrial development. The challenge for developing economies is now to move beyond emulating the paths of leading global economies (including China and other rapidly growing countries) towards a new, more equitable and sustainable development trajectory.

Innovation has historically been central to economic growth and industrial development. Four types are identified:

- Incremental (small technical changes),
- Radical (fundamental, sector specific changes),
- Systemic (radical innovations with application in a limited number of sectors, impact limited to the economic sphere)
- Revolutionary innovations are disruptive, impacting all sectors and aspects of life (economic, social, cultural, political, environmental). They unfold in long waves (five to eight decades) and involve coevolution across production, markets, social structure, infrastructure, lifestyles, organization, and governance. We refer to these as social and economic paradigms.

Paradigms: Five such revolutionary waves of innovation (change of social and economic paradigms) have been identified.

- Waterpower and factory organisation (late 18th Century)
- Steam and Railways (after 1830s)
- Steel, Heavy Engineering, telegraphy (after 1870s)
- Mass Production (20th Century)
- Digital (most recent, still embryonic).

Historically, governments play an important role in both the inception and deployment phases of each paradigm through policies shaping demand and guiding investment. The transition between paradigms is typically disorderly, marked by crises, upheaval, change of political orientation (e.g. populism, nationalism), and sometimes conflict.

The Mass Production Paradigm delivered widespread improvements in living standards, benefiting advanced economies and many low/middle-income countries, including China and East Asia. However, like preceding paradigms, it eventually degrades and leads to systemic instability. After the Golden Age gains (1950 to the late 1970s) productivity and growth rates declined, as did corporate profitability. The paradigm gained a "second life" by accessing cheap labour in developing economies through Global Value Chains (GVCs), leading to deep globalisation and the spatial separation of production and consumption. GVCs drove rapid export oriented growth in some developing economies. However, the exhaustion of the Mass Production paradigm has resulted in a world of increasing inequality, economic and political instability, and growing environmental fragility, rendering Business as Usual unviable.

The End of Business as Usual: The fracturing of the Mass Production paradigm is driven by four major forces of disruption, particularly affecting low and middle-income economies:

- *Changes in the Global Trade Regime and Erosion of Rules-Based Global Governance*: The rules based global trade system underpinning the Mass Production paradigm is under threat. The share of GVCs in global trade stabilised, peaked in 2008 and then declined. Protectionism is increasing, particularly in lead economies like the USA. This uncertainty suggests a trend towards reshoring, nearshoring, and friendshoring in GVCs. South-South trade and intra-regional trade have grown disproportionately. The ability to adopt a "flying geese strategy," replicating China's export-oriented growth, is diminishing. Business as Usual on the trade front in industrial goods is no longer an option.

- *Economic and Social Exclusion*: While there was aggregate progress in poverty reduction (especially in China and East Asia), it was uneven. Manufacturing's employment intensity is declining globally, partly due to digital automation and AI. This is a challenge for low and middle-income economies with large youth populations needing labour intensive industrialisation. The unregulated informal sector has grown alarmingly in these countries, concentrated in urban areas with precarious livelihoods. Labour displacing technologies, even with export oriented growth, offer little solution to this social and economic marginalisation.
- *The Rapidly Accelerating Environmental Crisis*: The Mass Production paradigm significantly impacted the environment, accelerating climate change's disruptive effects. Reliance on fossil fuels, single-use goods, and individual consumption worsened the crisis. Low and middle-income economies are particularly vulnerable to climate change impacts (agriculture disruption, water scarcity, extreme weather, migration). Climate change mandates that Business as Usual is not sustainable.
- *Geopolitical Changes and the Rise of New Hegemons*: The "Pax Americana" and the Washington Consensus (a policy agenda favouring liberalised trade and de-legitimising Industrial Policy) facilitated deep globalisation through GVCs. China and other emerging economies now challenge this unipolar authority. Industrial Policy is returning not just in low/middle-income economies but also in advanced ones, including the US. This multipolar world opens new policy space for low/middle-income economies, legitimising industrial policy, strengthening regionalisation, and potentially increasing their bargaining power. However, it is also linked to military power and regional contestations, creating a dangerous and uncertain world.

Beyond Business as Usual: The Digital Paradigm offers the opportunity to forge a new, distinct, more equitable and sustainable development path, though it also poses threats. The rapid deployment of digital technologies transforms the conditions for economic and social life, embodying "gales of creative destruction". Key characteristics of the Digital Paradigm include:

- *Flexibility*: ICTs are inherently flexible and reprogrammable, enabling differentiated/customised products and adaptation to diverse production environments, allowing innovation to meet a wider range of user needs. This is accompanied by a process of 'servitisation' in which the physical product is bundled with post-sales services.
- *Descaling of Production*: Unlike Mass Production's need for large-scale production of standardised goods, ICTs enable smaller-scale, modular expansion, allowing for customised products and for production closer to consumption and lowering barriers to entry for small enterprises.
- *Dispersal of Power*: Digital technology facilitates less hierarchical governance, horizontal information flows, and decentralised decision making, but also enhances centralised control and concentrated power in large tech firms.
- *Increasingly Disembodied Technologies*: Productivity gains come from intangible technologies, freeing production from physical limitations and hard-wired controls. This impacts skills and income distribution, favouring digital skills and potentially benefiting developing countries with digitally knowledgeable youth.
- *Inherently Systemic*: Digital systems use a common language, allowing seamless communication and integration across production, logistics, use, and disposal. These interconnected systems permeate social and governance spheres, offering potential for enhanced equitable and sustainable growth.
- *Different Patterns of Appropriability*: Intangible digital innovations are akin to public goods with near costless reproduction.

Beyond Business as Usual: Given that Business as Usual and past catch-up strategies (including the labour-intensive export assembly at a very large scale) are no longer viable, low and middle-income countries must forge a new, more equitable and sustainable development path. In this report, ten case-studies, termed ‘niche innovations,’ are presented to illustrate the potential offered by the Digital Paradigm for low and middle-income economies to leapfrog legacy systems and to forge a new more equitable and sustainable development path beyond the traditional catch-up strategies prescribed by development scholars in the past.

The case studies address Mobile Telephony for financial inclusion; Green Industrialisation for win-win environmental/economic outcomes; Renewable Energy enabling decentralised generation; Green hydrogen in steel manufacture, linked to renewable energy allows for industrial decentralisation; Smart Cities cutting service delivery costs; Smart energy management through ICTs and solar; South-South Trade promoting labour intensive tech diffusion; District heating using renewables/digital tech; Climate smart ICT in agriculture improving productivity and food chain management; and Drones using sensor tech for remote services and equity.

The future of industries for development – policy interventions: As the Digital Paradigm presents both threat and opportunity, policy interventions are crucial to foster further niche innovations and innovations that impact the broader development of less-developed countries to impart directionality towards an equitable and sustainable future. Key policy areas identified for moving Beyond Catch-Up include:

- *Prioritising the Needs of Informal and Urban Clusters*: Shifting focus from formal sectors to understanding the systemic needs of the poor and excluded in informal settlements, reorienting innovation towards appropriate, employment-intensive, small-scale production, products, and services. There is a need to apply digital technologies beyond services/banking to production and livelihood creation in urban clusters.
- *Meeting the Environmental Challenge*: Addressing the environmental crisis by recognising the economic benefits of greening and cleaner production. Adopting systemic responses facilitated by ICTs across the entire product/consumption lifecycle (production, consumption, recycling, disposal, pollution), including decentralised renewable energy, managing the water, environment, food, ecosystem (WEFE) nexus, promoting the circular economy, and improving value chain efficiency using ICTs. This involves both retrofitting existing systems and investing in new green production.
- *Development and Deployment of ICTs*: Supporting innovation and widespread deployment of ICT-based products/services by addressing connectivity costs, leveraging digital skills (especially youth), supporting entrepreneurship (particularly informal sector), and strengthening National Systems of Innovation.
- *Renewable and Distributed Energy*: Promoting the transition to low-cost, modular, scalable renewable energy generation to bring production closer to consumption and foster decentralised economic activity.
- *Making the Most of Commodities*: For resource-rich economies, maximising value through upstream/downstream linkages and increasing value addition of local production. The Digital Paradigm increases demand for certain minerals, ICTs improve extraction/processing efficiency, and renewables reduce costs, enabling processing closer to the mine.
- *Expanding South-South Trade and collaboration in industrial production*: Recognising the growing importance of South-South trade, promoting regional agreements and South-South value chains that offer more inclusive, labour-intensive production processes. There is scope for an enhanced role for regional industrial policies which facilitate specialisation and trade within sectoral value chains.
- *Decentralise Governance*: Shifting policy formation and execution towards regional and municipal authorities, reflecting the digitalisation potential for geographical and decision-making decentralisation, promoting a more inclusive and sustainable path.

Implementation: Paradigm change requires a systemic, integrated, contextual, dynamic, and process-oriented approach, a departure from past policies. Successful implementation involves six critical steps:

- Establishing a Vision and Leadership (central government, but also regional),
- Developing a Mission orientation with diverse stakeholders, focusing on specific 'Grand Challenges' such as the water/energy nexus in agriculture, and the systemic greening of processes throughout industry.
- Marshalling a coalition of the willing,
- Confronting obstacles (blinkers and fetters like lack of recognition or resistance),
- Assembling coalitions to pioneer niche innovations and promote wider rollout, and
- Sharing agendas and experience across countries with international support.

The development challenge is contextual. Each country has unique conditions based on social/cultural structures, resource endowments, and global/regional position. Therefore, no one-size-fits-all detailed policy agenda can be applied. Instead, contextually specific policies must be crafted, recognising the opportunities presented by digital technologies and utilising the policy principles outlined. This offers low and middle-income economies the opportunity to leapfrog legacy systems and forge a new industrial and developmental path. The challenge is no longer just "Catching-Up," but a bold transition to a new, more equitable and sustainable trajectory

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1. INTRODUCTION

It is increasingly clear that *the growth paradigm* which delivered decades of widespread global growth and poverty reduction *is no longer sustainable. Business as Usual is not an option if the developmental challenge is to be met and if the environment is to be safeguarded*.

The explanation for this collapse in sustainability is to be found in an historical framework which analyses the evolution of frontier and catch-up economies since the Industrial Revolution[1]. This analytical framework not only informs us of how and why Business as Usual in industrial development is no longer an option. The objective of this Report is to identify policies required to provide the policy directionality to transition to a new, dynamic and more inclusive growth and development trajectory. *The challenge is no longer one of emulating the path trodden by the leading global economies* (including those in East Asia which have made remarkable progress in recent decades) *but to transition beyond catch-up to new, more equitable and sustainable development trajectory*.

The historical significance of this transition in industrial production systems necessarily frames this Background Report for UNIDO's Vision for the Future. It is unusual for such a background study to dwell on history and theory. But we believe that it is an essential adjunct to the visions outlined later in the Report and for the resultant policy discussion. As we hope to show this digression is essential if a feasible way forward for industrial development is to be identified.

Focusing on globally lead economies, Section 2 of this Report observes the centrality of innovation to economic growth and industrial development. Based on a historical analysis of patterns of growth since the Industrial Revolution, Section 3 distinguishes four major types of innovation and identifies the significance of long waves of revolutionary innovation or paradigm shifts. This is essential to our understanding of the polycrisis now confronting the global economy. Section 3 also observes the critical role which government has played in managing innovation and the transitions between paradigms. Section 4, entitled *The End of Business as Usual*, analyses the reasons why the current global crisis results from the exhaustion of the Mass Production paradigm which dominated the 20th Century.

The remainder of the Report sets out an agenda for how developing economies can respond to this crisis. The exhaustion of the Mass Production paradigm and its adverse social and environmental consequences in most low and middle income economies means that catching up is no longer an option. A new growth path (*Beyond Catch-Up)* is required.

Section 5, *Beyond Business as Usual*, describes the character of the post Mass Production paradigm - the Digital Paradigm – and illustrates how these innovation attributes can contribute to the development of a more equitable and sustainable growth trajectory. This is evidenced in ten case studies in Section 6. Section 7 (*Beyond Catch-Up)* identifies the policies which will allow low and middle income countries to turn threat into opportunity and to forge a new, more equitable and sustainable growth path. Section 8 concludes with a discussion on leadership and policy implementation.

This Report draws on a review of a variety of academic literatures encompassing industrial and trade policy, economic history and innovation studies. It also draws on the experience of policy implementation across a range of economies. Interviews were conducted with leading scholars and policy makers in both northern and southern countries. Contributors to this Background Report have a multidisciplinary background including economics, engineering, sociology, politics and environmental studies which is essential for a Report which addresses the interaction between the economy, society and the environment.

2. INNOVATION AND GROWTH

Approximately 13,000 years ago, the earth's climate changed. The biosphere warmed and stabilised, ushering in an environmental epoch known as the Holocene. This climatic change led to an explosion in ecological diversity. and around 9,000 BCE, the first human settlements were established. The transition from hunter gathering to settled societies was made possible by the introduction of food crops (initially in south and north China and in Latin America) and the domestication of cattle in southeast Asia. These technological innovations diffused through communities and human settlements spread geographically. The growth and expansion of settlements gradually allowed for the development of new and improved technologies. For example, the first wheels were introduced in Sumeria in about 3,500 BCE and these resulted in investments in improved technologies which were utilised in crop production (capital goods), in transport (infrastructure) and in potteries (manufacturing). Human development cannot have taken place without industrial development.

Inovation is at the heart of human development

This *combination of new technologies, innovations, investments, infrastructure and the development of industry allowed humans to live in greater comfort, live longer and satisfy a broader range of human needs.* The benefits of innovation were often unequally distributed.[2] Although empires grew and collapsed, the reality was that the mass of the human population saw little sustained improvement in their living conditions until the second half of 18th Century.

The Industrial Revolution, ten millennia after the development of the first human settlements, resulted in a decisive change in living standards. It originated in England in the 18th century, spread to Belgium and France in the early 19th Century, and then decisively to Germany and the USA in the second half of the 19th Century. Whilst the USA was the world's dominant economy through the 20th Century, the second half of the 20th Century witnessed the extraordinarily rapid spread of industrial *capabilities* and the growth of per capita incomes globally, and especially in East Asia. The historical *global* significance of these developments is succinctly summarised in UNIDO's Background strategy document for UNIDO Vision 2050[3]:

> *'Two centuries ago, more than 80% of the global population lived in extreme poverty. In recent decades, this figure has fallen to less than 10%: lifting millions out of poverty and giving rise to a middle class in many low and middle income countries. Critical indicators such as life expectancy, education, and per capita income all showed continuous improvement...'*

But …. the UNIDO Background Strategy goes on to observe, these improvements are fragile and face a crisis of sustainability

- *.. - until they didn't. Global crises, including the financial crisis, the pandemic, armed conflicts, climate change, the depletion of natural resources, habitat contamination, and biodiversity loss, along with their effects on migration, inflation, and social welfare, have halted or even reversed much of the progress. Extreme poverty has increased in absolute terms, global hunger has surged, and the long term decline in inequality across countries has stalled…*

How do we make sense of these historical developments – stagnation for many millennia, a dramatic improvement in *global* development in a short period of three and a half centuries, and now the degradation of living standards for many hundreds of millions of the world's population?

A key element in the growth in industrial competences and output which allowed for improvements in the human condition is the role played by investment. A basic level of investment is required to repair and replace existing productive activities which inevitably wear out over time. But for living standards to *grow,* investment is required in new productive capabilities. In both of these cases it is necessary to recognise that ‘capabilities’ include not just physical capital equipment but also the human and organisational capabilities which allow production to take place, and the infrastructure required to deliver inputs to producers and output to final markets.

The link between investment and the growth of output has two components. The first is an *extensive* growth path in which an existing set of technologies is replicated – more of the same. The second type is an *intensive* growth path, that is, a change in the character of new investments in capabilities – better than before. Of course, these two types of investment are not exclusive, both can occur coterminously.

In some cases extensive growth has played the dominant role, for example globally before the industrial revolution, in Korea during the 1970s, 1980s and early 1990s, and in China until the turn of the millennium. But historically the evidence is unambiguous. *The primary source of economic growth has involved innovation – new products and services, changes in the way production occurs, how materials and final products are transported, how output is marketed and how they are consumed and where possible recycled.* In terms of changes in total factor productivity, both in the US and in the European economies catching up after WW2, extensive investments – more of the same – explained less than 20 percent of total output growth.[4]

Economic growth depends on innovation

Thus, innovation in its various forms was the primary driver of economic growth after the onset of the industrial revolution. If we are to have any reasonable foresight of the future challenges facing humankind, it is thus necessary to unpick the determinants and character of the various and complex components of innovation.

3. THE DIFFERENT TYPES OF INNOVATION

Innovation can be easily described at a general level - doing something which is new and different, and which offers enhanced processes and products. However, there are differences in the character of innovation which have important implications for the generation of policy responses to the manifold crises now confronting all humankind, especially those in low and middle income countries. There are four main types of innovation (Figure 1)[5]:

- **Incremental** changes in what is produced and how it is produced
- **Radical** changes in what is produced and how it is produced
- Changes in **production systems**
- **Revolutionary** changes which affect not just production, but all walks of life.

These spheres of innovation are not exclusive and can, indeed must, be pursued in an integrated fashion for the achievement of sustainable and equitable growth and development.

Figure 1: The Different Types of Innovation

Types of Innovation	Type of Change	Description	Focus
Incremental Innovations	What and how produced	Small marginal technical changes to what and how produced and consumed	Results from structured programmes to meet identified goals
Radical Innovations	What and how produced	Fundamental change in production process but implications limited to a particular sector	Tends to be science and R&D intensive
Systemic Innovation	Production systems	Innovations affecting number of sectors	Widespread general use to some sectors, limited to economic sphere

Revolutionary Disruptive Innovation	Economic and social disruption of entire society	Destroys economic basis of old order, creates new growth surge, affects economic, social, cultural, political and environmental activities	Widespread application, massive productivity increases, major cost reductions, no practical limits to supply

Incremental Innovations

Incremental technical change – making small marginal changes to what is produced, how it is produced and how it is consumed – is a fact of life. From the dawn of humankind's existence, incremental innovation occurred on an everyday basis, everywhere. To a greater or lesser extent production always runs up against constraints which need an innovative response, and small changes are invariably made to process and products as inputs change, consumers desire customisation and new customers are identified. Incremental innovations are especially important for producers who are catching up to the technological frontier.

The *systemisation* of incremental innovation in modern industries can be traced back to post war Japan during the 1970s, pioneered in what became known as Toyota Production System. A relative newcomer as a global producer in the auto industry, Toyota ran up against quality problems when it first began exporting to the USA in the late 1960s. There was no big jump available which would allow for competitive production of quality cars, so, instead, Toyota began by introducing structured programmes of rapid, sustained and small incremental innovations (Box 1). Each worker was expected to make suggestions for improvements in process and product. Its workforce contributed more than 2.5m suggestions for improvement in 1985 alone. The critical factor in the contributions made by these minor changes – known as *kaizen* – is that they did not take place haphazardly and by accident but resulted from structured programmes to meet identified goals.

Toyota's Kaizen programme was rapidly copied by other Japanese auto firms, and then by firms in the electronics and other sectors. Startled by this successful programme of incremental innovation in Japan, the world's largest manufacturing and service firms instituted similar kaizen programmes, with mixed success. In recent years, China's rapid growth in manufacturing competence has benefitted greatly from a system wide commitment to incremental innovation. A recent article in the Financial Times even ascribes the innovation of China's relatively low cost DeepSeek AI tool to structured programmes of continuous incremental innovation.[6] As the rapid growth in competitiveness of China's manufacturing sector has shown, Chinese firms have invested considerable efforts to utilise kaizen in their attempt to catch up to the global innovation frontier.

Radical Innovations

A second category of innovations is those which involve a fundamental change in industrial process but have implications which are limited to a particular sector of the economy. Take for example the textile and apparel sector, the oldest non-agricultural economic activity and the leading manufacturing sector in the early stages of industrial growth. Originally textiles and clothing were made from animal hides. Over time and with innovation, the primary raw material transitioned from hides to natural fibres such as hemp and cotton. After the onset of the industrial revolution, textiles and clothing began to be traded across national boundaries, with some countries specialising in fibre production and others in apparel.

The invention of synthetic fibres overturned the character and the global division of labour in the textiles and apparel value chain. Rayon, using wood pulp was invented in the 19C and produced a silk like material for half the cost of silk. Then, in the 1930s, nylon (using petrochemicals as its raw material) was invented and together with the innovation of acrylics and polyesters in the 1950s, the industry was transformed. By 2023, cotton only accounted for one fifth of the total global textile and fibre industry. Another example of radical innovation is nuclear power as a substitute for hydrocarbon based power. The technologies are distinctly different and the firms in these value chains are of a different character.

Radical innovations tend to be more science and R&D intensive than incremental innovations. The key element of radical innovations is that however transformative these innovations, they are confined to a single sector. Thus, although radical innovations transformed the textile and apparel industry and nuclear power has substituted for hydrocarbon power, in neither case did these innovations have any significant direct impact on other sectors.

Innovations in Systems

Innovations in systems represent radical innovations which affect a number of sectors. A good example is the invention of plastics. Because of its plasticity, it can be moulded, extruded or pressed. It is lightweight, durable and flexible and critically, is cheap to produce. Plastics are produced in enormous volumes – more than 400m tons a year. The global sales of the largest 50 plastics companies exceed $1tr. Of this, just over one third is destined for single use packaging; 15 per cent is used in buildings and construction, 14 per cent is incorporated in textiles, 10 per cent in consumer products and seven per cent in transport.

Because of its wide use across a number of industries the plastics intensity of global economic output has grown astonishingly since the first plastics were invented in 1839 and first introduced on a large scale in the late 1930s. By 2000, by weight, the use of plastics was more than double that of the next most utilised material input (aluminium). Thus, plastics fits the description of a systems technology in that it is a radical innovation which has widespread use across the economy. However, crucially, systems innovations do not affect all sectors, and their impact is limited to the economic sphere.

Revolutionary Innovation

Revolutionary industrial innovations are of a wholly different order for two primary reasons. First, unlike radical innovations and systems innovations, their impacts are not limited to a single or related set of sectors. They affect all economic activities. Second, their impact is not limited to the economy, but affect the near totality of human activities, including the social, cultural, political and environmental spheres.

Schumpeter argued that standing above the everyday process of innovation are periods of major economic and social *disruption* caused by the periodic diffusion of a series of major transformative technologies.[7] The widespread diffusion of these general-purpose technologies is accompanied by '*gales of creative destruction*'. On the one hand they render a great number of existing technologies obsolete and destroy the economic viability of much of the old order. On the positive side, these disruptive innovations provided enormous potential for a new growth surge.

Revolutionary disruptive innovations affect all economic and societal activities creating a new growth surge for economy and society

These revolutionary innovations originate, and diffuse and degrade over many decades. Points of transition are systemically disruptive and *when a revolutionary innovation degrades, Business as Usual (that is, continuing along well established paths) is no longer possible*.

Freeman and Perez identify four characteristics of disruptive revolutionary technologies:[8]

- They have widespread applications across all of the economy and society.
- They offer decisive and demonstrable cost reductions, improvements in existing products and lead to the innovation of new products and services.
- The cost of the new technology falls rapidly, with the expectation that its price will continue to fall further for the foreseeable future.
- There are no practical limits to its supply.

These disruptive technologies and their accompanying waves of creative destruction last approximately five to eight decades.[9] They begin with the invention of the core technology. The technology begins to be applied in a number of related innovations which clearly evidence their revolutionary potential to transform production and introduce new products. This is the *inception phase*. When the dramatic improvements offered by the technology become evident, it is rapidly *deployed* in all sectors of the economy and spheres of society. Once the major gains have been realised the marginal improvements in productivity decline and the wave begins to *degrade*. In this phase 'Business as Usual' no longer delivers growth or social cohesion. After a period of turmoil this degraded innovation wave is supplanted by a new revolutionary technology. The extent of disruption means that the transition between epochs is characteristically highly disorderly and generally includes major financial crises. Transition is also generally accompanied by major social and political upheaval, cases, war[10].

Revolutionary technology lead to disruptive transitions. 'Business as Usual' no longer delivers growth and social cohesion

Each of these disruptive waves develops standard ways of behaving, standard forms of economic organisation, standard forms of social organisation, and standard forms of institutional design. These social and economic features become the norm, affect the near totality of societal interactions, and are widely accepted as 'common sense'. Economic historians refer to these epochs as paradigms.

There have been five paradigms since the early 18th Century[11]. In each case they involved related changes in production, in final markets, in the social division of labour, in the infrastructure connecting producers to consumers, in lifestyles and in resultant changes in the way that society is organised.

These paradigms are (Figure 2):

1. The introduction of waterpower and the transition from household to factory production in England in the late 18th Century. This new form of inanimate energy was initially used to transform the textile industry and then diffused to other sectors. The development of canals allowed innovating firms to extend their market reach and to deepen the division of labour.
2. The introduction of coal fired steam power after the 1830s facilitated a greater division of labour and more efficient mechanisation across a range of economic sectors. Critically, the development of railways freed both producers and consumers from the need to locate near sources of water. For the first time inputs into production and perishable foods could be brought from afar to local markets, distant consumer markets could be addressed and national brand names began to develop.
3. The development of the steel and the electricity industries after the 1870s deepened and widened the capacity to mechanise production and introduce new products across a range of industries. Steel was also central to the development of long range cross border transport (particularly steamships). Together with the development of telegraphy, this widened the span of markets across continents. It also opened the door to mass migration from Europe to North America and was instrumental in the development of an industrialising USA.
4. The Mass Production paradigm originated in the USA in the early 20th Century. New forms of organisation opened the way to large scale factories and firms. Large concentrations of workers led to mass unionisation. Cheap oil accelerated automobile usage and other forms of mass and long distance transport. This facilitated the development of a global production system. It also enabled suburbanisation and new ways in which urban centres operated. Oil was also the feedstock for the plastics, chemicals and pharmaceutical industries which rapidly grew in importance. The mass production of electric appliances radically transformed domestic tasks and women entered the workforce in large numbers.

This paradigm exhausted its potential by the 1970s but was granted a 'stay of execution' by globally extending its reach through global value chains (GVCs) after the mid 1970s (Section 4 below).

5. The most recent period has seen the emergence of the Digital paradigm drawing on the power of Information and Communication Technologies (ICTs). These core technologies vastly improved the productive potential of existing industries. They also led to the development of wholly new products and services. However, critically, they also provided the means to control the complex interflows of information, people, components and products which allowed for the deepening of globalisation. The flexibility and labour-saving character of digital technology allows for production and consumption to be brought closer together, affecting the geography of global production.

ICTs allow the Digital Paradigm to develop new products, services and change the relation between production and consumption

Each of these paradigm waves is accompanied by related social and environmental factors. So, in the first wave (waterpower), production occurred in small firms, drawing on local capital and serving local markets in relatively small towns. The second wave (steam power) led to the development of larger firms. Innovations in the legal structure such as limited liability and joint stock companies promoted risk taking innovation and facilitated the development of large firms. Railroads allowed for the development of larger towns and for more diffused industrial settlements since production and consumption were no longer limited to watermills and waterways.

In the third wave (heavy engineering, steel and telegraphy), very large corporations and monopolies began to dominate production and to influence the reigns of political power. Ownership began to be separated from control, and senior and middle management became specialised functions. Towns grew into large industrial cities, accompanied by widespread poverty and the growth of an organised working class. Crucially, economic dynamism and the growth of cities became globalised; colonialism and imperialism transformed many economies in Asia, Africa and South America. They provided sources of raw materials for the dynamic industrial economies and markets for their final products.

The fourth wave (Mass Production) in the twentieth century witnessed the development of large scale production, vertically integrated corporations and the emergence of foreign direct investment. Many millions of people saw an increase in their living standards and new lifestyles developed (mass consumption, urbanisation and suburbanisation) Values and norms changed, characterised as a period of 'possessive individualism'.[12] Significantly, as we will see below, the latter phase of the Mass Production, through the spread of GVCs, led to the incorporation of hundreds of millions of people living in low and middle income countries. This transformed livelihoods, not just providing an increase in living standards documented in UNIDO Vision 2050 (The Future of Industries for Development, 2025) but also in social relations (especially for many women who were employed in export oriented factories).

Figure 2: Socio-Economic Paradigms in Historical Perspective

Paradigm	Economic Driver	Impact Economy	Social Life
Industrial Revolution	Waterpower Canals	Small firms, extended local market reach, deepened social division of labour	Growth of small towns
Steam and Railways	Coal fired steam power	Steam driven machinery, growth of coal and iron industries, great port cities, extension of domestic markets across local boundaries	Growth of large urban areas & consumer markets, movement of people across national borders

Steel, Heavy Engineering	Coal fired electricity	Great railways, mechanised production, steel steam ships, electrical equipment, chemical industries, telegraphs, market extension across national border	Science in production, industrial cities, new industry elites/working class, large corporations, mass migrations, colonialism, paper & packaging, canned/bottled food
Mass Production	Oil power, internal combustion engine	Vertically integrated corporations, product & process standardisation, large factories, continental markets, mass production of goods, long distance communications & transport, plastics industries, GVCs, global dispersion of production	Automobiles, mass transport, suburbanisation, mass consumer goods, revolutionised domestic work, mass connectivity (wireless & telephone), welfarism, global income rises, global economic integration
Digital Paradigm	ICTs	Computer based production & consumption, information and telecommunication spread,	Wholly new products and services, flexibility & integration of production & consumption, high speed mass transport,

The Role of Government in Paradigm Inception and Deployment

Governments have an important role to play in both the inception and the deployment phases in each paradigm.

During the *inception phase* the state necessarily creates a supportive environment for the invention of the revolutionary technologies. As technology has become more complex and more science intensive, this requires developing a diverse national system of innovation and support for R&D. Mazzucato has highlighted the critical role which the US government (often through the Defence Department) played in the early development of all of the fundamental building blocks of Digital Technologies.[13] Similarly, over the past two decades the Chinese government has been very active in supporting the growth of capabilities in the Science and Technology infrastructure. It also introduced an enabling environment to promote and develop technology intensive firms. This involved a battery of trade and industrial policies, including tariff protection, mandating foreign firms to transfer advanced technology to Chinese firms, the development of standards which provide domestic firms with some measure of protection from the brand power of foreign investors and substantial support for universities and higher education. A particular focus for policy attention has been the ICT and related sectors and renewable energy which the government recognises the core drivers of future growth.

Government plays a critical role in both the development and the diffusion of the new paradigm

The role of government widens in the *deployment phase*. Of course, it continues to support front end invention and provides the incentives for the widespread adoption of the revolutionary technology. But in addition, an important function of the state is to limit the power of legacy firms and institutions who played a dominant role in the previous paradigm from blocking the diffusion of the new revolutionary technology. This struggle between the old and the new is currently evidenced in the battle between the large oil firms seeking to maintain the core role of hydrocarbons in energy generation and transport (legacy innovation) and the emerging firms and institutions developing renewable forms of energy and transport. This battle between the old and the new is not only occurring in the energy sector. It spans the range of social and economic activities. For example, there is an opportunity to transform the health sector and government bureaucracy by taking advantage of AI technologies. This transformation is hindered by the stubbornness of the routines and institutional design which ere appropriate to the era of Mass Production but are no longer efficient or effective in the era

Government needs to support the new paradigm with leadership, innovation incentives and macro-economic policies

of ICTs. The regulation of new revolutionary technologies is another key area in which the state has an important role to play. Here it is not easy to find a balance between the protection of civil society on the one hand and the profitable opportunities opened to firms developing new technologies, particularly those developing social media technologies.

From the perspective of providing the new paradigm with the *directionality to meet the needs of low and middle income countries*, three essential roles for government can be identified.

- Leadership. When Business as Usual – the degraded paradigm – is no longer possible, it is critical that the state plays a leading role in providing a vision and enabling environment to facilitate the deployment of the new paradigm. Roosevelt's New Deal Programme in the 1930s promoted the deployment of mass production. In the recent era, the Chinese state is promoting the development of a broad spectrum of ICT related industries and services. A similar proactive role is being played by the government in Rwanda which is seeking to promote the development of knowledge intensive ICT based services, and Costa Rica has pioneered the transition to an ecologically friendly and carbon free economy.
- The externalities involved in the new deployment of the revolutionary Digital Paradigm and the need to address global environmental challenges show the limits to policies developed and implemented at the national level. In some respects, the key role of national governments is to subsume their national sovereignty within global agreements. No individual government can regulate the harm caused by some social media or address the environmental challenge on its own. Moreover, much of the communications infrastructure required by ICTs requires action at the supra-national level, for example, low-earth-orbit satellites which have particular relevance for low and middle income countries. The power of individual governments to tax productive activities in their territory is undermined by global tax avoidance schemes. In these cases, some power at the national level needs to be foregone and to be passed up to a higher supra-national level.
- Government has a key role to play in balancing production and consumption, both to ensure macroeconomic stability and to provide directionality to the emerging paradigm. The need for the state to promote consumption to meet growth of the productive sector responds to a problem which is central to the growth of innovative capitalism. That is, innovation is invariably labour saving. Unless the fruits of this productivity growth are shared with the population at large through higher wages and/or lower product prices, the expansion of production in itself will not provide the incomes required to consume expanded output. This may seem an abstract discussion. But as we will see in the policy discussion later in this Report, if the new Digital Paradigm is to be given the directionality required to deliver inclusive and sustainable development government in low and middle income countries need to play a central role not only in augmenting production but also in shaping the character and extent of final consumption.

4. THE END OF BUSINESS AS USUAL

During the 20th Century, and especially in the two decades after the Second World War, Mass Production resulted in a widespread improvement in global living standards. But as in the case of the Belle Epoque in late 19th Century Europe, each paradigm inevitably degrades and runs out of steam. This leads to a period of systemic instability until the new paradigm is deployed and, in turn provides for a new era of prosperity. It is this transition which currently forces an end to Business as Usual and offers low and middle income countries the opportunity to transition to a new, and different growth trajectory.

Mass Production Fractures

Mass production as a form of productive organisation was invented by Henry Ford in 1908. Once the benefits of this production organisational system became apparent, mass production diffused rapidly to other auto manufacturers and then began to spread to other sectors. Although the productivity gains provided by mass production had become increasingly apparent during the 1920s and 1930s, the true scale of the potential gains became graphically evident in the factories churning out weapons during WW2.

Mass production changed all economic and societal activities from production to consumption to governance to life styles and cultural values

The significance of Ford's innovation was not confined to the production line. It was complemented by profound structural changes in the organisation of society at large, and in the growth of mass consumption. A key driver of the Great Depression in the 1930s was the collapse in consumer confidence and demand. Roosevelt's New Deal in the US made a head start in resolving the problem of deficient demand, but it was the war economy between 1939 and 1945 that consolidated the dominance of mass production in US (and then European) manufacturing. After the end of WW2, demand was boosted through a massive expansion in house construction, supported by large investments in the infrastructure required to support the spread of personalised automobilisation. The advertising industry grew to encourage the rapid increase in demand for TVs and a variety of 'machines' (vacuum cleaners, food processors, etc.), which allowed for the mechanisation of the household. In Europe (and to a lesser extent the USA) the expansion of the welfare state was an additional spur to support mass consumption.

What had begun with the introduction of mass production in a single firm in the productive sector resulted in profound and sweeping changes in economic, social and political organisation. Even government was modelled on Ford's innovations, focusing on scale, top down authority and uniformity of final service. Each of the post Industrial Revolution paradigms had characteristic consumption patterns and associated lifestyles as these co-evolved with the deployment of the core general purpose technology. Figure 3 contrasts the lifestyles preceding the deployment of the Mass Production paradigm with those which characterised the deployment of Mass Production. As will become evident in later sections of this Report, for low and middle income economies transitioning to the Digital Paradigm, the policy challenge cannot be reduced to the adoption of digital technologies. There will have to be associated changed in consumption patterns and lifestyles.

Figure 3: Paradigm Changes in Lifestyles: Mass Production and emergence of the 'American Way of Life'

As a paradigm shift from the 1910s	…	Consolidated as a "lifestyle" after WWII
Energy is expensive, often inaccessible	→	Energy is cheap with unlimited availability. Energy-intensive homes & mobility.
Trains, horses, carriages, stagecoaches, tramways, ships, bicycles	→	Automobiles, buses, trucks, planes, motorcycles
Local newspapers, posters, theatres, parties	→	Mass media, radio, movies, television
Ice boxes, coal stoves	→	Refrigerators and central heating
Doing housework by hand	→	Doing housework with electrical equipment
Natural materials (cotton, wool, leather, silk)	→	Synthetic materials
Paper, cardboard, wood & glass packaging	→	Preference for disposable plastics of all sorts
Fresh food bought daily from specialised suppliers	→	Refrigerated, frozen or preserved food bought periodically in supermarkets
Urban or country living and working	→	Suburban living separate from work

Source: Carlota Perez, personal communication

The deployment of the Mass Production resulted in unparalleled progress.[14] *Rates of economic growth in the Golden Age (1950-1975) were historically unprecedented. Critically, these improvements were not limited to the leading high income economies but also spread to the developing world*. But good things generally come to an end, and after the early 1970s, this widespread and sustained growth surge slowed down. Between 1961 and 1973, the US economy grew at an annual rate of 4.6 per cent and that of Europe at five per cent; subsequently, economic growth in both regions fell to an average of around three per cent and collapsed further to around one per cent between 2006 and 2017.

A critical factor underlying this falling rate of economic growth was a prolonged decline in productivity growth. With the exception of a brief IT-led boom in the US (1997-2006), labour productivity growth fell and continued to fall throughout the high-income world after the early 1970s. This was because the efficiency gains resulting from the extension of the Mass Production paradigm tailed off through a combination of declining marginal productivity growth within the productive sector, the growing tertiarisation of economic structure (service sector activities are more difficult to mechanise) and the growth of large and powerful trades unions. Not surprisingly, in the light of falling productivity rates, the rate of investment, which was a necessary driver of sustained productivity growth also declined. Associated with this falling productivity was a decline in the rate of corporate profits (Kaplinsky, 2021).

In the face of declining productivity growth and declining rates of corporate profitability, a new route to profitability had to be found within the mass production paradigm. This involved the exploitation of cheap labour in developing economies. Not only did developing countries have virtually unlimited supplies of labour but, as a consequence of investments by the state in these economies (many of whom had recently decolonised), an increasing proportion of this labour force was educated and skilled.

The growing scale of production in mass production, and the increasing requirement for large investments in knowledge creation and marketing, led the corporate sector to spread its operations outside of its domestic economy, not just to other high income countries, but to the developing world as well. Through the spread of GVCs a range of developing economies, particularly China, became offshore export platforms, low cost suppliers of intermediate goods and final products for outsourcing lead firms in the high income countries. As the lead firms sought ever lower costs of production, GVCs spread unevenly to trusted and competent suppliers primarily throughout Asia but also elsewhere in the developing world.

Global Value Chains led to the global dispersion of production extending the life of the Mass Production Paradigm and leading to economic growth and higher living standards for some export oriented developing countries

In previous eras competitive manufacturing had been concentrated in the former countries with the developing world primarily operating as the source of raw materials within the international economic order. However, the rise of GVCs fundamentally altered this relationship, because it turned the previous international economic order on its head by giving rise to the global dispersion of production. Deep globalisation also provided a new market to support mass consumption. Final consumption and production was increasingly spatially separated on a global scale - much of global production was located in selected developing countries separated from the bulk of consumption occurring in the high income economies. Critically, this global extension of free trade was imbedded in, and underwritten by, a new rules based system of global governance known as the Washington consensus.

A limited number of large Asian low income economies were drawn into GVCs, resulting in very rapid export oriented economic growth and historically unprecedented improvements in living standards for hundreds of millions of people. Originating in the Asian Tigers (Korea, Taiwan, Hong Kong and Singapore) the primary success story was China, and the surrounding regional economies drawn into its GVCs. Although inequality grew rapidly in China, the very large number of people with growing incomes meant that global inequality – measured not as country per capita incomes, but the incomes of global citizenry – fell sharply. And because China's population was so large, so too was there also a fall in global poverty. However, outside of this east Asian growth pole, improvements in living standards and the reduction in absolute poverty were more limited.

This spectacular improvement in living standards in China and other east Asian economies played a determining role in growth, industrial and trade policy globally. China's exemplary success was based on the development and implementation of evidenced-based long term strategies, promoting innovation not just within sectors but also in moving into new sectors (such as industrial automation). *Replicating this Chinese success story became the beacon of economic policy for most low and middle income economies, as well for the international institutions supporting the quest to achieve the MDGs, and latterly the SDGs. By the end of the twentieth century, the growth and development orthodoxy was clear – liberalise, open up, and benefit from the fruits of trade specialisation.*

However, many of the elements supporting this extension of the Mass Production paradigm showed signs of decay after the turn of the millennium culminating in the Global Financial Crisis in 2008-9. The covid epidemic sharpened the crisis by exposing the vulnerability of extended supply chains. The share of GVCs in global trade began to stabilise and retreat. The combination of growing unemployment, stagnant and falling wages, and increasing migration from developing countries has resulted in the increasing rise of populist political forces mobilising under anti-immigration rhetoric and calling for the imposition of protectionist trade policies. Changes in geopolitics, particularly during the first Trump administration and now during the second Trump Administration have transformed the world economy and its institutions of governance.

Deep globalisation stutters, GVC share of global trade hit barriers, mass production starts to decay, protectionism reappears, and increasing global disruption pervades

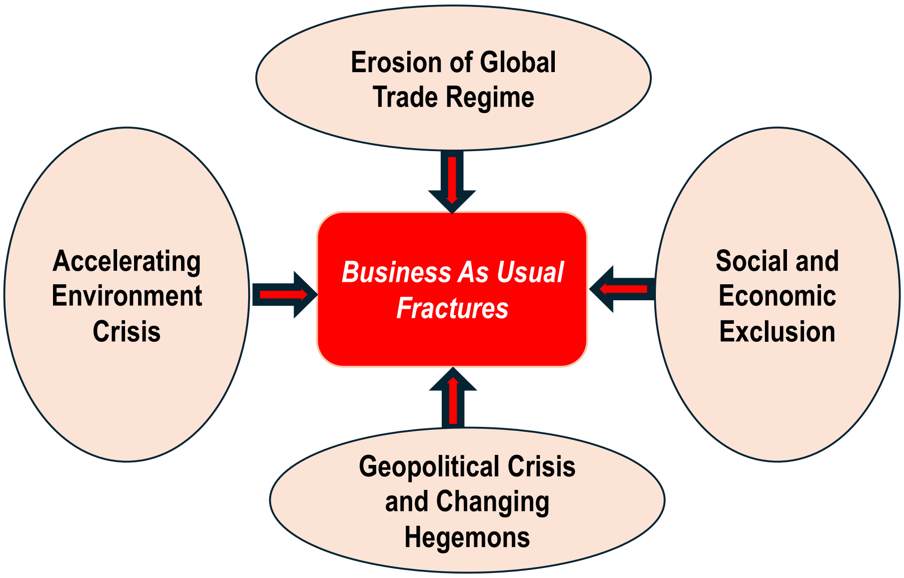
We are experiencing a world of significant global disruption. Business as Usual is no longer possible. We need a more equitable world economy.

Forces of Disruption

In this disrupted era, four major sets of disruption affect low and middle income economies and determine the policy options open to generate equitable and sustainable development (Figure4).

- Changes in the global trade regime and the erosion of rules based global governance
- The systemic prevalence of economic and social exclusion
- The rapidly accelerating environmental crisis and degradation as well as depletion of natural resources
- Geopolitical changes and the rise of new hegemons

Figure 4: Forces of disruption fracturing Business as Usual



Changes in the global trade regime and erosion of Rules Based Global Governance

GVCs were the primary vehicle for the deep globalisation in industry after the early 1980s. The impetus to outsourcing in the manufacturing sector followed from the adoption of core competence strategies in the corporate sector.[15] Firms focused on capabilities which were difficult to copy and outsourced those which were devoid of rents. Initially outsourcing was local (pioneered in Toyota City), but as trade logistics improved outsourcing went global, initially to the four Asian Tigers, and subsequently from the mid 1980s to China and lately to Asian and Latin American periphery countries such as Vietnam, Bangladesh, Indonesia, Mexico, Colombia, Costa Rica, or Honduras.

The first steps in global outsourcing were initiated by the US retail chains which became increasingly concentrated and dominated by a small number of large retailers.[16] Faced with growing competition, and selling at scale, these retailers cultivated suppliers in the Asian Tigers and later Asian and Latin periphery countries as a source of low cost and large volume production. This established a global outsourcing structure which fed into the emerging core competence revolution in manufacturing and services. Thus, the growth of global supply chains across the spectrum of traded goods and services was initiated at the consumption end of the value chain. (As we will see below, particularly in low and middle income countries the role played by demand and consumption in promoting supply has been under recognised in policy formation).

Deep globalisation driven by outsourcing, global dispersion of production to low cost economies and harmonisation of standards required a rules based global regulatory framework. However this rules based trading system is now in crisis

It is important to recognise the systemic character of deepening globalisation. As we have seen, the drive to outsourcing in low income economies was driven by the maturation and slowdown of productivity growth in the Mass Production paradigm. To be successful, the extension of GVCs required major changes at the macroeconomic level - the GATT and subsequently the WTO provided a set of multilateral rules which encouraged trade; the Washington Consensus, backed by multilateral

Bretton Woods institutions, encouraged and forced many low income economies to limit industrial policy interventions and open up their economies to imports and exports; harmonisation of standards and technological changes were necessary for the development of the infrastructure required for trade expansion; values and consumption patterns changed from ‘buy local’ to ‘buy the best international brands’.

The growing fragmentation of production and the rapid expansion of GVCs resulted in the ‘centrifugalisation’ of production, initially in manufacturing and subsequently in services. Production and consumption became increasingly separated at a global level, mirroring the intra-national geographical structure which emerged after the war in which suburbanisation, the automobile and highways gutted inner cities and led to a commuting labour force.

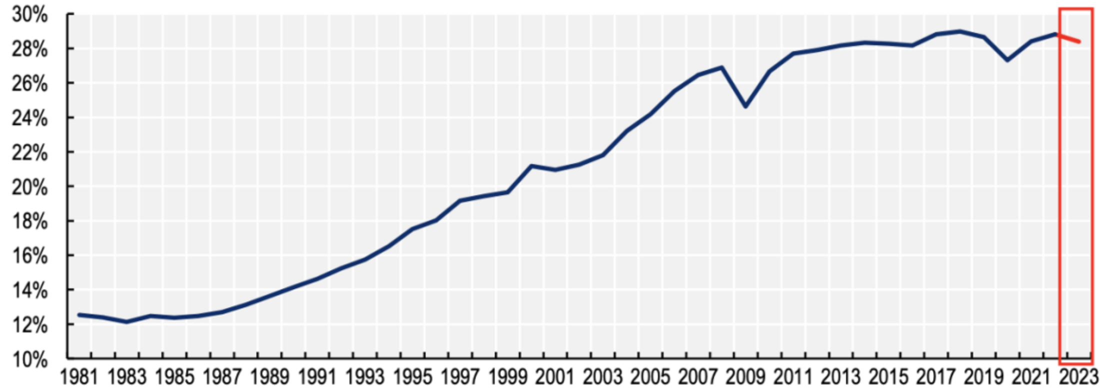
This changing character in the global division of labour resulted in high rates of export led growth in some low and middle income economies, particularly those in east Asia. At an aggregate level, the share of developing economies in global trade rose from 21 to 38 per cent between 1995 and 2022.[17] Significantly, the dynamism of these successful Asian exporting economies was reflected in an increasing technological intensity in their exports.[18] Beginning with low value added assembly, these economies increasingly developed the capabilities to produce and export high tech goods and services, and domestic companies such as Samsung and BYD became world leaders in their product offerings.

Another important consequence of the outsourcing of production in GVCs was a growth in trade imbalances. Major high income economies – particularly the giant US economy and the UK – sank into increasingly large trade deficits, mirrored by the surpluses generated in export-oriented Asian economies and some high income economies such as Japan and Germany. Throughout the advanced industrial world, this led to the displacement of labour and the growth of structural unemployment and poverty. Previously prosperous industrial regions degenerated into rust-belt regions. Consumption in these deficit economies was supported by a large and growing descent into debt at the personal, corporate and state levels. Opposition to trade openness was increasingly reflected in politics and the combination of friction free trade and the regulation of trade through a rules-based trading system was increasingly challenged. ‘Buy local’, ‘Make America Great Again’, and ‘Industrial Policy’ came to dominate social and political discourse in many countries. At the same time, as we shall see below, technological developments such as robotisation have begun to erode the competitive advantage provided to low income economies by low labour costs. Here again, we can observe the systemic nature of change, with a number of reinforcing dimensions (trade and macro-policy; innovation trajectory; value systems; industrial geography).

Deep globalisation was accompanied by increasing economic, political and social opposition

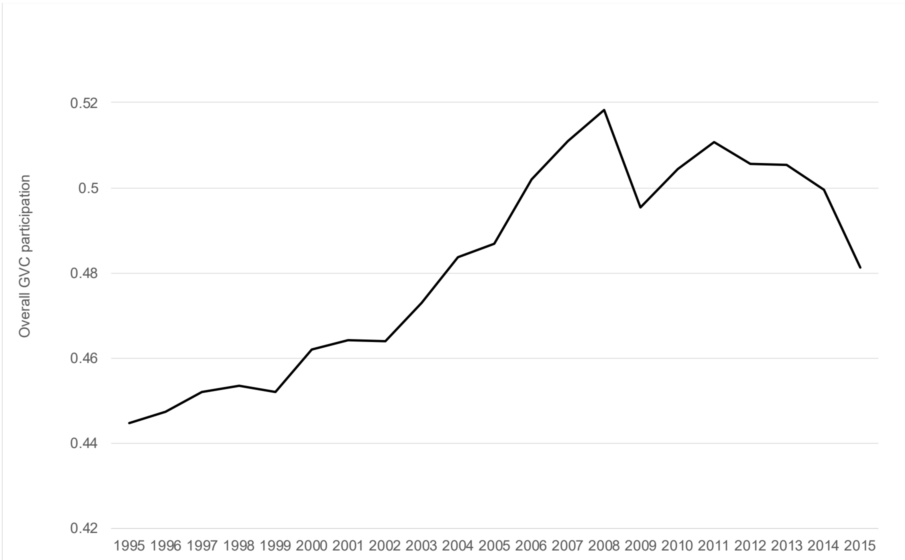
The combination of these economic, social and political developments meant that after decades of steady growth, the ratio of global trade to GDP stabilised after 2008 (Figure 5). This slowdown in trade intensity was reflected in the decline in the GVC intensity of global trade. After two decades of rapid GVC deepening, the share of GVCs in global trade peaked in 2008 at 52 per cent. By 2014 the share had fallen to 48 per cent (Figure 6).

Figure 5: Ratio of global exports to GDP (%)



Source: OECD (2024), *Risks and Resilience in Global Trade: Key Trends in 2023-2024*, OECD Publishing, Paris, https://doi.org/10.1787/1c66c439-en.

Figure 6: Share of GVCs in Global Trade (%)



Source: Calculated from World Bank World Development Report (2020)

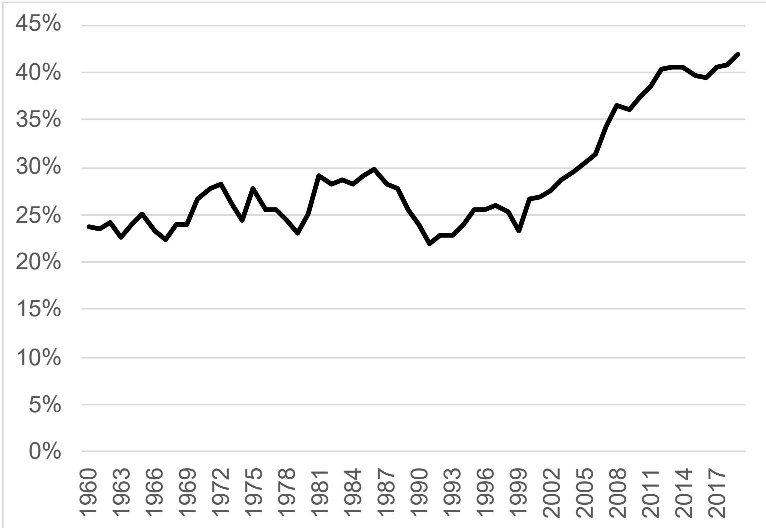
As of early 2025, a number of important and related emerging developments will affect the global trading environment which will frame the strategies which low and middle income economies can adopt to promote equitable and sustainable growth. At least for the foreseeable future, trade protectionism will increase, particularly in the leading global economies. There is much uncertainty about the shape of the growth of protectionism but as two prominent trade economists observe, [it is possible that] '*the world will end up fragmented in rival camps and that a new cold war will unfold, this time between the US and China (and their respective allies). The consequences of the latter scenario could be severe'.*[19]

What does this portend for low income east Asian export oriented growth strategies? One possibility is that there will be a trend towards the *reshoring* of some parts of production to the leading global economies. This may be also accompanied by the *domestication* of new production in high income economies, utilising a variety of highly skilled, knowledge intensive and digitised production techniques and no longer requiring cheap labour to make them viable which would previously have been offshored to low cost developing economies. Another possible outcome is a shift from dispersed outsourcing to *nearsourcing*, reflecting the insecurity of extended global supply chains which surfaced dramatically during the blockage in the Suez Canal in 2021 and in attacks on shipping passing through the Gulf. The rising costs and environmental damage resulting from geographically dispersed GVCs will further undermine extended global supply chains. Nearsourcing is inextricably linked to regionalisation and the growth of regional value chains. A further problem limiting the adoption of policies seeking to replicate China's successful export oriented growth strategy is the rise in geopolitical tensions, in which case *friendshoring* may increasingly influence the structure of global production and trade.

GVCs will not vanish but there will be a trend towards reshoring, nearsourcing and friendsourcing and domestication of supply

Amidst this uncertainty about the evolution of global specialisation in the production and trade of manufactures and services, it is possible to observe two important developments which has received less attention than the change in the aggregates of global trade. The first is that the share of South-South trade in total global trade trebled from eight per cent in 1995 to 25 per cent in 2024.[20] Second, at a global level, intra-regional trade grew more rapidly than total trade. Intra-regional trade growth was particularly marked in the case of low and middle income economies where its share of total trade rose from less than 25 per cent in 2000 to more than 40 per cent in 2017 (Figure 7).

Figure 7: Share of Intra-Regional Trade (%), Emerging and Developing Economies, 1960-2017



Source: https://www.worldbank.org/en/publication/wdr2020

To some extent this growth in intra-regional trade reflected the rapid growth of regional value chains, particularly in East Asia. Chinese firms increasingly outsourced labour intensive assembly to neighbouring countries as wages rose in China and in expectation of the growth in protectionism against Chinese exports. This growth in regional trade around China is reflected in SE Asia's top trading partners. China was the largest merchandise regional trade partner in 2021 with 17.6 per cent of regional exports and 25.4 per cent of regional imports in 2021.

Regionalisation, South-South trade, and regional value chains are becoming increasingly important

But the growth in intra-regional trade in the developing world was not limited to China's emerging problems in exporting to the leading global economies. There has also been an expansion of trade in products destined for developing country final markets. The Africa Continental Free Trade Agreement (AfCFTA) signed in 2021 marks a recognition in Africa of the potential of the regional market as a source of future trade expansion. [21]

Focusing on the emerging scenario in global trade there are nine factors which will frame the role which external trade can play in equitable and sustainable development in low and middle income economies in the future:

- Trade growth is led by demand. Supply responds to market opportunities.
- Macroeconomic trading agreements and industrial policies between the mid1970s and the 2008 Financial Crisis underwrote a policy regime which led to a limited number of low and middle income economies expanding manufacturing exports to meet demand in high income economies. The development of a rules based free trade global economy was an intrinsic component of the mature phase of the Mass Production paradigm.
- The rules based free trade order is under threat and access to the largest economy, the USA, is increasingly restricted.
- Exports from China, previously targeted at the US market will be diverted to other countries. For low and middle income countries, this holds both threat (displacing local production) and opportunity (cheaper imports).
- In the face of these pressures, many of the worlds largest firms are reshoring, nearshoring and friendshoring their supply chains.
- Nevertheless, despite these shifts in the trajectory of trade, there remains scope for south-north manufactured exports, albeit without the extraordinary growth rates which characterised the three decades after 1985.
- Recent decades have seen disproportionate growth in exports by low and middle income countries.
- Intra-regional trade across low and middle income countries has grown disproportionately.
- It is possible that external trade will increasingly occur within trade blocks involving preferential trade agreements. But the likely evolution of these blocs remains unclear.

Thus, Business as Usual on the trade front is no longer an option.

Economic and social exclusion - Manufacturing can create jobs but often doesn't!

Between 1990 and 2020, significant progress was made in pursuit first of the MDGs, and subsequently the SDGs. Per capita incomes rose in many economies, and the share of global population living below the absolute poverty level fell from 38 per cent in 1990 to 8.7 per cent in 2018.[22] Other indicators of welfare also improved, such as access to basic services (water and energy), participation of women in paid employment and health indicators (such as infant mortality, polio and even malaria).

So much for the aggregates. The more granular picture is less satisfactory. First, much of this progress occurred in China and in the surrounding east Asian region. Progress in other regions of the developing world was less impressive. improvements in poverty alleviation were spread unevenly, within and between countries, genders and age cohorts. Arguably, the absence of inequality is in itself a public good, and many countries (and most notably China) showed growing income disparities. Third, insecurity, conflict and the damages caused by climate variability and climate change extreme events undermined many of the achievements reflected in economic aggregates.

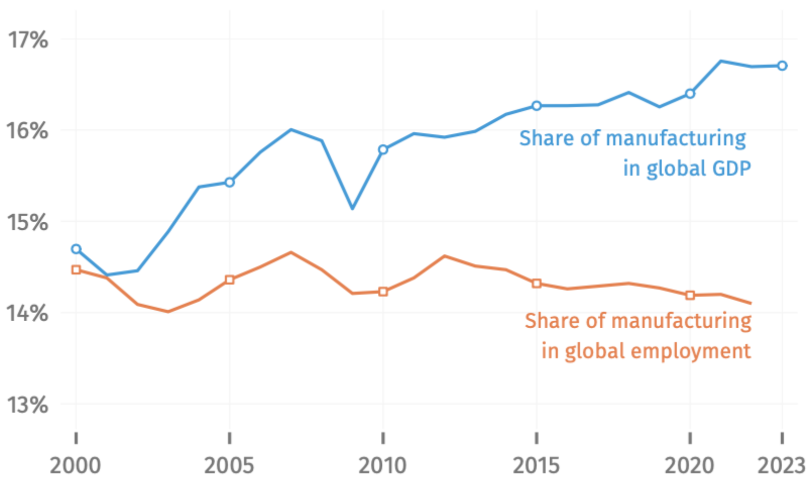
A combination of the aftereffects of the covid pandemic, the slowdown in the growth of the Mass Production paradigm and the unevenness of global growth have begun to put a brake on this trajectory of developmental progress. In recent years, absolute poverty has increased[23] – 700 million people live in extreme poverty and experience chronic hunger; global hunger has begun to rise; 760 million people lack access to electricity; and 2 billion people do not have access to clean drinking water. If these trends continue, by 2050 the number of malnourished people is expected to exceed 230 million, with sub-Saharan Africa and Central and Southern Asia bearing the heaviest burdens. Moreover, the poverty count, homelessness and precarity are no longer just a problem faced by low and middle income countries; life expectancy has begun to fall and the incidence of many developmental pathologies has increased in some of the leading economies.

The progress in income growth and living standards which China and some of the economies in surrounding region achieved during the period of deepening globalisation was largely a consequence of the growth in industry, and particularly in manufactures. This mirrored the experience of European economies and the US after the Industrial Revolution. Manufacturing creates employment, and employment creates incomes. On the flip side, the primary cause of falling incomes and growing precarity in the lead economies in recent years was a fall in manufacturing employment, in part a consequence of the stellar exporting success of China and a select few emerging economies. Thus, to a large extent, developmental welfare will continue to be driven by the growth of manufacturing and employment in manufacturing, in both northern and southern economies.

Manufacturing played a critical role in employment for development but its employment intensity is declining

But after centuries in which the growth of manufacturing led to an increase in employment, this no longer seems to be the case. The employment intensity in global manufacturing growth has declined over the past two decades (Figure 8) and in many countries employment in manufacturing has fallen. To some extent these trends are a statistical artefact arising from the fracturing of production in GVCs. Specialisation in core competences by the world’s largest firms has led to information intensive processes in value chains such as design, coordination, marketing being outsourced to firms specialising in services, leaving only the physical transformation of inputs into outputs within the manufacturing sector. However, the employment crisis in manufacturing is larger than this change in industrial structure.

Figure 8: Share of Manufacturing in Global GDP and Employment



Source: UNIDO International Yearbook of Industrial Statistics, 2024

It is likely that this decline in employment in manufacturing and manufacturing related services will be exacerbated in the future as labour saving digital automation technologies and AI are increasingly deployed throughout the advanced economies. Although these developments will raise major challenges for structural change and reskilling, they may contribute to sustainable growth in high income economies faced with an ageing population and growing labour scarcity.

However, the developing world is faced with a different problem. It needs to pursue a path of labour intensive industrialisation and growth to deal with large pools of underemployment, especially amongst the youth, and the increasing migration of people to the cities. It is also driven to use digital technological applications to ensure productivity gains but through the application of newly skilled workers in a collaborative relationship with AI platforms.

Industrialised countries seek AI for labour saving. Developing world with under and unemployment needs AI driven industrial employment growth

These problems caused by declining employment intensity in manufacturing are compounded for low and emerging economies by the restructuring of GVCs. These countries face a number of challenges. First, unlike the leading industrial countries who have a history of large scale employment in manufacturing (and whose challenge is to maintain and revive high levels of manufacturing employment), the challenge confronting low and middle income is to create manufacturing jobs from a low industrial base.

Second, China’s stellar expansion in manufacturing exports which resulted in rapid and sustained income growth and a significant reduction in poverty was made possible by the outsourcing strategies adopted by the corporate sector after the mid 1970s. Replicating the Chinese growth path will be much more difficult in the future due to the growth of protectionism, the reshoring of production and advances in automated production.

The inability of manufacturing to create enough employment to spread the gains of economic growth to the expanding urban populations in developing countries has led to an alarming growth in what has loosely come to be termed the ‘informal sector’, that is employment which occurs in unregulated activities. Whilst some of this informal sector employment provides high incomes (private consultancies, drugs, crime), in most of the world, the livelihoods generated in the informal sector are low and insecure.

The ‘informal sector’ has grown alarmingly particularly in the developing world but also in industrial economies, generating low and precarious livelihoods

Significantly, as can be seen from Table 1, outside of the agricultural sector, more than half of the world’s population in developing economies earn their living in this precarious environment; in Sub-Saharan Africa and Southern and South-Eastern Asia the share is even higher (75 per cent and 64 per cent respectively). Moreover, informalisation is no longer confined to labour markets in low and middle income economies; unemployment (often hidden by welfare payments) and precarity are now widespread in many of the leading industrial economies.

Table 1: Share of the informal economy in non-agricultural employment (most recent year, later than 2012)

	Share of the informal economy in non-agricultural employment
Sub-Saharan Africa	74.5
Western Africa	81.5
Central Africa	78.7
Eastern Africa	71.2
Southern Africa	63.6
Southern & South-Eastern Asia	63.7

Latin America and the Caribbean	54.7
Western Asia	48.8
Northern Africa	48.3
Central Asia	39.1
Transition countries	21.7

Source: Adapted from Charmes, J., 2020. *Research Handbook on Development and the Informal Economy*. Edward Elgar Publishing.

Hence, insofar as the future prospects for achieving equitable and sustainable development in low and middle income economies are linked to employment in general and manufacturing employment in particular, six major conclusions can be drawn:

Developing countries dominated by informal economy. Need manufacturing growth to raise employment. But replicating Chinese and South East Asian path is difficult in the new global economic order

- Without sustained growth in employment in manufacturing it will be difficult to generate adequate incomes to support equitable and sustainable development.
- Without sustained growth in employment in manufacturing governments will find it difficult to fund the infrastructure and skills required for economic growth, provide their populations with the services required to meet their needs and protect their populations from the harms and insecurity resulting from climate variability and climate change.
- The employment intensity of growth – particularly growth in manufacturing – has been falling. Digitally based technological progress in modern industry is labour saving.
- The likely future trajectory of digital automation (robotisation) is likely to exacerbate the decline in the employment intensity of production.
- The 'Chinese model' which was so successful during the period of deepening globalisation (a rapid growth in exports to markets in the global lead economies leading to rising employment in manufacturing) is unlikely to be replicable in the future
- Without an increase in the quantity and quality of employment in the informal sector, it is unlikely that adequate livelihoods can be generated to provide for equitable and sustainable income growth

The brute reality is that the manufacturing sector, as currently composed, is unable to meet the challenges of supporting equitable and sustainable development. Business as Usual is not an option.

The rapidly accelerating environmental crisis

The deployment of the Mass Production paradigm after WW2 saw a marked inflection of the impact of human activity on the environment. Climatologists refer to this as The Great Acceleration. Focusing on long term trends, an international team of earth systems scientists who evidenced the character of the Great Acceleration, identified nine 'Planetary Boundaries'. Six of these had been transgressed by 2023 and the consequences for climate change are evident. The earth is experiencing a rapid growth in disruptive climate change.

Global warming is one important determinant of the negative impact of climate change. Even at a limited 1.5 degree of warming the Intergovernmental Panel on Climate Change (IPCC) anticipates a major disruptive effect on economic and social life (Table 2). At a two degree temperature rise, each of these impacts are magnified considerably. Perhaps even more problematic is that these changes become cumulative and self-reinforcing. Thus, even if corrective actions are taken at some point in the future, changes in the global climate and the biosphere may have become irreversible and self-reinforcing.

Table 2. Projected impacts of global warming at 1.5^{0}C and 2^{0}C

Impact	1.5^{0}C	2^{0}C
Extreme Heat – Global population exposed at least once every 5 years	14%	37%
Arctic Ice – Number of ice free years	1 every 100	1 every 10 years
Sea level rise by 2000	0.4 metres	0.46 metres
Vertebrate species loss	4%	8%
Plant species loss	8%	16%
Area of global land with shift in local ecosystems	7%	13%
Amount of arctic permafrost thaw	4.8m sq kms	6.6m sq kms
Reductions in crop yields in tropics – eg maize	3%	7%
Decline in coral reefs	70-90%	99%
Decline in marine fisheries	1.5m tonnes	3m tonnes

Source: World Resources Institute https://www.wri.org/blog/2018/10/8-things-you-need-know-about-ipcc-15-c-report 24 Feb 2019

The Mass Production paradigm has had major systemic environmental impacts. The accelerating negative impact of the Mass Production paradigm after 1950 was not just a consequence of an increase in the human population and an improvement in living standards.

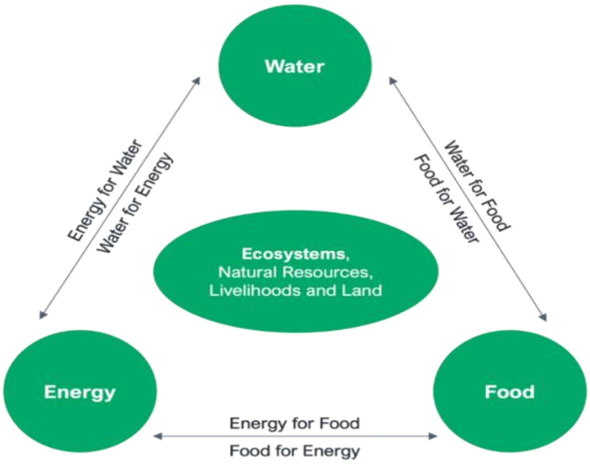
Mass production paradigm has led to environment and climate change crises heavily impacting developing countries

It also reflected the character of the Mass Production paradigm such as the use of non-renewable fossil fuels as a primary source of energy, throwaway, single use consumer goods (especially plastics which are perhaps the biggest environmental threat), individualised consumption rather than the collective use of public consumer goods and the externalisation of negative externalities in the pricing system. Each of these adverse drivers of environmental impact reflects a societal choice, as well as the intrinsic character of the technologies central to Mass Production, notably individualised, fossil-fuel automobilisation.

The unfolding environmental crisis has important implications for low and middle income economies. The dependence on hydrocarbons for production and transport has been a direct cause of climate change raising global temperatures and disrupting and creating unpredictable weather and rainfall patterns, as well as the increasing frequency of extreme events (such as flooding, droughts and wildfires). Floods have devastating effects on households, agriculture and the built environment, washing away or damaging crops, key infrastructure (such as roads, bridges, schools, hospital and telecommunication infrastructure), and disrupting service delivery. Although the effects of these adverse climatic events are not confined to low and middle income countries (witness the fires in Los Angeles in 2024), in general it is the poorer members of the population who most suffer the consequences because they lack the resources needed to enhance their coping capacities and resilience.

Agriculture is negatively affected by climate changes and an increasing variability of climate ('climate chaos)'. This has led to significant rural urban migration and an increase in population in urban conurbations. Cities in developing countries have not had the residential infrastructure to cope with increases in urban populations. Large areas of land on the urban peripheries are dominated by informal settlements putting a massive strain on available water, sanitation and energy infrastructure, exacerbated by a major deficit in investment for necessary maintenance as well as providing new infrastructure. Agriculture has struggled to meet urban food demand and food insecurity has become a major issue in many developing countries.

The crises of water, energy, food security, and ecosystem health – known as the WEFE nexus – result in the acceleration of resource scarcity in many developing countries. However, if they managed to engage in nexus informed policy interventions based on interconnected and interrelated development decision making and governance processes, then they would be able to navigate towards resource security. This would require abandoning government silo approaches focused solely on sector decision making, in favour of optimising synergies and minimising trade-offs.



Migration from the countryside has also led to an increase in global migration, a key factor driving the growth of protectionism in the major consuming markets which facilitated export led growth in China and other low and middle income economies.

Thus, climate change has a number of consequences which undermine the capacity to achieve more equitable and sustainable growth in low and middle income economies:

- Climate change is not just a consequence of increasing population. it reflects the manner in which society is organised. There are elements of the Mass Production paradigm which have fed directly into the exacerbation of climate damaging forms of production, lifestyles and social organisation.
- Climate change leads to a reduction in agricultural production, not just reducing economic growth, but also eroding national self-sufficiency thus undermining food security.
- One of the major consequences of climate change is a disruption to the availability and flow of water which is not just a key input into agriculture but also affects production in industry, energy reliability and sustainable livelihoods throughout the economy.
- Climate change and climate variability lead to an increase in extreme environmental events. This not only threatens economies and livelihoods, but has a disproportionate impact on the poorer members of society
- Climate change is often linked to social conflict and economic crisis which contributes to mass migrations, within and between countries, increasing the pressures in urban conurbations and affecting political processes within countries. in some cases these political impacts further erode the sustainability of the global rules based order which developed in the regulation of the Mass Production paradigm.

In summary, climate change is a factor of extreme and urgent relevance to equity and social and political sustainability. Perhaps more than any other factor, it forces policy makers to confront the reality that Business as Usual is not sustainable.

Geopolitical changes and the rise of new hegemons

2025 is a pivotal year, ushering in a period of major disruption to the global economy, as the second Trump Administration retreats from the rules based neoliberal global order which developed after the post-war Bretton-Woods Conference. This disruptive inflection should not be a surprise. As we have observed, the postwar global order developed to serve the needs of the Mass Production paradigm. But as this paradigm has become increasingly exhausted, so it is to be expected that the framing conditions for global growth will change.

Each of the four preceding paradigms were dominated by a hegemonic country defining the ‘rules of the game’ for related and competing economies. The first three paradigms (the water based wave; the second wave based on steam power and the third relying on heavy engineering, steel and telegraphy) were dominated by Britain. The power of hegemony was particularly marked during the third wave in the second half of the nineteenth century when rapidly growing manufacturing in England required raw materials and a market for its output. The Royal Navy 'ruled the waves' and policed maritime trade routes; ports were built to facilitate trade; and the British Empire spread in Africa and Asia (400m people were added to the Empire between 1815 and 1915). Countries were forced to adopt laissez faire policies of free trade, effectively 'kicking away the ladder' of protected industrial development which Britain and other pioneering industrialising economies had used to promote their own industrial development.[24] The dominance of Britain during the nineteenth century is referred to as an era of *Pax Britannia*.

During the twentieth century, Britain ceased to be the hegemonic power. After two decades of protectionism and war, the mantle of supervising the spread of free trade and laissez faire policies globally was passed on to the new global hegemon, the USA. Although the USA was not the only large dominating economy (until the late 1980s its power was challenged by the Soviet Union), it was unquestionably the dominant global power. It was able to construct a global trading regime to meet the needs of the Mass Production Paradigm which it dominated. Initially FDI by American firms in the pursuit of markets clashed with the import substituting industrial policy pursued by most developing countries seeking to grow their domestic industrial base behind tariff walls. However, as US lead firms sought to outsource and offshore parts of production to low cost locations this radically altered the relationship between the US and the developing world. The need to exploit cheap labour fuelled the development of global supply chains and the growth of export oriented industries in selected developing economies – initially the Asian Tigers but then spreading to China and other countries. The global dispersion of production accelerated by? a neoliberal policy agenda of free trade, privatisation and the erosion of industrial policy. The Washington Consensus was deployed widely, partly through interventions by the IMF, the World Bank and bilateral aid agencies. A new rules based global order was constructed as a framework in which investment and trade could be expanded. The nineteenth century was the era of *Pax Britannia*, the twentieth century was one of *Pax Americana*.

The USA played the key role in creating the global framework for the spread of GVCs in the era of Deep Globalisation

How did developing economies fit into this evolving and 'supervised' global order? During *Pax Britannia*, their primary role was to provide the raw materials to fuel the growth of manufacturing in Europe and as a market for the European finished goods. In the twentieth century, the era of *Pax Americana,* these historic functions were supplemented when some low income economies (primarily in East Asia but subsequently also in Central America and North Africa) became low labour cost export platforms operating within GVCs.

Towards the end of the twentieth century, the hegemonic power of the USA was increasingly challenged by a new large and dynamic economy with its own distinctive rules of engagement. China's presence grew increasingly powerful. The bridgehead for its growing global expansion was developing economies - Africa, Asia and Latin America. Initially China's operations in these economies was directed to provide the raw materials to feed China's manufacturing sector. The Belt and Road Initiative was designed to improve the infrastructure required to ship raw materials to China. But it is also intended as a route to open up final markets to Chinese exports.

China's stellar growth was built on a focused and effective Industrial Policy and involved extensive use of state investment and trade restrictions – a sharp contrast to the neoliberal Washington Consensus agenda. Although a quasi-formal Beijing-Consensus had not been constructed, the demonstration effect of China's policy success played a vital role in allowing for the development of a new policy consensus favouring industrial policy and focused protectionism. Ironically, the new orthodoxy has spread from the south to the major OECD economies. Industrial Policy and protectionism are now centre stage.

Geopolitical developments in early 2025 are very fluid. Policies introduced by the second Trump administration are highly interventionist (and erratic) and this has radically altered many of the accepted global trading regulatory pacts, broken trust that the US is the guarantor of the long established rules based regulatory regime, upset longstanding diplomatic and political alliances, overturned established development cooperation practices, disrupted international institutional arrangements, and weakened many international agreements to counter climate change. The rules based regulatory trade regime underpinned the Mass Production paradigm, especially its extension into globalisation and GVCs. It may well be possible that a post Trump US will help to rebuild a consensus on a new rules based regime, but it will be much harder to create the level of trust invested in it over the last seventy years. These geopolitical development will further reinforce the fracturing of the Mass Production paradigm and make a return to Business as Usual more difficult.

New global players have entered. A new global multipolar order is emerging, with strengthened regionalisation, further fracturing mass production paradigm and making Business as Usual to achieve equitable and sustainable growth more untenable

It is possible that the world economy will transition into major economic and trading blocs – the US with its 'friendshoring' economies; Europe in large parts of Africa; China with its surrounding economies and with a growing trade presence in Latin America and Africa. The positioning of other large middle income economies such as India, Brazil, Turkey and Indonesia is still unclear. However, the trajectory of trade growth is likely to shift from the predominantly south-north pattern which was reflected in the growth of GVCs over the past four decades and which led to rapid growth in some low and middle income economies, particularly those in east Asia.

What implications does this changing geopolitical environment from a unipolar to a multipolar world have for the capacity of low and middle income economies to pursue equitable and sustainable growth?

- New policy spaces have opened, legitimising a more active role for the state in industrial policy, in trade policy and in state-owned industries
- In many respects, a new powerful hegemon, China, has more relevant experience of industrial and trade policy than the USA and other leading global economies. India's growing presence provides another point of reference and potential source of support for other low and middle income economies
- Regionalisation will be strengthened, as existing regional blocs look inwards. Within these regional blocs, 'economic hub' economies such as Nigeria and South Africa in Africa will play an important role in the promotion of intra-regional trade.
- Low and middle income countries now operate in a multipolar world, with more bargaining power to achieve assistance and trade concessions from regional hegemons.

The sharp turnaround in US policy in 2025 is thus a major point of disruption. It complements the redirection of trade which we observed earlier and offers new policy space to low and middle income countries. With the withdrawal and reduction of aid flows from the US and Europe in 2025, it is another reason by the pursuit of equitable and sustainable growth cannot be achieved by following a Business as Usual strategy.

5. BEYOND BUSINESS AS USUAL – TURNING THREAT INTO OPPORTUNITY

As we observed earlier, each of the long waves is driven by a major general purpose technology. These revolutionary technologies provide very substantial benefits to innovators; have a trajectory of dramatic falling prices; the expectation that improvements in price and performance will continue in the future; have no supply constraints; and, crucially, have pervasive applications generally throughout the economy *and society.* In each case, the new revolutionary technology is invented whilst the old wave begins to lose its dynamism. Once its potential becomes recognised the technology diffuses through pioneering firms and sectors. After a period of considerable economic, social and political disruption – which is inevitable given the revolutionary and systemic character of the new wave – the technology is deployed and spreads throughout the system. A period of prosperity follows with the different components – economic, social and political – synergistically reinforcing each other.

The wave which we are now exiting - Mass Production - was 'invented' by Henry Ford in the early Twentieth Century. Its inception phase in which the technology was introduced by pioneering innovators occurred during the 1920s. Investor frenzy in the new technology led to a stock market bubble and depression during the 1930s. But during WW2 mass production grew of age and was deployed throughout the American and then European economies. Economists refer to this era of widespread growth as The Golden Age, which flourished between 1950 and the mid 1970s, after which through its expansion in the era of globalisation and GVCs it began to mature and finally by the end of the century begin to atrophy.

The new ICT general purpose technology which supersedes mass production depended on four key inventions – the solid-state transistor in 1947; the programmable multi-transistor chip in 1971 (the integrated circuit); the introduction of the internet in the 1990s; and currently the artificial intelligence revolution which is sweeping through the economy and society.

The challenges which low and middle income economies are now confronting – outlined in the previous section – reflect this disruptive stage as the two paradigms clash. To begin with it is necessary to identify the key elements of the ICT technology and to contrast it with the central characteristics of the old Mass Production system. ICT technologies have a number of critical components which differentiate it from Mass Production. (Figure 9).

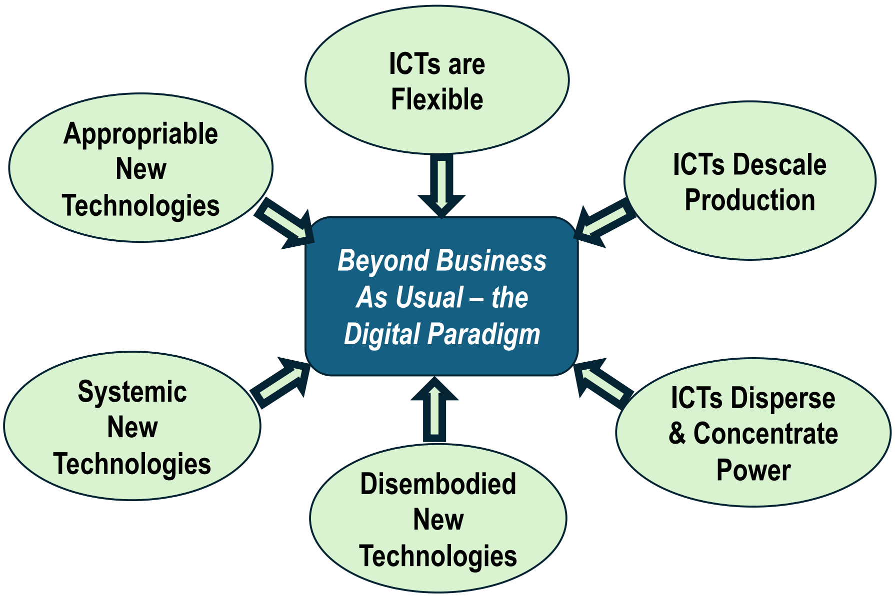
Figure 9. The contrast between Mass Production and Digital Technologies

	Mass Production Paradigm		Digital Paradigm	
Characteristic	**Definition**	**Examples**	**Definition**	**Examples**
Variety	Standardised products, specialised machinery	Model T Ford Dedicated pick-and-place assembly machines	Differentiated and customised products, Flexible machinery	Made-to-order photo albums Programmable robotic assembly and warehousing
Scale	Large scale Scale as entry barrier Standardised products	Large scale nuclear and hydro energy	Smaller scale plants, modular expansion	Small modular nuclear reactors, SPV and wind renewable energy
Location	Large plants maximising economies of scale Production and consumption separated	Global Value Chains and cities dedicated to production of single sector products	Flexible production reduces geographical distance between production and consumption	Nearshoring regional value chains

Power and control	Central state Taylorist work organisation	Top down ministerial budget allocation Quality control at end of production line	Regional government Worker-oriented continuous improvement	Citizen assembly budget allocation Total Quality Control, kaizen
Hard and soft automation	Knowledge embedded in machine	Fixed line telephony	Reprogrammable products and machinery	Mobile phone updates
Connectivity	Standalone machinery – 'mechanisation'	Individual stamping machines and lathes	Flexible manufacturing systems	Digitally controlled Flexible Manufacturing Systems (FMS)
Appropriation	Patents, replication involves new machinery	Films in cinemas	Copyright Replication costless	Films through streaming

Mass Production is in crisis and the Digital Paradigm is deploying rapidly. This transition provides the potential to create a new Golden Age. But whether this can be realised depends on how societies and political systems react to the new possibilities opened up by the new Digital Paradigm. It is to this agenda which we now turn with a specific focus on ushering in an era of more equitable and sustainable growth in the developing world (Figure 10).

Figure 10: Beyond Business as Usual – The Digital Paradigm



ICTs are flexible.

Flexibility of ICTs makes it easier to meet a wider range of uses and productive environments

When he invented mass production Henry Ford boasted that '*you can have a Model T Ford in any colour you like as long as it is black*'. His moving production line involved the specialisation of task and product, using special purpose inflexible machinery. In contrast, ICTs are inherently flexible and, very importantly, are reprogrammable. Robotic machinery is capable of performing several tasks and can be reprogrammed to do so. Products can be reprogrammed so instead of discarding an outdated product, it can be reconfigured to meet existing and new needs. Remote monitoring can make it easier to diagnose and repair faulty equipment and products. Enhanced flexibility also provides the capability to meet a greater variety of individual needs even whilst producing at scale, sometimes referred to as *mass customisation*.

Additive manufacturing (3D printing), which is able to produce one-offs, lies at the extreme end the spectrum of flexibility. However, it is highly unlikely that bespoke production will be widely used across the manufacturing sector. Instead, it will primarily be used to manufacture products required in very small numbers and spares (including replacement ‘parts’ for the human body!). These products are highly specific, often of high value and may be required at very short notice. But whilst 3D printing shows the extreme potential of flexible production, other ICT based technologies (such as robotisation and inventory control) offer an enhanced degree of flexibility – not single unit production *or* mass production but varying degrees of flexibility across the spectrum of economic and social activity.

In summary from the perspective of promoting more equitable and sustainable development, the crucial impacts of enhanced flexibility are the capacity to tailor innovations to meet a wider range of user needs, and to adjust to a wider range of productive environments.

ICTs are descaling of production

> ***Descaling production promotes more distributed production, brings production closer to consumption, and lowers entry barriers for SMEs***

The flexibility of ICTs has important impacts on the scale of production. The inflexibility of mass production and the heavy investments in dedicated special purpose machinery meant that economies of scale in plant size were critical. Factories became ever larger. There was a drive to scale across the system. A similar process was true for suppliers in the value chain. This imperative to large scale meant that industrial concentration was central to mass production. At the extreme end of the scale-spectrum, the economic benefits of very large plants resulted in ‘world factories’ shipping their products across the oceans to meet customer demand in world markets. In the extreme case, almost all of the global production of a particular item was concentrated in a single city. For example in 2020, 5,000 footwear firms in JinJiang in China employed more than 500,000 workers and produced 20 per cent of global production of sports shoes and sneakers[25].

This division of labour – large plants producing for large, distant and relatively undifferentiated markets – was a characteristic of late phase of Mass Production’s evolution. Production was located in China for consumption in North America and Europe. Similar process of concentration emerged within economies. Production, consumption and residence were increasingly dislocated, goods were transported across the economy, and many people commuted long distances to work. These centrifugalising forces have been a core component of industrial societies since the onset of the Industrial Revolution. The infrastructure required to support these developments transitioned from canals to railways, from railways to bulk carrying steamships, and from steamships to air and containerised shipping.

It was not just production that was centralised. So too was much of infrastructure. This was particularly the case in respect to power generation. Electricity was produced in large plants and distributed around the economy with a considerable amount of power loss. In the most extreme cases, electricity was generated in massive, high cost and environmentally degrading hydroelectric plants. The reliance on fixed deposits of geographically concentrated fossil fuels involved a further degree of dislocation between production, and consumption with environmentally damaging ships transporting coal and oil across the globe.

Whereas Mass Production involved a centrifugal trajectory (production spreading to the periphery), the Digital Paradigm enables a centripetal trajectory (production located closer to consumption). Staying with the example of power generation, renewable energy technologies (which are centrally dependent on ICT technologies), provide greater scope for bringing production and consumption closer together. Moreover, renewables are also less susceptible to cost over runs and delay and are more scalable. This further facilitates the decentralisation of production and power. Recent heavy investments in small modular nuclear reactors are an indicator of the increasing logic of descaled production.

The capacity to descale production has very significant implications for the promotion of more equitable and sustainable development. It provides the capacity for a more distributed productive sector, both within and between countries. It reduces the need for energy intensive transport since production and consumption can be brought closer together. Smaller scale production can also lower barriers to entry for small scale and micro enterprises.

ICTs both disperse and concentrate power

Henry Ford drew on the structure of work organisation schema produced by F. W. Taylor which differentiated tasks in production and introduced a hierarchical pattern of specialisation. Decisions were made at the top of the pyramid and passed down – worker autonomy was limited. A similar configuration of top down authority came to be the dominant pattern in a wide range of social and political institutions. In all these cases, information was fed up the system (often with increasing error as it ascended the decision scale) and instructions were passed down to the operating level. Horizontal flows of information were generally minimised, as was decentralised autonomy in decision making. As in the case of scale, we are observing trends across a spectrum rather than absolute states of behaviour.

Digital technology provides the potential for a rather different and less hierarchical form of governance and institutional design. Just as the flexibility of the technology enables a greater variety of production processes and products, so too do ICTs provide the potential for more distributed and differentiated forms of governance and service design and delivery. The systemic nature of information capture and communication provides much greater scope for horizontal interactions – not all information and instructions need to be communicated vertically. Moreover, the integrity of information is often more reliable than in paper based systems and is available in real time. Handheld devices put this information at the disposal of many more people, allowing for decentralised decision-making. Horizontal transmission of information also empowers social interactions, and ICT based social media provide the opportunity and glue for local action.

ICTs create opportunity to disperse and localise power

This capacity to disperse power across production and society reinforces the capacity to descale production. It opens the possibility for the localisation of power and decision making, reinforcing the possibilities opened up by more flexible production technologies.

Nevertheless, whilst ICTs do provide the capacity for greater decentralisation and devolution of power, at the same time they enhance the capacity for centralised control. This affects not just the social sphere – for example, CCTV and face recognition can reinforce the Big Brother State – but it is also evidenced at the economic level. Economic power is being increasingly concentrated, most notably in the high tech ICT sector. In the US, the *Magnificent Seven* (Apple, Nvidia, Microsoft, Amazon, Alphabet, Meta and Tesla) have accounted for almost all the gains in the appreciation of stock exchange values over the past five years. Many commentators of the ICT revolution accuse these mega-corporations of acquiring new innovative firms in order to stifle rather than to promote innovation. The mega-firms dominating the global corporate economy are currently all based in the US, but there is evidence of similarly large firms developing in China.

Hence, the transition to the Digital Paradigm is simultaneously redolent in pressures towards descaling (in production, in institutional design and in social interaction) and concentration (in ownership and political influence). It provides enhanced potential for decentralised patterns of governance – for example there is greater scope for regional and district industrial policies.

The capacity provided for enhanced horizontal flows of information strengthens the capacity for localised based enterprises - such as in regard to distributed energy generation for municipal level, or residentially communal, or entire shopping mall, or even individual householder based energy provision.

New technologies are increasingly disembodied

Each of the four paradigms preceding the ICT wave increased productivity in manufacturing by substituting inanimate power for human power. Water mills mechanised human-paced weaving; steam power was not just more powerful than waterpower but also allowed mechanisation to be spread away from sources of running water; electricity (from the late 19th Century) meant that individual machines could be mechanised independently. During Mass Production in the 20th Century the generalisation of electric power and the internal combustion engine, allied to changes in the organisation of production, vastly improved manufacturing productivity. Thus, over the past three centuries, directly and indirectly, sources of inanimate power substituted for human power, with increased effectiveness. This increased productivity and fuelled the growth of industrialisation, leading to the vast improvement in human welfare.

ICTs demand new skills and institutions to take advantage of the new digital opportunities

The digital revolution is of a fundamentally different order. In the preceding paradigms productivity was enhanced by improvements in the application of inanimate physical power. Human skills and hard wired 'baked-in' controls set machinery in motion and guided its progress. But each of these control-mechanisms faced natural constraints – skills could be improved, but only incrementally; machine controls could be improved, but only at the stage of machine construction. The digital revolution has freed production from these constraints and transformed these processes of machine control.[26] In the extreme form of 'Artificial Intelligence', machine learning algorithms lead to improvements in productivity without any increase in the skills of workers operating the machines, and without the need to stop the machinery and introduce new hard wired control mechanisms.

A particularly important consequence of the growing dominance of disembodied technologies is its impact on skills and income distribution. As a general rule, digital technologies require wholly different skills to embodied technologies, and this characteristically has major impacts on patterns of employment and on relative wages. 'Blue collar' wages have fallen as college-educated 'white collar' salaries have increased; younger workers with digital skills have gained at the expense of older workers; in many cases, a reduction in the need for physical force (electronic typesetting rather than hot metal typesetting) has also allowed for greater participation of women in the labour force.

This transition from hard to soft technology has changed the locus of productivity growth from the factory floor to the office and from the manufacturing sector to the service sector. It is one of the reasons - but not the only reason - why employment in manufacturing has fallen (coterminous with a non-commensurate increase in employment in the service sector). It is one of the factors which explains the rising power of The Magnificent Seven and other large digital mega corporations. And it is one of the reasons why despite a significant growth in employment in exporting developing economies, the fruits of industrial growth continue to be appropriated by high income countries where the disembodied digital technologies have been developed.

The economies most likely to make the transition to more equitable and sustainable development will be those which have developed the skills and the institutions and routines required to take maximum advantage of the opportunities opened by the transition from embodied to disembodied technologies. Since many low and middle income economies are not saddled with the legacy of skills required to operate the mass production economy, and have a plethora of youth who are more digitally knowledgeable and also lower cost relative to advanced economy workers, in some respects they may be advantaged by the transition to economies which are more reliant on disembodied skills.

The new technologies are inherently systemic

ICTs are built on digital logic systems. Digital systems enable all data to be recorded and analysed in binary terms.[27] ICTs handle these binary ‘bits’ through the interrupted flow of electrons and light, with enormous speed and with growing efficiency. Critically, since all systems use this common digital language, it is possible for different digital equipment to speak a common language and communicate with immediacy and accuracy, at very low cost.

In the manufacturing sector, these systemic gains were initially confined to individual machines (intra-activity digitalisation), then to what is termed ‘intra-sphere digitalisation (within design, coordination and manufacture), and ultimately to ‘inter-sphere’ digitalisation (the integrated firm).[28] The development of the internet from the mid 1980s provided the capability to interface digital equipment over very long distances, thereby facilitating the expansion of GVCs. It also enabled the outsourcing of knowledge intensive systems from manufacturing to the service sector.

Soon after the millennium, these systemic gains were no longer confined to production processes but allowed an interface between digitally controlled products as well. The Internet-of-Things (IoT) has come of age, and we can now observe the emergence of an industrial system which integrates conception and design with production, logistics, use and disposal. These interconnected digital systems are not confined to the world of production. They also permeate the social and governance spheres, including in the explosion in social media and horizontal flows of information across society.

New digital interconnected systems create opportunities to enhance productivity, employment and sustainable and equitable growth

Thus, interconnected digitally based systems are omnipresent, including in low and middle income countries. As the case studies in Section 6 show they provide the potential to enhance equitable and sustainable growth. But crucially the capacity to reap these gains will depend on the capacity to access the internet. In this respect the rapidly growth of low orbit, satellite internet connectivity provides the potential for a globally connected population. It will be much easier for those living in distant rural areas and nomadic populations to be connected to national, and in some cases global production systems and knowledge bases, and to connect with others with similar interests and to customers. This offers the capacity to reinforce descaled and decentralised production, service provision and general living.

The new technologies involve different patterns of appropriability

Physical, tangible innovations are appropriable. They are ‘private goods’ – one person or an operating unit can use it at a time, and (with varying degrees of ‘life’) these products are used up in consumption. Characteristically they are owned, and their use is restricted. Ownership also extends to intellectual property which is routinely protected through a range of well developed intellectual property rights such as patents. Replications of the technology are costly; if additional units are required, they need to be physically created.

The new digital technologies create opportunities to expand public goods

Intangible innovations have very different characteristics, and unlike embodied technologies, are more akin to public goods. For one thing they are not used up in consumption and unlike tangible technologies, the marginal costs of reproduction are often almost costless.[29] Intangible technologies are much more difficult to appropriate, since their lack of physicality makes it difficult for someone to own them and thereby to restrict use. The property rights required to balance the incentive to innovation in knowledge intensive technologies with the need to protect social interest pose new challenges and are much more complex. This shows up in the very large profits which have been earned by some high tech firms such as The Magnificent Seven.

Digital technologies require investments in intellectual property rights. The digital divide must be addressed to provide access for all and achieve equity, employment, economic growth and a sustainable environment

These developments pose challenges to equitable and sustainable growth, particularly in low and middle income economies. One the one hand, the physical barriers to entry are low and disembodied technologies are relatively easily replicated. The absence of traditional skills, honed in decades of manufacturing production, are no longer such a constraint to countries with low levels of industry. But on the other hand, the new ICT based disembodied technologies are increasingly protected by copyright and other forms of IPRs, and the skills based barriers to entry can often be formidable.

6. NICHE INNOVATIONS

Economic historians documenting the transition between paradigms identify the key role played by 'niche innovations'[30]. These represent isolated innovations driven by local needs and circumstances. They draw on the advantages conferred by the general purpose technologies which will power the incoming paradigm. They illustrate the potential of the new wave and act as role models for future investments in the economy and society. Critically, these niche innovations are not just technological in nature, and they are not limited to hardware. They also require changes in institutional design, in behaviour and in the actions required by a range of social parties.

We now describe ten *niche innovations which illustrate the potential of the new Digital Paradigm to provide for a more equitable and sustainable trajectory of development.* The majority of these innovations occur in low and middle income economies. To a greater or lesser extent, directly and indirectly, each of these niche innovations are critically reliant on digital technologies. In different ways, each draws on the contribution which digital technologies offer in the construction of a more equitable and sustainable economy and society (Figure 11). They are:

- Mobile telephony. This case study highlights the contribution made to greater inclusion of poorer citizens, women, rural households and distant and inaccessible regions.
- Greening industrialisation in Africa illustrates the win-win benefits made possible through the adoption of environmentally friendly investments. Retrofitting in legacy systems and investments in new green systems contribute to growth in the economy, in employment and in exports.
- The global surge in renewable energy especially rooftop solar illustrates the disruptive shift towards decentralised energy and the breakup of highly centralised electricity generation monopolies.
- The introduction of green hydrogen powered steel production in Brazil illustrates the growth opportunities provided in the green economy and the synergies between renewable energy and the minerals sector. It also shows how the decentralised production of renewables can contribute to the development of relatively impoverished regions of the country and the importance of collaboration between government and the private sector.

- The introduction of Smart Cities programmes is centrally dependent on the synergies offered through connecting digitally based technologies and data bases. It illustrates how digital systems can cut the costs of service delivery and enhance consumer access to services. AI is becoming a major focus of innovation in these programmes. However, a critical gap in these Smart Cities programmes is that they are directed towards service provision (and potentially surveillance). Outside of the gig economy, there are few indications that existing Smart City programmes enhance production and support the generation of livelihoods for low income households.
- A combination of renewable energy generation and smart energy management by household users in South Africa reduces household energy costs, minimises the harmful impact of intermittent and unreliable energy supply, and allows for the efficient balancing of demand and supply of energy. This system is enabled by the diffusion of IoTs in the home. It places control over energy supply and usage within households rather than utility suppliers, exemplifying the role that users can play in the transition to a more sustainable paradigm. It also highlights the central role to be played by national and local governments in the reshaping of the energy market.
- The growth of south-south trade is important in the context of growing obstacles to south-north exports and the emerging trend towards greater regional integration. South-south trade in capital goods promotes the diffusion of more appropriate labour intensive technologies, with enhanced opportunities for greater inclusion and decentralised production. On the negative side south-south trade illustrates the dangers of a trade-off between inclusive growth and environmental degradation.
- Stockholm’s district heating programme illustrates how the collective provision of public goods is made possible by the transition to renewable energy. It highlights the critical role played by national and local government in the transition to a more environmentally sustainable world.
- In the face of the disruption caused by climate change, the agricultural and food sector is forced into making significant innovations across the value chain. ICTs play an important role in each of the links in this chain. Not only do these innovations enhance resilience and improve productivity within each off these chain links, but they also allow for the reaping of systemic gains. Without the adoption of Smart Agricultural innovations, the world’s most vulnerable poor farmers will suffer substantial harm as climate change progresses.
- Drones are playing an increasingly important role in the monitoring and construction of infrastructure, in the retail sector, in the health sector and in disaster management. This not only improves productivity in a range of sectors but plays a particularly important role in promoting equity by serving the needs of producers and consumers in remote and inaccessible areas.

Each of these case studies is relevant to low and middle income countries. They illustrate the opportunity which developing economies have to leapfrog the legacy systems which dominate in the industrialised world. In Section 8 of this Report we will address the policy route to realising the potential offered by these niche innovations to foster a more sustainable and equitable trajectory of development.

Figure 11: Summary of Ten Niche Innovations in Relation to the Digital Paradigm

Niche Innovation	Description - Meaning for Digital Paradigm	Key Messages	Digital Paradigm Principles
Mobile Telephony	Low cost distributed access to finance for poor, lower income, women, rural households, distant regions. Linked to low cost solar energy. Supported by government and banks. Raised employment and entrepreneurship. Broadens access to education and training. Allowed escape from bureaucratic administrative procedures	• Driven inclusiveness • Public/private support key • Widened digital spread • Raised education/skills • Productivity gains facilitated	• Flexibility • Descaling • Dispersion • Disembodied • Systemic • Appropriation
Green Industrialisation	Showed green investment innovations can synchronise with economic growth/profitability. Can retrofit green investment/innovations. Government support in three industrial zones in Tunisia to integrate resource efficiency and adopt global environmental management standards. In an Ethiopian industrial park green policy across value chain led to increased growth and exports.	• Private sector engagement critical • Environmental investments yielded economic benefits • State support through green industrial policy was key	• Descaling • Dispersion • Systemic
Solar Renewable Energy growth	Illustrates exponential global growth of solar renewable energy (RE) generation and battery storage. Shows benefits of disruptive shift towards decentralised energy and breakup of centralised electricity generation monopolies. Growth is in both advanced and developing economies. Scale increases in market demand creates local manufacturing potential.	• Private sector plays key role • Economic needs drives solar • Dynamic now exponential • Government support critical • RE led to inclusive growth • Scale facilitates localisation	• Flexibility • Descaling • Dispersion • Disembodied • Systemic
Green Hydrogen	Green hydrogen driven steel plant in Brazil aimed to reduce climate damage. Projected to have spin off benefits for supply chain and local port. Shows fusion between RE and decentralised industrial development	• Collaboration between public and private sector critical • Green can be profitable	• Descaling • Dispersion Systemic
Smart Cities	Connecting digital technologies and data bases cuts service delivery costs and enhances consumer access to social services. Can enhance production and generate livelihoods for poor and marginalized. Smart cities in developing countries catching up with India good example. Depend on software which creates comparative advantage.	• Public/private collaboration critical • Government intervention key • Go beyond department silos • Need to go beyond service delivery to economic activity	• Flexibility • Descaling • Dispersion • Systemic
ICT/Solar Smart Energy Demand Management	Enabled by rooftop solar and home diffusion of IoTs. Households control energy supply and usage, significantly reduces energy costs. Can assist cities and utilities efficiently manage demand. Central role for government in reshaping of the energy market. Sidesteps mass	• Demand not supply driven • Smart balancing RE demand & supply • Drives decentralised/distributed RE	• Flexibility • Descaling • Dispersion

	production paradigm for energy. Uses local assembly manufacturing to enable flexibility in innovation.	• Enables circular economy • Private sector driven. • Government facilitative role	• Disembodied • Systemic
South-South Trade	Less standards intensive aimed at lower income consumers in developing countries. Allowed for integration of small enterprises in supply chains. South-South products cheaper but lower quality. Promoted the diffusion of more appropriate labour intensive technologies. Enhanced opportunities for greater inclusion and decentralised production.	• Greater regional integration • Inclusive for small firms • Promotes labour intensity • Grows maintenance/repair • Decentralised production	• Descaling • Dispersion • Appropriation • Systemic
Stockholm District Heating and Cooling	Collective provision of public goods made possible by RE. Heavy reliance on RE generated through circular economy. Led to similar air cooling system. Enhanced through applying digital technologies.	• Critical role by national and local government	• Descaling • Dispersion • Disembodied • Appropriation • Systemic
Climate Smart Technologies Agriculture and Agri Processing	ICT technologies enhance resilience and improve productivity across the food chain. Digitisation, particularly in agri-processing, enables systemic improvements. Projects (Slovenia and Ghana) reduced energy demands and emissions, water usage, climate change adaptation, enhanced supply chain productivity, educated farmers,	• Helps small farmers • Government and NGOs key • Regional organization finance/education • Inclusive of rural poor	• Descaling • Dispersion • Disembodied • Systemic
Drone Technologies	ICT drone technologies key role in monitoring, constructing infrastructure, and improving productivity across sectors. Allows delivery to producers/consumers in remote and inaccessible areas. India expanding drone usage and production. Local industry grown substantially.	• Equity in services delivery across regions and sectors • Government policy critical • Government incentives and regulation key to develop local industry	• Flexibility • Descaling • Dispersion • Disembodied • Appropriation • Systemic

Mobile Telephones Transform the Financial Sector and Facilitate Inclusion

One of the most important arenas of digital innovation has been the development of mobile telephony. This not only provides low cost access to verbal communications and to the transfer of data, but it does so in a manner which transforms the communications infrastructure. The fixed line telephones which revolutionised communications after the late 19th century operated through a centralised and hard wired grid. This required the construction of costly transmission lines and consequently often excluded isolated and distant consumers from access to communication channels. By contrast mobile telephony provides access on a much more distributed scale, without the need for costly hard-wired interconnections.

Low and middle income economies had lagged behind in pre-digital fixed line telephony. The development of digital mobile phones enabled many low and middle income economies to close this gap in communication technology to leapfrog high income economies with legacy systems. A case in point is the development of mobile phones to bypass the formal banking system and to make payments by phone. Mpesa (pesa means money in Swahili) was pioneered in Kenya in 2007 and has diffused rapidly to other economies, including Egypt, Lesotho, Mozambique, South Africa and Tanzania in Africa; Afghanistan and India in Asia; and Romania and Albania in Eastern Europe. This pioneering innovation in mobile money transfer was followed by linking this payments system to a rental and higher purchase system for solar power, TVs and refrigerators (Mkopa), and has been central to the supply, monitoring and payment systems of utilities in large urban conurbations of low income consumers. These payment systems allow for decentralised access to the services (including in distant rural areas) which have traditionally been provided by (urban based) centralised systems.

Mobile telephony has had a wide range of economic benefits, promoting greater inclusion, employment and economic growth. In Kenya, where mobile payments systems were invented, It has been particularly important in enabling people in distant rural areas to participate in the economy and to solidify social networks as family members have migrated to urban areas. It also played a major role in supporting remittances from urban areas to rural areas, and (with international migration) from migrants abroad to their families of origin. The rate of uptake of mobile banking has been highest in low income households and the proportion of households completely excluded from financial intermediation fell from 41 per cent in 2006 to 17 per cent in 2016. An important transformative characteristic has been that a high proportion of users are women, live in rural areas and are relatively less well educated. Reflecting the character of this customer base, mobile banking is predominantly used for small payments. Although in 2014 it accounted for only seven percent of total national payments value, this comprised two thirds of total financial transactions.

Government played a critical role in the development of mobile money technology in Kenya. The Kenyan Central Bank quickly recognised the advantages of mobile banking and resisted the pressures exerted by the formal banks to limit the Mpesa payment system. A number of new regulatory measures were introduced to protect the mobile banking sector from money laundering and related potential problems.

Mobile telephony has had a wide ranging impact in low and middle income economies:

- It has supported employment generation, not only though growth in the national and local economies, but the communications sector itself
- It has supported the rapid growth of the informal gig-economy, especially in providing hope and opportunities to the large number of digitally accomplished youth
- It has empowered entrepreneurs to tap into global value chains, facilitating exports and easing the import of inputs and cheap consumer goods.
- Telemedicine is beginning to have a major impact on health outcomes, including in rural areas which were previously cut off from health provision. Mobile phones aid disease surveillance and facilitate a rapid response to disease outbreaks.

- Mobile technology provides important opportunities for deepening and broadening access to education and skills development. Education can be delivered remotely through on-line learning; the internet provides access to much of the world's accumulated knowledge and widens the access of students to a range of educational subjects. Teachers in remote areas can gain access to previously unavailable resources
- Digital telephony increasingly facilitates employment, productivity and output growth in the agricultural sector in low income economies. But this is a rapidly changing innovation frontier. It enables the more targeted use of fertiliser and pesticides, and poor farmers in distant areas can obtain advice on disease control. It also allows farmers to access input and final markets and to arbitrage between markets to obtain the best prices.
- In urban low income conurbations, mobile phones provide the capacity to settle bills in small increments (pay-by-use) and to escape from previously heavily bureaucratic queue based payment systems.

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Win-Win outcomes in Green Industrialisation

Green Industrialisation is often portrayed as a cost, a necessary investment in order to mitigate the consequences of climate change. But Green Industrialisation also provides the win-win opportunity to simultaneously deliver economic growth, employment and improved environmental outcomes, and to achieve these outcomes with enhanced profitability. As recent experience in Africa shows, these outcomes can be realised through innovations which both retrofit existing legacy investments and which determine the design and delivery of new investments.

Transforming legacy investments

Transformation of legacy investments was the subject of a UNIDO green industry initiative in 2011-2012 (MED-TEST). The objective was to demonstrate the effectiveness of introducing best practices and integrated management systems, and to build national capacity in industry of the Southern Mediterranean Region to enhance productivity and to improve environmental performance and thus to reduce costs. The programme supported 43 manufacturing sites, mostly SMEs, across industrial sectors in Egypt, Morocco and Tunisia.

MED TEST targeted three industrial sectors in Tunisia - textile, agro-food and leather. These are crucial for the country's economy and rank among the major contributors to industrial pollution generation in terms of wastewater, organic loads and toxic substances. Companies received assistance to integrate resource efficiency into their industrial management systems and to adopt international environmental management standards, including through the implementation of the ISO 14001 Standard.

As can be seen from Table 3, the results were impressive. This reports the costs and the benefits arising from the adoption of new greening practices in 15 firms – six in food processing, six in textiles and apparel and three in tanning and leather. The size of these firms varied, from 35 to 546 employees. In aggregate the annual short term cost savings of $3.3m were not far short of the investment cost of $4.5m. In some cases the costs of investment were more than recouped within a single year, and in only one case did the benefits not exceed costs within two years. At the same time there were major reductions in water and energy use, in BOD5 emissions (Biochemical Oxygen Demand is a standardised unit for measuring organic water pollution) and in COD emissions (Chemical Oxygen Demand measuring the amount of oxygen required to oxidize all soluble and insoluble organic compounds present in a volume of water).

Table 3. Financial performance and water/energy savings through green industrialisation

Company	Size (*)	Investments [USD/yr]	Savings [USD/yr]	Water Savings [%]	Energy Savings [%]
Food & Beverage Sector					
Générale Industrielle Alimentaires Slama (GIAS)	493	191,200	133,700	12	17
Société de Conserves Alimentaires du Cap Bon	50-250	98,139	73,639	44	9
Tunisie Lait	308	827,410	746,638	16	13
Société de Boissons du Cap-Bon (SBC)	119	56,331	75,454	22	21
Societè Nouvelle de Boisons (SNB)	202	29,200	194,600	12	14
Centrale Latiere du Cap nord (CLC)	547	484,945	546,903	13	19
Textile Sector, Finishing					
Teinturerie et Finissage Mediterraneenne (TFM)	55	1,264,645	491,860	56	10
Gartex	185	76,200	67,200	19	15
Megastone	150	76,500	55,600	10	30
Traitex	60	181,800	111,836	19	39
Garment Dyeing Service	80	139,000	91,300	24	7
Star Wash	40	37,500	28,000	30	14
Leather Sector, Tanneries					
Tanneries Megisserie du Maghreb (TMM)	180	523,000	446,800	14	15
Société Moderne des Cuirs et Peaux (SMCP)	35	287,000	97,200	22	3
Tannerie du Nord Utique (TNU)	50	184,000	125,000	8	70
TOTAL		4,456,870	3,286,530		

(*) n. of employees, 2009

Estimated Environmental Benefits

Water Savings [m³/yr]	Energy Savings [MWh/yr]	BOD5 Reductions [tons/yr]	COD Reductions [tons/yr]
650,00	25,083	1,610	2,762

Source: Source: UNIDO, 2012. Towards Green Competitive Industry. MED TEST. Transfer of Environmental Sound Technology in the South Mediterranean Region. Project Summary and Achievements. United Nations Industrial Development Organization.

Greening in new investments

Although the recent civil war in Ethiopia and the introduction of tariffs in 2025 undermined the prospects for market entry into the US final market, the Hawassa Eco-Industrial Park (HEIP) is an exemplar of the benefits to be obtained from greening new investments. It illustrates how an imaginative and flexible strategy can enable an economy to take advantage of green industrialisation. Whilst the transition to the Digital Paradigm has reduced the prospects for export oriented manufacturing it has not eliminated these opportunities.

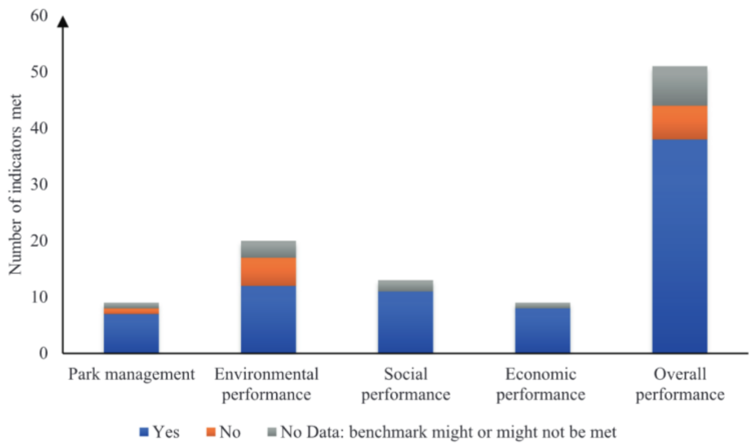
Export Processing Zones played a major role in China's successful expansion of manufactured exports, and many low income economies have sought to replicate China's experience. Mexico and some Caribbean economies have had considerable success in promoting EPZs, although the developmental and environmental outcomes have been less beneficial than anticipated. But unlike these economies which are in close proximity to the USA, African experience with EPZs has been far less successful. A number of African countries have built EPZ Industrial Parks, often with support from the Chinese government and Chinese firms. But few have resulted in significant exports, employment or manufacturing value added.

The shining exception to this African experience has been the Hawassa Eco-Industrial Park in Ethiopia. Its success arises from an innovative government policy which recognised that entry into foreign markets could not be achieved by conventional supply sided policies limited to building Industrial Parks and providing tax exemptions and freedom from bureaucracy and labour controls. A number of African countries had followed this route, with poor outcomes. Instead, the Ethiopian initiative began at the demand end of the value chain. Before constructing the zone, the largest US buyers in the apparel industry and the major material suppliers in India, Sri Lanka, Indonesia, Hong Kong and China were approached. The retailers were asked what was missing in the offerings provided by their Asian suppliers. The answer was that these legacy suppliers had built capabilities over a number of years in which environmental considerations had not been a key factor in final markets. The space was thus opened for a new supply chain which was green from beginning to end. This opportunity which was grasped by the Ethiopian government.

The HEIP was established in 2016 at a total cost of $300m. The park was designed to have a capacity of up to 60,000 workers with projected annual exports of $100m. A large global textile firm, PVH (formerly Phillips Van Heusen), was incentivised to enter as an anchor investment and by early 2021 it was joined by more than 20 firms. At its peak the Park employed 35,000 workers with exports exceeding $30m. However, as a consequence of the civil war which flared up in late 2020, Ethiopia lost is preferential access to the US market. This stunted the growth of the HEIP. But it did not however negate the value of Ethiopia's pioneering strategy in developing a green GVC.

The commitment to greening spanned the whole value chain. The Park recycles water, uses LED and intelligent systems to save electricity, uses natural ventilation and lighting and has a collective 'zero liquid discharge' (ZLD). Greening is not confined to the Park itself. All of its energy inputs are provided by renewables and final product is transported to the port by Africa's first electric railway, powered by renewables. Figure 12 indicates the Parks impressive performance in adherence to a series of global standards used to assess the performance of eco-industrial parks. It is instructive that these standards are not limited to environmental performance but also includes a range of social objectives.

Figure 12: Hawassa Eco-Industrial Park performance on various standards



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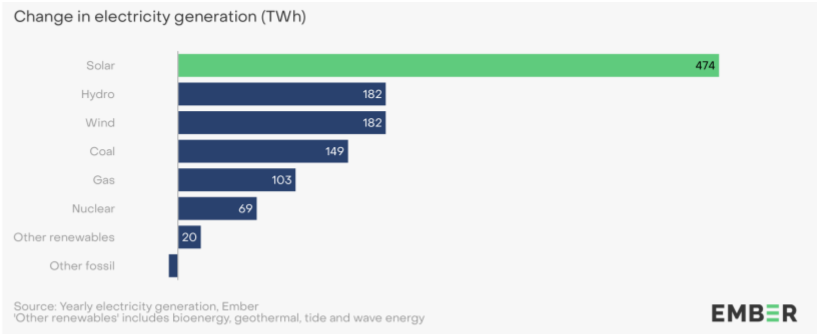
Solar renewable energy surges globally - Vietnam and South Africa examples

Driven by record growth in renewable energy sources clean power from all low carbon sources surpassed 40 per cent of global electricity generation in 2024 (Figure 13). Solar is the fastest growing source of electricity globally, doubling between 2022 – 24, with 53 per cent of the increase in China. Solar is doubling every three years. This is a global phenomenon as 99 countries have doubled their solar generation between 2019 – 2024.

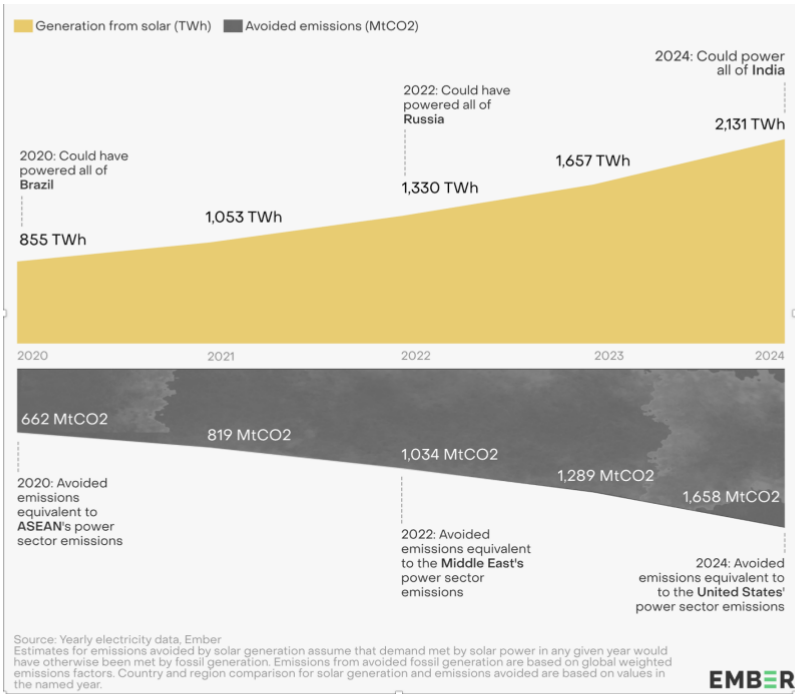
Figure 13: Electricity generation by source 2024



Source: Graham et al, 2025

These advances in solar generation are not confined to the industrialised high income countries or China. In 2024 India became the world's third largest generator of electricity from wind and solar, overtaking Germany. In 2024 Brazil also overtook Germany and became the fifth largest global solar generator. The extent of this accelerating global drive towards solar renewable energy is graphically represented in Figure 14.

Figure 14: Rise of global solar renewable energy

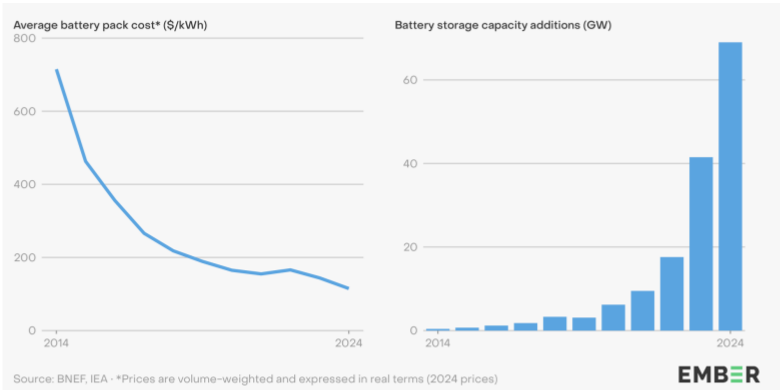


Source: Graham et al, 2025

Figure 14 shows how global solar power generation was equivalent to the entire electricity demand of India in 2024, to that of Russia in 2022, and Brazil in 2020. It also shows how the global increase in solar generation over the past four years has avoided significant power sector emissions equivalent to that emanating from the US, Middle East and ASEAN.

Major advances in battery storage and its rapidly increased adoption is also significantly accelerating the role of solar generation. The cost of lithium ion batteries has decreased by 84 per cent over the past decade and is accelerating. It declined by 24 per cent between 2023 – 2024, and global battery storage installation capacity almost doubled in one year (Figure 15). This accelerates the process of distributed energy and creates the opportunity for round the clock solar power becoming a reality.

Figure 15: Average battery cost decline and battery storage installation 2014 - 2024



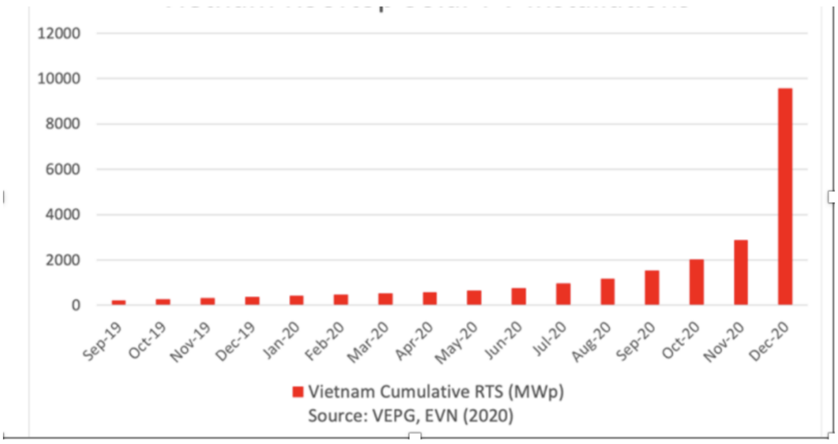
Source: Graham et al, 2025

The rapid global uptake of renewable energy massively increases the scale of the market for solar panels, inverters and batteries. Changing the scale of demand creates the possibility for local manufacturing and assembly of these components and a lessening of dependence on Chinese imports which has the potential to maintain industrialisation in developing countries[31].

Vietnam – Rooftop solar enables peasants in the countryside

The case study of Vietnam shows how the surge in adoption of rooftop solar (apart from China) has led to the highest level of rooftop solar uptake in Southeast Asia. Rooftop solar in Vietnam was extremely low, and the poor lacked access to energy. To counter this, in 2020 Government implemented a radical household solar investment programme with very favourable feed-in tariffs. As a result rooftop solar installations in Vietnam rose from a 2019 base of 378MWp to 9.583GWp. In 2022 solar power (at 16.5GW) accounted for a quarter of the national power system (615). The distributed solar energy programme has radically altered the energy poverty of swathes of Vietnamese poor peasants and workers, and through the feed-in tariffs also significantly contributed to raising their household incomes.

Figure 16: Vietnam rooftop solar installations Sep 2019 – Dec 2020



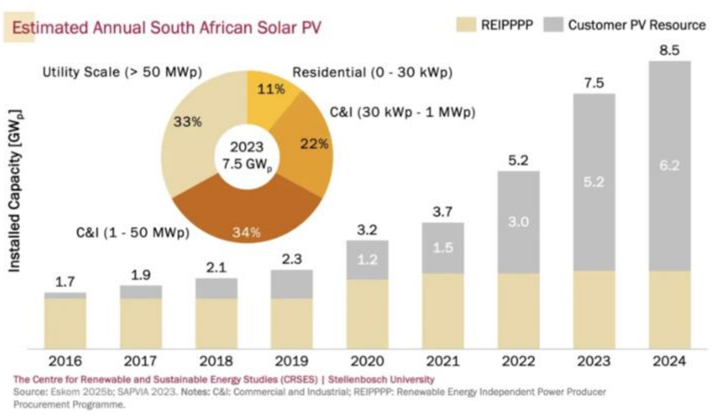
South Africa – Solar allows households, large and informal business energy access

In South Africa interruptions to supply and price increases by the centralised national electricity utility (ESKOM) led to the rapid installation of rooftop solar in middle-high income households as well as commercial and industrial enterprises. The surge has been driven by supply problems with the national utility (ESKOM), dependent on coal fired power stations, being unable to meet demand and imposing various degrees of load shedding spread over different time periods. The supply deficiency is a result of four major factors: most coal fired power stations are past their decommissioning age and subject to breakdowns; corruption; many municipalities unable to pay ESKOM for the electricity supplied; and a culture of nonpayment by consumers in poorer townships. These supply problems have driven many middle-high income households as well as commercial properties and industrial enterprises to install rooftop solar to ensure continuity of electricity provision. Moreover, the fiscal problems besetting ESKOM has resulted in escalating electricity tariff increases accelerating solar adoption. Cost of electricity has now become the major driver of rooftop solar for commercial and industrial consumers. The recent policy shift allowing suitably metered consumers to feedback surplus energy into the local city grid has also contributed to an acceleration in solar energy installation.

A new solar-battery “plug-and-play” solution is also transforming energy access for informal business in poorer townships and informal settlements. The system uses appropriate technology designed a) to counter theft, b) customised to low weight bearing informal tin shack structures, c) for low/unbanked clients without resources to insure and maintain solar systems. This is a modular and stackable solution which can be scaled up as demand increases - solar panels (up to 8) with adequate battery storage (up to 5kw) and inverter (up to 6kw). The system comes with a point of sale device, remote monitoring, theft resistant enclosures, and a daily payment model that avoids upfront payments via conventional finance institutions.

Notwithstanding the reality of a massive surge in RE in South Africa over the past few years, there is a problem is specifying the exact amount of capacity that has been installed due to unregistered installations of household solar. The most reliable estimates are that total installed solar PV capacity in South Africa is 8.5 GW (Figure 17). This includes utility scale solar farms installed through the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) initiated by government to attract private sector investment in electricity generation. Since 2021 private residential and commercial/industrial rooftop solar installation has taken off at a rapidly escalating rate. As of the end of 2024, 6.2 GW of rooftop generation capacity was currently installed in South Africa. This is 13 per cent higher than the installed capacity as of the previous year and almost 230 per cent higher than at the end of 2021. Moreover, it is estimated in 2023 that around 22 per cent of household embedded solar installations were unregistered.

Figure 17: Total renewable energy capacity in South Africa 2016 - 2024



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Renewable energy to power green steel manufacture and industrial decentralisation in Brazil

After the second half of the nineteenth century, steel became a core general purpose technology. It was rapidly adopted throughout industry and played an especially critical role in infrastructure. Steel rails made it possible to transport larger and heavier loads on the rail network at faster speed, and steel hulled ships made it possible to transport raw materials and final products across the oceans. Steel remains a core general purpose technology today. Half of current annual global steel output goes into building and infrastructure, 16 per cent is used in the manufacture of mechanical equipment and 12 per cent is absorbed by the automotive sector.

Steel production makes a significant contribution to climate damaging emissions. Greenhouse gas emissions weigh roughly twice as much as the steel which is produced, and global steel production accounts for about seven per cent of global greenhouse gas emissions. Electric arc furnaces are less climate damaging than the more widely used coal powered blast furnaces, but their less damaging climate impact depends on the carbon intensity of electricity generation.

Hydrogen has a large positive role to play in reducing the climate footprint of steel production, both in the manufacturing process and in the provision of energy. Currently, green steel is not cost competitive, largely because of the high cost of hydrogen. Advances in renewable energy offer the possibility of reducing this cost premium. It also offers the possibility of generating the energy required to produce hydrogen close to the location of steel plants. This synergy between low cost hydrogen, green steel and renewable energy is thus contingent on location.

These opportunities for green steel production are currently the focus of a major initiative in Brazil which has 21 steel plants, and is the world's ninth largest steel producer and exporter. Brazil is the second largest producer and exporter of iron ore. High grade deposits (exceeding 60 per cent) are especially advantageous in the production of hydrogen based steel. Brazil has invested heavily in renewable energy production which accounted for 93 per cent of its electricity generation. In 2022, investments in clean energy were only exceeded by China and the US. It is the second largest producer of hydro and biopower, ranks seventh for wind power, and ninth for solar power. Its announced investments in future solar and wind power will cement its leading role as a low-cost producer of renewable energy.

An in-depth study assessed the likely future levelised cost of green steel manufacture (that is, costs net of subsidies) using hydrogen in process and as a source of energy. It concluded that access to low cost renewable energy, close to the site of hydrogen production and hydrogen use would enable the competitive production of green steel by the early 2030s. Brazil and Australia were identified as the two most favourably located economies.

Both the Brazilian government and the private sector have recognised this potential, The National Hydrogen Programme was launched in 2021 and a legal framework was created to facilitate the production of low cost hydrogen. The privately owned port of Açu has invested heavily to provide the infrastructure for hydrogen and green steel production and Vale (the giant Brazilian owned resource company) has made large upstream investments in ore processing.

This Brazilian commitment to hydrogen and green steel production is embedded in attempts to invigorate decentralised economic growth in a relatively impoverished region. The Port of Açu is located in the relatively poor North East region, 320 Kms from Rio de Janeiro. Between 2021 and 2024 investments exceeding $5bn were announced in its vicinity to manufacture wind turbines, metallic iron (used in green steel production), ammonia and sustainable aircraft fuels. Shell Brazil and the Port of Açu signed a Memorandum of Understanding (MoU) to develop a green hydrogen pilot plant. YamnaCo has secured land for a large scale green hydrogen based ammonia project, targeting one million tonnes of annual production by 2030; and Fuella is planning an ammonia plant at the Port of Açu. The port is developing renewable energy infrastructure, including a solar PV power plant to support green hydrogen production. Almost all the energy inputs into this regional industrial cluster will be generated by renewables.

In these developments we can observe the fusion between renewable energy generation (produced in situ), industrial development and decentralised industrial agglomeration. They also illustrate the importance of collaboration between the government and the private sector. It represents an example of the opportunities opened to the greening of the economy. ICTs are a central part of this story, not just as incorporated in the renewable technologies (particularly wind and solar power), but in logistics, in the design of new technologies and plants and in the plethora of everyday objects (phones, calculators, internet and no-doubt AI) which make modern industrial development feasible.

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Smart Cities

A Smart City programme seeks to draw on synergies made possible by the digital revolution in integrating and analysing the databases which document a range of activities in urban environments. Smart Cities gained traction towards the the end of the first decade of the 21st Century. Using data generated in the provision of services and in some cases data collected from the Internet of Things (IOT, digitally controlled products) Smart Cities are primarily concerned with the provision of services such as traffic control and transport, utilities (water and energy), schools, health systems (such as clinics and hospitals) libraries, community services and surveillance and policing.

With the exception of Singapore (a middle income economy) and China, almost all of the most advanced Smart City programmes are in high income countries. A 2025 ranking of Smart Cities placed eight out of the top 10 cities in Europe. The highest ranked African city was Cairo (117), followed by Cape Town (124) and Nairobi (136). The highest ranked cities in Latin America were Mexico City (118), Santiago (120) and Buenos Aires (131). Delhi was ranked at 104 and Mumbai at 106.

Cities in most low and middle income countries are thus in catch-up mode. However, some developing economies are making great strides and have ambitious Smart City programmes. The Smart Cities Programme introduced by India's Ministry of Housing and Urban Affairs aims to capitalise on the abundance of IT skills and the databases generated by its digital citizens programme ('Digital India') launched in 2015. The Smart Cities Programme targets more than 500 towns and cities with a population exceeding 100,000.

In recent years India has drawn on its reservoir of high tech software skills to address this programme through the use of AI. As Figure 18 shows, this involves six sequential activities

– data identification and collection; forecasting and prediction; clustering (identifying patterns); optimisation of response routes; detecting anomalies; and enhancing decision making. As in many AI applications these interventions rely on big data and inferential analysis.

Figure 18: Smart Cities Programme in India

AI Implementation Cases	Description	Applications
Detection & Classification	Identify & categorize objects in images	'Classification' is identifying whether an image contains a specific type of object, such as a helmet, face mask, etc. for better law enforcement.
Forecasting & Prediction	Estimate the next value/response in a sequence	Forecasting the demand of road repair inventory, based on a set of input data such as previous time series consumption data, weather, traffic volume, etc. for better resource planning.
Clustering	Find patterns among disparate data points & categorize them based on similar attributes	Health record synchronization where multiple near-duplicate records of one person can be unified into a unique health profile.
Optimization	Generate a set of outputs that optimize outcomes for a specific objective function	Generating an optimum route for a vehicle using a combination of time of day, traffic data, fuel use and other variables.
Anomaly detection/ prediction	Determine whether specific inputs are out of the ordinary	Predictive maintenance: AI systems trained on time series data from IoT sensors, such as those monitoring temperature or vibration can detect or predict anomaly, such as leakages in a water distribution system.
Decision-making	Help with informed decision making	AI systems can help in detecting incidents in real-time and can dispatch the help or escalate the issue to appropriate authority in time for taking necessary actions

Whilst India has a clear strategic vision to promote Smart Cities, it is not the only developing country with the ambition to take advantage of the synergies made possible by the digitisation of the lives of ordinary citizens, including those with low incomes living in dense urban clusters. In Kenya mobile telephones are widely used for digital payments, including in densely populated areas with low income households. They reduce the costs of utility provision and ease the bureaucratic burdens which have historically plagued many low income consumers of utilities.

Critically, the diffusion of digital Smart Cities can be undertaken incrementally, so that scale barriers to entry are a relatively small impediment to innovation by comparison with earlier vintages of urban governance and utility supply. Moreover, since the innovations are predominantly based on software, the growing availability of digital skills in many low and middle income economies further reduces barriers to entry. In principle therefore, cities in low and middle income economies have the potential to leapfrog cities in the north who are often stuck with outdated legacy systems. It is significant that there is not a single US city ranked in the top 20 Smart cities.

However, there is a large gap in these global Smart City programmes. This is because they are predominantly focused on service and governance delivery and in some cases surveillance. A review of global experience shows an absence of interventions which target employment, production and the generation of livelihoods. This significant policy gap arises from the siloed nature of government interventions with Smart Cities Programmes being developed and implemented through city authorities and ministries, as in India's case in which the programme is the responsibility of the Ministry of Housing and Urban Affairs. There is a glaring absence of participation by Ministries of Industry and Innovation and institutions in the National Systems of Innovation in complementing interventions addressing utility provision, transport and congestion.

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Smart energy management through the use of ICTs and solar power

As a general rule, and particularly in low and middle income economies, energy utilities meet energy needs through the lens of supply. The response to shortfalls in the availability of energy is to impose cuts to supply. These interruptions to supply are highly damaging to industry, to households and to the meeting of social needs such as traffic control, hospitals, education and security. Utilities are forced into these draconian supply side actions because they lack the capacity to meet energy shortfalls through interventions on the demand side of the supply-demand equation. They are further hampered by the inability of households to manage their needs in a nuanced manner.

These difficulties in meeting energy needs arise not only from an insufficiency in generating capacity but also from the character of energy production and use in the Mass Production paradigm which was based on large-scale centralised energy generation, extended delivery infrastructure and the inability to differentiate between consumers with very different needs and consumption patterns, The transition to renewables and the power of digital technologies offers the opportunity to remove these impediments to energy availability. Renewables (which, as we have seen, are reliant on digital technologies) can be provided as modular, scaleable investments allowing for generating capacity to be built incrementally. Moreover, renewables can be generated closer to users, avoiding the disruption caused when large scale centralised systems encounter problems in both generation and transmission. But the opportunities offered by ICTs transcend the generation of energy. Crucially, they allow for a more targeted and sophisticated use of energy, thereby reducing demand. Notwithstanding this contribution i reducing demand, ICTs also enable the feedback of surplus household energy back to the grid, thereby simultaneously increasing energy supply.

A small startup company in South Africa (Plentify) has turned the supply driven model on its head, focusing on consumption. It works on the premise that significant energy is wasted, or used inefficiently, or unnecessarily sourced from expensive or dirty sources. It uses the green energy transition to revolutionise energy management, to optimise energy consumption, and to maximise energy produced by solar panels in the home or business. At the heart of the system is the SolarBot, an intelligent device linked to the home solar generating system. SolarBot draws on the pattern of energy use in IoT connected appliances, and combines this with weather forecasts, estimates of power generated by the home's solar panels and loadshedding schedules published by the energy utility to optimise the domestic battery storage system. The battery system charges as much as possible with solar and as little as possible from the grid, avoiding expensive peak time tariffs and reducing demand on the utility's grid. It also automatically turns off appliances which can be used intermittently at times of peak utility demand. Surplus energy is then fed back from the battery to the external grid.

An example of a connecting modular device is the HotBot which attaches to the hot water geyser. It uses sensors to collect data about home hot water usage and how the geyser is operating. It sends that data over the Internet to the Plentify analytic system in the Cloud, which uses the data, coupled with the information regarding hot water preferences provided through the user app to predict future hot water requirements. This is supplemented with externally sourced information on utility schedules and weather. These data are analysed and used to make decisions around when to turn the hot water geyser on, providing hot water when it is wanted, delivering hot water as efficiently as possible, and timing the energy use of the geyser for when it makes the most sense for the household energy ecosystem. When the solar battery storage is full and there is surplus energy, SolarBot switches on other IoT connected devices such as the refrigerator and the washing machine which require intermittent power. SolarBot then feeds the surplus energy stored in the battery back into the grid, selling electricity for whatever rate the utility provider has agreed.

Plentify uses local contractors to assemble imported inputs in a complex process into the final product. Localisation of production is driven by a number of factors – duties and cost – but a major incentive is that using local contractors provides the firm with the manufacturing flexibility required to monitor, tweak and innovate the utilisation of its various Bots.

Although the system is designed for home energy management it can be applied to businesses and institutions where collective demand is centralised (for example, nursing/retirement homes, residential estates, and shopping malls).

Maximising the potential impact of this demand based innovation on the grid requires complementary changes in the energy utility and in the incentives provided by local and national government to energy utilisation. This involves a change in mindset from a supply push obsession to a more nuanced model which recognises the differentiated needs of different consumers and the capacity of consumers to feedback surplus energy to the grid. It is a system centred around ICTs.

A trial of the Plentify system was undertaken with support from local government in Cape Town, South Africa. It deployed 500 HotBots into homes, delivering significant energy efficiency benefits to these homes with an average saving to the household of 24 per cent. Simultaneously it provided aggregated data services to the local energy utility, helping it reduce the electricity load during peak time hours and to manage load across all of those homes to ensure there was never a spike in demand that could be damaging to infrastructure. Whilst this innovative system is unique in a low and middle income country context, similar innovations are occurring in Portugal and South Australia.

Jon Kornik, founder of Plentify concludes that '*data is the fuel that drives the whole engine. Data is the brain, but hardware is the hands and the eyes. The target is increasing the amount of clean energy that can be used. We're going to have to move from the centralized model of energy generation. In the past the utility's job was to keep supply and demand in balance by turning supply up and down because demand was completely uncontrollable to it. Now demand is becoming controllable and so this is becoming a two sided equation. You can change supply, and you can change demand, and we're helping on that demand side because what we do is we aggregate all of this demand from all of these homes into a big enough data bucket that is actually a value to the utility. This demand management system with its data generation theoretically allows the utility to keep the whole system in balance'*.

The systemic role that renewable energy and ICTs can play in the new Digital Paradigm in redefining the relationship between supply and demand in the energy sector is summed up by the Head of Electricity Research, Oxford Institute for Energy Studies:

" …… the renewable energy transition triggers profound system level transformations that extend far beyond simple technology substitution. Traditional fossil fuel systems operated through well-defined boundaries, clearly demarcated sectoral divisions, and linear, predictable flows from extraction to consumption. Renewable energy dissolves these comfortable boundaries by blurring the line between producers and consumers, driving integration across previously separate sectors, creating bidirectional networked energy flows, and generating complex emergent behaviours. The resulting system increasingly resembles a complex adaptive network more than a linear infrastructure, necessitating entirely new governance approaches, market designs, and operational paradigms. In sum, this transition not only reshapes traditional energy markets but also redefines geopolitics, industrial strategy, and the global economy for the decades to come. The competitive advantages of the new energy paradigm will accrue to those nations and organisations that most effectively navigate these shifts - recognising that manufacturing prowess, technological innovation, and systems integration capabilities now determine energy leadership more than geological fortune or resource control." (Poudineh 2025)

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South-South Trade – New opportunities for Inclusion (but with social and environmental costs)

Southern exports to northern markets in GVCs became increasingly standards-intensive from the early 1990s, affecting all firms in the supply chain. Without these standards, market access was constrained. Some of these standards were introduced by the lead firms governing GVCs in the interests of economic efficiency, affecting quality, cost and delivery (the QCD standards). Others were introduced in order to respond to government-determined safety standards in the importing northern economies (such as phytosanitary standards). Increasingly, standards were also set by lead firms responding to consumer demands for ethical and environmentally friendly production processes. The consequences for firms and labour operating in these chains was that they were required to engage in costly certification, and to be able to show a trail of monitoring and conformance to standards.

There are many developmentally positive consequences of these standards intensive GVCs. They improve product quality, reduce the use of child labour, promote the greater incorporation of women in production and limit negative environmental spillovers. However, they simultaneously also have harmful consequences. Standards intensive value chains invariably result in the exclusion of small firms, especially informal sector firms, and relatively unskilled and uneducated workers. They also generally require the use of capital equipment which is relatively capital intensive in comparison to production processes used to meet domestic needs (even though this equipment is relatively labour intensive by comparison with the machinery used in high wage developed economies). The output of these GVCs is overwhelmingly targeted at medium and high income consumers favouring brand image and with exacting look-and-feel quality standards.

Although consumers in low income developing economies have similar aspirations for look-and-feel quality and brand intensive products, they cannot afford the cost premium which this involves. They are thus prepared to settle for lower equality, as long as the price is lower. Similarly, whilst some producers in low income countries might prefer to use equipment imported from northern economies, this generally involves a substantial cost premium, is costly to acquire, difficult to maintain and operates at high scale.

A comparison of the operating characteristics of machinery imported into three East African economies in three basic manufacturing sectors illustrates the nature of the trade-offs for low income economies. The three sectors were rice tilling in Tanzania, garment manufacturing in Uganda and wooden furniture in Kenya. Figure 19 illustrates the nature of the contrasting operating characteristics of the northern origin and southern origin capital goods involved. Chinese (and in some cases Indian and Thai) machinery was generally much cheaper, more labour intensive and operated at much lower scale than their northern origin equivalents. Their cost of production was lower than products manufactured by northern origin capital equipment and consumer prices were therefore lower.

The downside was that southern origin machinery was more prone to breakdown. But this proved to have important spillovers to the local, predominantly informal economy. Frequent breakdown led to the mushrooming of local workshops, often decentralised through the country since the scale of production was small. Unlike the more technologically sophisticated northern origin machinery, relatively low level skills were required both in operation and in repair and maintenance. Moreover, the rural workshops which developed to repair this equipment also supported other sectors, particularly in metalworking. Southern origin equipment tended to be less environmentally friendly, chiefly resulting in more oil spillages and noise in operation.

Crucially, products manufactured through the use of southern origin capital goods were much cheaper than imports (of clothing and furniture) and products manufactured locally using northern origin equipment.

The upshot was that the balance of economic and social appropriateness was firmly in favour of the southern origin equipment. Since these product and operating characteristics were not unique to rice tilling, garment manufacture or furniture production, it is not surprising that there has been a significant increase in the import of Chinese and other southern origin capital goods into low and middle income countries (Figure 120). The share of Chinese origin imports of capital goods into Africa, S E Asia and Latin America grew rapidly from near zero in 2000 to more than 30 per cent in 2023. Thus, from the perspective of social inclusion (but not necessarily environmental sustainability), south-south trade provides considerable opportunities for employment and growth.

Figure 20: China's share in capital goods imports in Africa, S E Asia and Latin America, 2000-2023 (%)

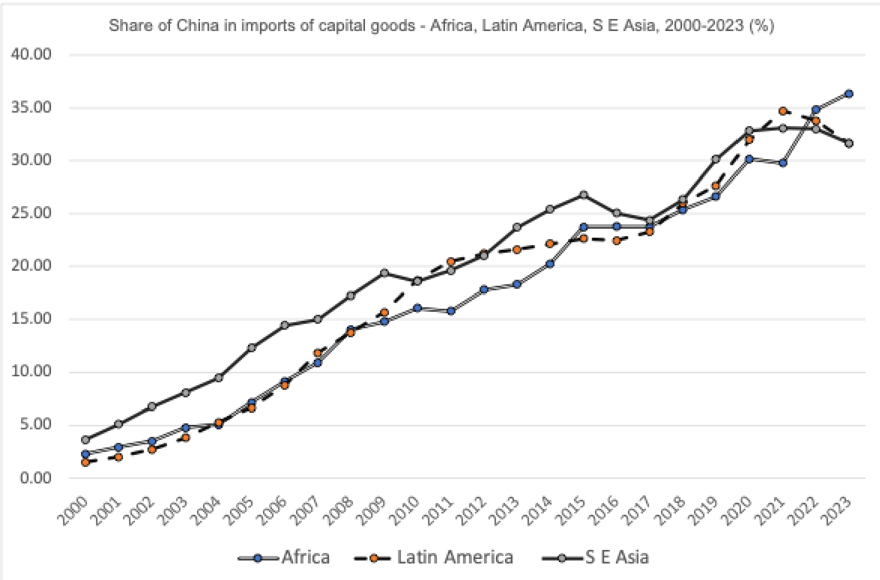

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Figure 19: Operating characteristics of southern and northern equipment in East Africa availability of spares

Sector/ Country	Source	Acquisition cost (US $)	Lifespan (years)	Spares & after sales support	Repair	Labour intensities⁺ at actual capacity utilisation	Skill profile
Power tillers in Tanzania	China India	3,529 - 4,705	3-4	Spare parts easily found in local markets but are of lower quality and require frequent replacement	Breaks down often (about 9 times more per season). Repair costs are relatively low.	High labour intensity	Skill intensive because of the fragile nature of the parts
	Japan	7,647 - 9,412	7-12	Spares relatively more difficult to find in local markets and are very expensive	Repair costs are relatively high	More than twice as capital intensive compared with the South	Machines are robust and can withstand rough handling by less skilled operators. Skill requirements for repairs are also scarce
Woodworking machines in Kenya	China Kenya	1,118	10	Spares hard to find on the local market; Resort to locally fabricated spares.	Frequent breakdowns. Acquisition plus repair costs much lower than the acquisition cost for the Northern machine	High labour intensity	Not highly skill intensive
	UK	11,765	30	Spares hard to find locally. Rely on locally fabricated spares or import directly.	Rare breakdowns	Three times the capital intensity of the South	Not highly skill intensive
Garment making machines in Uganda	China	202 - 363	10	Spares cheap and easy to access	Frequent breakdowns (about three times that of Northern machine per year)	More labour intensive than machine from North	Requires more learning by using experience to operate. Repair skills are available but in short supply
	Europe	323 - 524	10	Spares expensive and hard to find	Minimal breakdowns. But annual repair cost are similar to Southern machines	Nearly one and half times more capital intensive than South	Skills for repair are available but in short supply. More complicated and difficult to repair

District heating in Sweden: Collective production and collective consumption

As was the case in many European countries, Stockholm and other Swedish cities were increasingly troubled by acidification and air pollution during the late 1960s. It was recognised that coal fired hearing systems were a primary cause of this pollution. Moreover, the 1973 and 1979 oil price hikes highlighted the costs of dependence on imported carbon based energy – high cost, price instability and energy insecurity. This resulted in a commitment to reduce reliance on carbon based energy production and to transition to more environmentally friendly forms of energy consumption

The concern with urban pollution resulted in the transition from gas-fired home-specific heating technologies (as adopted in the UK and other European countries) to the collective generation of household heating, relying on renewable energy. The collective generation programme came to be referred to as a 'centralised chimney', making it possible to better control the purification of flue gases. The development and rollout of this collective system of generation was linked to the construction of more than one million new homes. Thus the system was designed *ab initio*, rather than requiring the retrofitting of the legacy heating of individual homes.

The collective generation system of heating has resulted in a network of more than 3,000km of piping. Instead of firing the collective heating system with coal, gas or oil, the Stockholm local authority invested heavily in renewable energy. Currently, less than five per cent of energy needs are provided by carbon based power. Renewable energy is powered by drawing on the residual heat in resident's wastewater, excess heat generated by datacentres (which power the digital economy), heat displaced by supermarket cooling systems, biowaste and by heat obtained from incinerating non-recyclable waste. The world's largest heat pump in Hammarbyverket generates 225MW, enough to heat 95,000 two room apartments during a normal cold winter. Following Stockholm's example, collective heating systems have been widely adopted throughout Sweden, and in 2023 accounted for more than half of all heating and hot water nationally.

The centrally generated system was originally introduced to provide hot water and heating. The same principle has now been applied to the need for cooling in summer, utilising cold sea water. Stockholm now has the world's largest sea water based cooling system. More recently, digital systems have been introduced to optimise the integrated system's generation and distribution of heat and cooling throughout the district network.

Both national and local government played a pivotal role in the design, rollout and continuous improvement of this system of collective generation and distribution of power. At the national level, a carbon tax was introduced in 1991, and support was provided for innovation in renewable energy technologies, including in large scale hydro plants in the frozen north of the country. Municipal and regional government provided direction and support throughout the system's development. The combination of national and municipal government reduced risk, allowed for externalities to be reaped, generated employment, increased the security of energy supply and had a major beneficial environmental impact. These benefits would have been much more difficult to achieve had an individually based heating and cooling system developed, as was the case in the UK which had been confronted by similar problems of pollution during the 1960s.

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Adopting climate smart technologies and practices to create climate resilience for sustainable agriculture and agri-processing

Climate change impacts on agriculture have introduced new challenges and uncertainties requiring all stakeholders in the value chain to adjust practices and adopt innovative strategies and technologies which are integral to sustainable and climate smart agriculture. Sustainable agriculture rests on three interconnected pillars - environmental, social, and economic (United Nations Food and Agriculture Organization 2018).

Climate Smart Agriculture (CSA) strives to counteract the negative impacts of climate change. CSA promotes climate resilient technologies and practices across the food value chain – harvest, storage; processing; timeous harvesting; storage; management of pests and diseases; early warning systems; processing; packaging; climate resilient drainage; road and transport systems; adoption of renewable energy; technologies to prevent food spoiling; and reducing Greenhouse Gas Emissions. It requires farmers and other stakeholders in the chain to adjust their practices and to adopt CSA innovative strategies and technologies. International best practice makes it clear that governments and non-governmental organisations play a critical role in the adoption of CSA.

Each of these links in the agricultural value chain is witnessing the adoption of ICTs to enhance performance and to deliver new services. Digitisation, particularly in agri-processing, enables real time data sharing and interaction between stakeholders, predicting food quality along the chain, minimising food waste, optimising resource management, facilitating packaging and other postharvest processes. It reduces the need for excessive energy consumption in producing, storing, and transporting surplus goods that might otherwise go to waste. Digital marketplaces connect farmers directly to buyers enabling streamlined transactions, fair pricing, and reduced postharvest food waste by eliminating intermediaries and ensuring fresher produce reaches consumers. Blockchain technology enhances tracking and verification against fraud, and promotes fair trade practices and ethical sourcing. In postharvest supply chains it enhances trust and food safety standards, contributing to increased value chain confidence and promoting global food security and accessibility.

Thus, chain wide digitisation not only improves performance within each link in the chain but also provides the potential for the reaping of substantial systems based productivity gains.

However digitisation involves technological challenges which are exacerbated in the developing world. These include the digital divide, up-front investment and recurring maintenance expenses, data security, inadequate infrastructure, and skill gaps. National government, assisted by international agencies, play an important role in addressing bottlenecks to adoption. These include ensuring better information about costs and benefits, investing in necessary skills, ensuring appropriate incentives, playing a role as knowledge brokers, and facilitating mechanisms for secure data sharing.

Country experience in Slovenia, Ghana, Kenya, Tanzania and Egypt evidence the fruits of adopting CSA technologies and practices.

Slovenia - Adapting to climate change by improving irrigation practice

The Vipava Valley is characterised by favourable natural conditions for intensive agriculture. However, as a result of climate change it is increasingly also exposed to drought, floods, frost, and strong winds. Climate change projections indicate that agriculture will be challenged with more heatwaves and prolonged periods without rain, resulting in higher crop water demand. With irrigation, farmers have been able to ensure crops receive adequate water for their growth in critical development periods. However, they have tended to both overuse water resources and to deliver the water too late. Historically, extensive measures have been applied to improve irrigation reliability during dry periods to enhance water availability from large and small reservoirs, micro and drip irrigation, heat tolerant plants, greenhouses, and agrometeorological variable monitoring. The introduction of ICT technologies substantially enhances the capacity to manage water supply and use.

A pilot project was initiated in 2016 with the overarching goals of increasing both climate change resilience in agriculture and contributing to climate change mitigation. The project was co-designed with farmers with the objective of improving their preparedness for drought by optimising water and energy use, whilst also reducing CO2 emissions. Historically, irrigation decisions were based on experience and general assumptions. The project introduced a Decision Support System for Irrigation (DSSI) to deliver water to crops both timeously and in optimal quantity. This helped farmers make informed decisions about water use, optimizing irrigation efficiency and water resource management based on real time information. DSSI delivered an irrigation recommendation for five days via email or a web based interface to each farmer based on a range of data collected and analysed – sensors, weather forecast, soil water retention properties, real time soil water content measurement, type of plant, and type of irrigation system.

The 2019 mid-term evaluation in 2019 showed that using DSSI achieved a 25 per cent reduction in total irrigation volume consumption, a 24 per cent reduction in energy requirements, and a 24 per cent reduction in CO2 emissions. Involving farmers in the design process resulted in an increased sense of ownership of the adaptation strategy developed in the project and an increased attention on the use of water resources. The initiative also led to increased awareness of farmers of the dangers posed by climate change.

Financing the project was critical. The European Commission contributed 60 per cent, of project costs, and the Government and project partners each provided 20 per cent. When the pilot (‘niche’) innovation was successful, the DSSI was extended to the national level where it is managed by the Slovenian Environment Agency. DSSI is now a public system available for use by every farmer in Slovenia, free of charge.

Ghana – Developing Climate-Smart Agriculture in the Cocoa Supply Chain

Ghana is one of the world’s largest producers of cocoa. Over four million farming households rely on cocoa as their main source of income. The impact of climate change constitutes a major economic threat, especially for smallholder farming in the Ghanaian cocoa belt. From 2015 until 2019, the Rainforest Alliance implemented a project amongst cocoa farmers to promote the adoption of climate smart agriculture practices. The aim was to create more resilient agro-ecosystems and livelihoods, enabling farmers to produce more cocoa while adapting to and minimising the impact of climate change, as well as reducing GHG emissions.

The project focused on mainstreaming climate smart agriculture technologies and practices through applied climate science, certified supply chains, impact investing, and actionable strategies along the value chain involving farmers, processors, certifiers and investors. The project improved the knowledge and capacities of actors and institutions in the cocoa supply chain, sharing the results with government officials and industry leaders. Working with the World Cocoa Foundation, science based training materials were produced addressing climate risks and promoting the wide scale adoption of locally relevant climate smart agriculture practices. The project taught partners within the supply chain how to use scientific climate data to promote sustainable and profitable business and livelihood decision making in the face of climate change and variability. It has also been inclusive of the rural poor (and particularly of the most vulnerable among them).

Mobile phones improve farming practices in Africa

Mobile phones support smallholder farming practices in Africa. In Tanzania, the M-Kulima mobile platform connects smallholder farmers to a wealth of information and resources via SMS, and interactive voice response. It facilitates planning around climate change and offers important market information on best prices for the products. Integrated with the financial services platform M-Pesa it also fosters financial inclusion by providing a mobile money transfer service and enabling payments and microfinancing. In Kenya, the DigiFarm platform provides basic farming advice as well as advanced and mechanised support using drones to perform aerial surveys of smallholder farms. This helps small farmers keep track of the best time to spray fields for pests and to fertilise their crops. In Egypt, through digitalising irrigation systems and adding sensors to the soil, farmers can control the irrigation system remotely via their mobile phone and water accordingly.

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Drones using sensor technology

There has been an explosion on the use of drones in recent years. Perhaps the most dramatic example has been in warfare where un-manned drone based weaponry has begun to change the face of warfare. However, their low cost, their capacity to operate in hostile environments and their versatility have led to a mushrooming of applications across industries. They play a particularly important role in activities which involve operating in hostile and inaccessible environments and are reshaping approaches to military, disaster response, and humanitarian aid.

ICTs are central to drone technology. They not only allow for the miniaturisation of the technology, but crucially also for their interconnectivity and the capacity this provides for systemic innovations. A few examples illustrate their potential to contribute to a more equitable and sustainable growth trajectory in low and middle income economies.

Infrastructure Inspection and Maintenance

Drones play an increasing role in infrastructure maintenance and repair. Their ability to access hard-to-reach locations improves monitoring, reduces costs and improves safety. Drones are able to detect structural defects and potential hazards when inspecting structures such as bridges, buildings and pipelines.

Drones are being used to monitor the progress of project construction to determine if work is being undertaken in accordance with technical specifications and contractual timelines. In the energy sector drones inspect solar panels, wind turbines, power lines and pipelines. They can provide early detection of faults or damage, locate inefficiencies, prevent accidents, and minimise potential downtime of electricity supply. Drone inspections reduce the need for dangerous worker inspections and lower associated risks.

Drones are streamlining the mapping and surveying process, improving accuracy and reliability, reducing time required, and saving money. Because drones can cover large areas quickly and are able to capture high resolution imagery, they have increasingly become a valuable professional tool in civil engineering, construction, mining, and environmental monitoring and management. Drones have the versatility to adapt to various surveying scenarios - corridor infrastructure mapping of pipelines, railways, power lines. Drones can also capture high accuracy data in areas of difficult vegetation which is essential for planning and decision making. Drones are being used in mines and quarries for surveying hard-to-reach, dangerous remote locations where access is limited. They can safely access such locations, maintaining the safety of the operator and reducing the risk of accidents.

Climate Smart Agriculture

Commercial drones are revolutionising crop and field management in the agriculture sector by providing valuable and real time data on crop health and irrigation needs. Real time data allows farmers to make informed decisions about planting, fertilising, pesticide application and harvesting. Drones are able to collect and analyse data on soil conditions, irrigation, and plant health. This has enabled farmers to identify nutrient deficiencies, pest infestations, and various diseases. Drones also enable farmers to identify water scarcity or overwatering and optimise irrigation, thereby reducing water waste and ensuring conditions for optimal growth. Drone technology and data provision results in more efficient farming practices and increased crop yields.

Environmental Monitoring and Conservation

With their ability to access remote locations and capture real time information drones have become essential for environmental monitoring and conservation. They provide valuable data and insights to support sustainable resource management, tracking ecosystem health, monitoring wildlife populations and land use, assessing the impact of development, supporting conservation efforts and revealing climate change impacts on the environment. For example, drones are being used to monitor deforestation, counter illegal logging, protect ecosystems, and to monitor climate change impacts on species and their habitats. Drones also play a crucial role in disaster risk management, emergency response and management of extreme climate induced weather events. Drones are able to rapidly assess damage, locate victims, and deliver essential supplies of food, water, or medical equipment.

Shopping and consumer delivery services

Drones are increasingly being used in the retail sector to deliver a variety of small packaged consumer goods to customers. This is a rapidly advancing application in high income economies. Amazon and other large retailers are in advanced trials. In Ireland, Manna Sero’s autonomous drones each make more than 80 drop-offs per day to households. But drone deliveries are not confined to high income economies. In Szenhen a drone, taking off from a shopping mall roof, delivers takeaway food into a sealed airdrop box in a local park which can only be opened by entering the customers mobile phone number. Szenhen has become known as the ‘drone capital of China’, driven by the local authorities relaxing regulations to allow low altitude flying relative to other regions in the country.

Medical and other freight delivery to remote regions

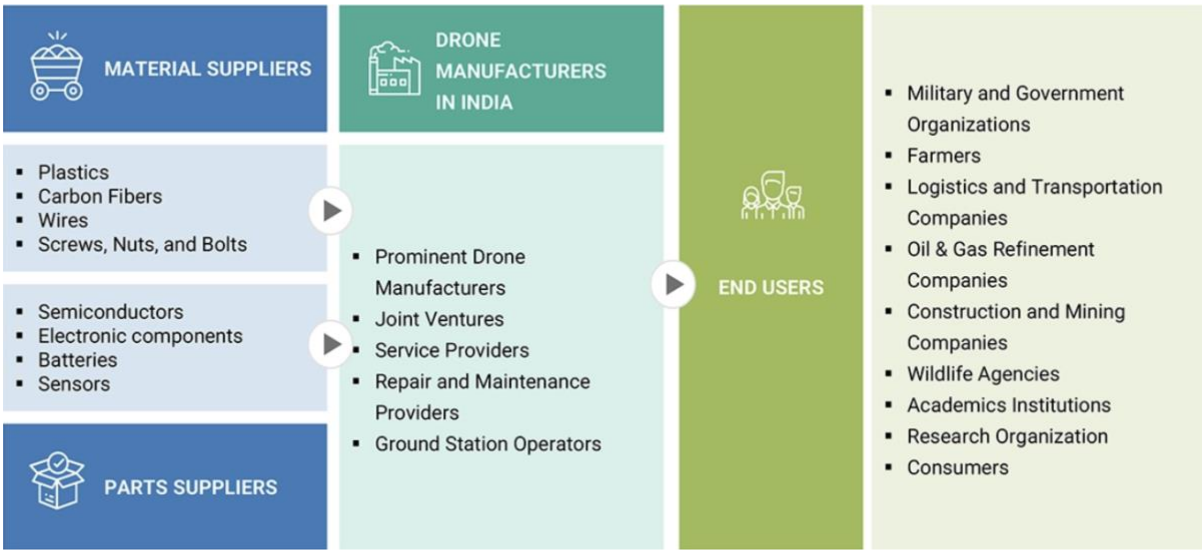
Drone delivery is revolutionizing the transportation of goods, particularly in remote or hard-to-reach locations. In Rwanda, where the mountainous topography cuts off many rural areas from vital services, the government contracted a California based startup to improve blood delivery to rural areas. Lives were saved and blood wastage nearly eliminated. Building on this successful innovation in Rwanda, in 2019 the World Economic Forum initiated a programme to extend the drone delivery of blood to distant rural arteas in other low and middle income countries.

India invests in drone technology

India was one of the first countries to embrace drones, mostly for safety and monitoring requirements. Drone technology in India has transitioned from military applications to widespread use in civilian sectors. Consequently, India has seen a significant increase in the adoption of drone technology across various sectors. The majority of businesses using drones do not purchase their own drones because the expense of an enterprise level drone may be prohibitively expensive. Instead they buy in drone services from external suppliers.

The Indian government has ambitious plans to make India a global hub for drone technology by the year 2030 and to expand the use of drones across a variety of fields and sectors. It has policies to regulate, incentivise and promote their use. Users in the agriculture, infrastructure, and logistics sectors have embraced drone technology for enhanced efficiency and precision. For example, Indian companies are increasingly using drones in agriculture for infrastructure inspection and disaster management. Agricultural drones monitor crop health, and construction firms employ drones to undertake surveying and mapping. As a result, there has been a surge in the domestic production of drones customised to the needs of the Indian market (Figure 21). The drone services market in India is divided into three categories: maintenance, repair and overhaul, platform services, and training and education services.

Figure 21: India's drone value chain



Source: Markets and Markets (2024): Indian Drone Market Size, Share, Trends and Growth Analysis.

The Indian drone industry has grown rapidly in recent years, virtually doubling between 2023 ($344m) and 2024 ($654m) and projected to grow to $1.4bn in 2029. In terms of units, production is projected to increase from 10,803 drones in 2024 to 61,000 in 2029. Five leading manufacturers are producing 'Made-in-India' drones, operating across defence, agriculture, infrastructure, and surveillance. These are: IG Drones (defence and industrial); ideaForge (defence, law enforcement, and industrial); NewSpace Research & Technologies (earth observation and communication); Paras Defence & Space Technologies (military, surveillance, and homeland security); and Asteria Aerospace (defence, agriculture, and infrastructure). The Indian Government provides incentives and support to promote domestic manufacturing and restricts the imports of all but the most specialised drones. This support includes import protection, facilitating startups and encouraging institutional collaboration between academia and industry. Financial incentives are provided to companies manufacturing drones and components through the Production-Linked Incentive (PLI) scheme.

Source: KPMG Assurance and Consulting Services (2022)
(https://assets.kpmg.com/content/dam/kpmg/in/pdf/2022/07/indias-emerging-drone-industry.pdf)
https://url.za.m.mimecastprotect.com/s/KZ4yCy8AEXUNN83gWfZfJcx095D
https://www.weforum.org/stories/2019/01/what-the-world-can-learn-from-rwandas-approach-to-drones/
https://dronedj.com/2025/04/21/drone-delivery-has-become-the-norm-in-dublin/

7. BEYOND CATCH-UP – POLICIES WHICH CAN TRANSFORM THREAT INTO OPPORTUNITY

What implications does this in-depth historical analysis of innovation have for the formulation and implementation of policies delivering a more equitable and sustainable developmental trajectory in low and middle income economies?

Drawing on the insights provided by a series of niche innovations described in Section 6, in this Section we address the major policy arenas in which transformative action can be directed. In the final Section 8 we consider how these policies might be implemented. But before we engage with the policy agenda, it is helpful to briefly highlight the central conclusions which emerge from our historical analysis.

- Industrial development provided the basis for longer and more secure livelihoods. Progress was achieved through investment in fixed assets, and particularly in innovations in processes and products. Whilst innovation spurs economic growth, the fruits of productivity growth may not be shared equally – the developmental outcomes are a reflection of the social and political context in which innovation occurs.
- The Industrial Revolution led to unprecedented improvements in livelihoods, including in low and middle income economies. However in recent decades some of this progress has been lost. Without a change in direction, the prospects for equitable and sustainable growth are bleak.
- Innovation lies at the centre of developmental progress. But not all innovations are of the same order. It is possible to distinguish four major types of innovations – incremental innovations, radical innovations, systems innovations and revolutionary innovations.
- Revolutionary innovations are associated with systemic and interrelated changes in the economy, society, governance and the environment. These bring about radical change and are referred to as Techno-Economic Paradigms or 'long waves' and last for many decades; each wave has a dominant form of infrastructure which connects producers to markets. When a paradigm degrades and a new one emerges, the process is characterised by disruptive 'gales of creative destruction', invariably accompanied by major economic, social and political disruption. At these times, 'Business as Usual' is no longer possible. New avenues need to be developed to allow the incoming revolutionary technology to diffuse and to provide for a stable period in which the gains of productivity growth can be spread to the wider population.

  Since the Industrial Revolution, the world has passed through four overlapping paradigms – waterpower, canals and factory organisation; steam power and railroads; heavy engineering, steel, electricity, telegraphy and internationalisation; and mass production, the international firm, fossil fuel powered automobilisation and deep globalisation. The fifth of such revolutions is the Digital Paradigm which is still at the early stage of deployment as its technological potential is held back by the social and economic fetters of the preceding Mass Production paradigm.
- Governments played a key role in creating the infrastructure, the legal and institutional framework and the geopolitical arena which each of the paradigms required. During the Mass Production Paradigm in the 20th Century governments intervened to create and manage aggregate demand for the output of the deploying system. In the most recent knowledge intensive Digital Paradigm, governments supported the development of the key inventions that has led to the development of this revolutionary technology.
- As in previous eras of transition, we are currently experiencing massive disruption in the economic, social and political spheres as well as environmental and climate spheres, reflecting the fact that Business as Usual is no longer possible. Acute disruption in the framing conditions for achieving more equitable and sustainable development in low and middle income economies is reflected in the fracturing global trade regime; the prevalence of economic and social exclusion (including the inability of manufacturing to create the jobs which spread the gains for productivity growth to the wider population); a rapidly accelerating environmental crisis; and the crisis in institutions of global governance.
- As in all paradigm transitions, the threats posed by the disruption of the old order are simultaneously accompanied by opportunities opened up by the new revolutionary paradigm. The digital technology at the heart of the new paradigm – ICTs - is flexible. It provides the opportunity to descale production and to bring production closer to consumption and to decentralise economic and political power. Embodiment of ICTs in

products and infrastructure allows for a range of unmet and new needs to be satisfied. It also allows for the innovation of new institutions, work routines and patterns of consumption. Crucially, the new wave is characterised by technologies which are inherently systemic in character. Within this world the social, political, economic and environment are interconnected, and this is a source both of threat and opportunity.

The ‘niche innovations’ described in Section 6 above evidence the potential which the new paradigm holds for a more equitable and sustainable growth trajectory in advanced and developing economies alike. The challenge now is to promote the rapid and wide scale deployment of these innovations, which embody a combination of complementary technological, economic and social changes.

The future is however very uncertain. Moreover, the world is heterogenous, and context is critical. Hence, we have avoided identifying particular subsectors which should be targeted to meet these developmental goals. Industrial policy based on the dynamics identified above will be different and specific for each country or sub region. Instead, we identify a number of generic policy areas which should be addressed. These will allow for the emergence of economic activities and social innovations which are context specific, and which take advantage of the revolutionary potential offered by the new technology. These policy agendas (Figure 22) are:

- The prioritisation of the needs of the informal sector and low income urban agglomerations
- Taking advantage of ICT based technologies across the economy and society
- Meeting the environmental challenge through applying nexus approaches and policies
- The deployment of renewable energy
- Making the most of commodities
- The expansion of South-South Trade
- The decentralisation of governance.

Figure 22: Policies to Transform Threat into Opportunity

These new policy agendas do not require the wholesale destruction of existing industrial and social structures. Nor do they invalidate the battery of industrial and innovation policy instruments which currently support economic growth. Much of what exists, such as heavy industry, minerals extraction, transport infrastructures, investments in human resources and trade with northern economies *will continue to play a role in meeting future developmental needs.* There is a continuing need to deepen a presence in early-stage growth sectors such as textiles, footwear, furniture and there remains a need to move into new more advanced and technology-intensive sectors, as well into the service sector. *In all of these cases, policies designed to compensate for market failures and to promote long term capability growth remain of crucial importance.*

What we are proposing is a series of bold policy interventions which will take advantage of the potential offered by digital technologies to change the trajectory of growth, both within existing sectors of activity and in the expansion of new sectors.

New and bold interventions, supplementing some existing industrial policies, to take advantage of new opportunities in the digital paradigm

The path which we map out begins with innovations at the margin, then speeding up diffusion to enable a transition to a development trajectory which is appropriate to meeting context-specific developmental objectives. In each of the indicated areas of policy intervention we will highlight the importance of a systemic response and the key role to played by revolutionary ICT technologies. Both of these are central to the Digital Paradigm and stand in sharp contrast to the Mass Production Paradigm.

Benefitting from the opportunities opened by the new Digital Paradigm requires a recognition that Business as Usual is no longer a feasible policy option and that low and middle income countries no longer seek to catch-up and mirror the path of the economies leading the Mass Production paradigm. Instead they need to forge a new more equitable and sustainable path for development.

Two Key Policy Lessons for Low and Middle Income Economies

Continuing with the past policy trajectory is not feasible. The world is experiencing a period of disruption across a number of fronts, and Business as Usual is no longer an option.

It is necessary to move from a ‘catch-up’ strategy (replicating the success of the rich countries, China and the ‘Asian Tigers’) to a bolder ‘beyond catch-up’ policy agenda which charts a new path for a more equitable and sustainable development agenda.

Prioritise the needs of informal and urban clusters

The challenge of meeting the needs of the excluded populations for higher incomes, enhanced livelihoods and less precarity is one of the most important agendas confronting policy makers in low and middle income economies. As we observed more than two thirds of the non-agricultural population in Africa and south Asia and more than half the population in Latin America earn their livelihoods in the unregulated informal sector. The expansion of the large scale, modern formal sector has clearly not met their needs in the past and is even less likely to do so in the disrupted world which now frames the development challenge.

In addressing this agenda we can learn an important lesson from the evolution of the Mass Production Paradigm. Henry Ford’s innovation turned craft production on its head, producing very large volumes of standardised products. Since the Great Depression of the 1930s was accompanied by a shortfall in demand the problem which Keynes addressed at a theoretical level and Roosevelt at the policy level was how to match the vastly enhanced production capacity provided by Mass Production with adequate levels of consumption. Roosevelt’s response was the New Deal. This involved massive deficit financing to renew business confidence and to create demand. It was supported by the success of trades unions in increasing wages which enhanced consumer purchasing power. From the late 1930s and during WW2, state backed expansion of armaments production created the market pull which the deploying Mass Production Paradigm required. After the War, in both Europe and North demand was stimulated by the expansion of the welfare state and the construction of highways and affordable homes.

Learning from history about the relationship between supply and demand

These developments - in each case driven by government - which were critical to the successful deployment of Mass Production have largely been overlooked in industrial and innovation policies which have focused on the supply side of the growth equation. So, the first important conclusion from this historical experience is that demand is at least as important in creating supply as supply is in creating demand; in some cases and at some times, demand is the handmaiden of supply. The second important conclusion, which is especially relevant to meeting the needs of those excluded from past decades of growth in the developing world is that innovations are malleable. The particular form they take is *induced* by the character of demand. A war requires innovation in the design and production of armaments; crudely speaking, if demand is dominated by the 'needs' and preferences of high income consumers, then technological change will be biased in the direction of capital and skill intensity; when wages are high, innovation will be labour saving. This is the major conclusion which can be drawn from the case study of the character of Chinese and Indian capital goods imported into East Africa and described in Section 6 above.

Hence, the development of a more appropriate production structure which offers the possibility for enhanced manufacturing employment and more inclusive industrialisation requires reorienting the character of final demand from meeting the needs of the global rich to also meeting the needs of the poor. This is not just a matter of designing new products and processes to meet existing needs but producing wholly new products and services appropriate to the needs of the poor and the excluded.

Committing to meeting the needs of the poor, knowing what these are, understanding their interlinkages, and committing to systemic interventions

There are three problems confronting this agenda. First, it requires a commitment to put the needs of the poor genuinely at the forefront of development rather than just noting these needs as a 'good thing'. Second, we know very little about the complex and interrelated challenges faced by this large community of the poor and excluded. This includes knowledge about the level and specific characteristics of the varied components of their requirements – production, incomes, health, education, potable water, sewerage, mental health; the list is almost endless. Third, it is necessary to understand the interactions between these various needs. For unlike most policy interventions which target individual components of needs (for example, health, employment, technology) and which are delivered by specialised agencies (Ministries of Health, Industry and Labour), the complex needs of these excluded communities (and indeed all communities) are systemically interlinked.

What does this boil down to in practice? The markets for products targeting high income consumers are well understood, as are the needs and consumption patterns of high and middle income consumers. Global corporations devote large expenditures to understanding the nuances and complexities of this structure of final demand. In contrast, despite the prospect of exploiting profitable opportunities in these large markets of excluded populations, little is known of the complexity and heterogeneity of how livelihoods are supported in these vast and sprawling conurbations. In the absence of structured formal employment, or when employment provides below-the-bread-line wages, how do individuals, families and communities stay alive? At a general level we know that they do so through a portfolio of activities involving not just the bread winning adults but children as well. We also know that self-employment is the predominant form of survival and that by their nature these livelihoods involve systems of activities, often informally integrated with the pursuit of livelihoods by neighbours and friends. To a greater or lesser extent (depending on country and context), these informal populations also come into contact with services (such as education, healthcare, sanitation) provided by municipalities, governments and NGOs. But we know little of the detail of all of these activities and interactions which is necessary for an effective policy response.

The first task therefore is to map these complex communities – their needs, their consumption patterns, their involvement in production, their interactions and the role played by external actors. The primary route into this understanding will be listening to the voice of these excluded populations and this will require extensive social interventions. New digital technology has an important role to play in the process, not just in generating data, but in analysing large data sets which will provide a better picture of the complex needs and systemic interactions in these communities of the excluded. A key window into these informal urban settlements is the ubiquitously used mobile phone. It tells us how people move around; what sorts of people are using phones; and what phones are used for. It charts the extent to which phones are used for commercial activities, and the sorts of commercial activities for which they are used. Critically, this data gathering will need to protect privacy so procedures will have to be installed to anonymise the data – advances in data anonymisation are under development and to a greater or lesser extent useful anonymised data will become available.

Using new technologies to understand the complex nature of communities and appropriate interventions

Thereafter big data analysis and AI can be used to throw light on these interactions. This can illuminate the complex systemic character of livelihoods and the linkages between the service delivery (energy, health, education, water, social care) and the character of developmental needs (nutrition, education, security).

It is only after this detailed and nuanced picture of demand has been created that effective steps can be crafted to create supply and employment. The analysis will provide an understanding of what sort of products will be demanded, most likely involving less individualised forms of consumption. Will some of these products be difficult to appropriate – that is, are they public goods? If so, who will provide the resources so that the externalities can be addressed? What sorts of consumer needs are currently not met because low incomes mean that ‘effective demand’ is supressed?

Entrepreneurship is another agenda which will require action. In reality, entrepreneurship is abundant in these excluded communities and informal economies because it is essential for survival. Often these talents and energies pass beneath the radar. The incorporation of youth (increasingly highly conversant with digital skills through their use of mobile phones) and women will not just be a development objective, but a development opportunity as new business opportunities are opened up, and this will require business development and support.

Building on entrepreneurship in the informal sector with the involvement of the National System of Innovation

Next is the question of what production technologies are appropriate not just to generating these products but to adopting and innovating technologies which are employment intensive, small scale, safe and have low barriers to entry. This will require reorienting the National and Local Systems of Innovation from their historic focus on middle and high income markets and drawing on highly skilled workers. Universities, laboratories, research institutions and educational systems will need to refocus their activities and strategies. In so doing, and in response to the new market opportunities, a domestic and often local capital goods sector will develop to address the need for appropriate technologies and services.

Many of these and similar inputs fall under the remit of existing agencies in government. The challenge will be to orient them toward meeting the needs of low income consumers and facilitating processes in which these various stakeholders will act in concert rather than in isolation. We will return to this challenge in Section 8 below.

In a growing number of countries, the Smart City programmes described in Section 6 above have already begun to map many of the relevant activities of people living in these vast urban conurbations. However, as we observed, the data collected and the use to which the data is put is overwhelmingly geared to the delivery of services and infrastructure. The bold strategy now required is to turn the agenda towards the mapping of productive activities, and then to support the growth of productive activities which can take advantage of the potential offered by digital technologies to enhance the livelihoods of much of the population who have been excluded from the fruits of economic growth during the Mass Production era.

Meeting the Environmental Challenge

As in the case of including marginalised communities, *meeting the environmental challenge is of first order importance.* This involves a complex agenda of sustainable development, mitigation and adaptation. It spans the whole sphere of human interaction with the environment, including production, consumption, recycling, disposal and pollution.

The costs of environmental damage, and particularly climate change, are enormous and have been extensively chronicled by various reports from the IPCC, UNEP and other agencies. *Resistance to addressing these challenges is often phrased in terms of the costs of greening the economy and society. But this resistance is frequently misinformed or short term in nature.* With respect to misinformation, many of the costs of environmentally damaging growth are not pecuniary or are difficult to measure. Hence their impacts are obscured in conventional methods of growth accounting. Moreover, because many of the costs of environmental damage and climate change occur over a long time horizon the discounted financial value of these costs in relation to returns on relatively short term investments are low, limiting the financial incentives to invest in climate resilient innovations.

The combination of these blinkers has meant that the economic benefits of greening economy and society are significantly unrecognised in investment decisions. The reality is that *greening will not only reduce environmental damage but also offers many opportunities for value added activity, as well as for social inclusion and equality. Some low and middle income countries such as Costa Rica and Uruguay have begun to take advantage of these growth related opportunities.*

The environmental impacts of the ‘Great Acceleration’ after 1950 augured in the transition from the Holocene era to the era of the Anthropocene and this resulted in a series of environmental challenges, in many cases overstepping the planetary boundaries which determine the limits of environmental sustainability. Because of the heterogeneity of these challenges we will confine the discussion to three illustrative greening agendas, each of which has derived implications for industry, manufacturing and employment. In each case, the required responses are systemic in character and involve the use of ICTs. The three areas are the water-food nexus, the dematerialisation of production, and the importance of integrating changes along the domestic supply chains, including in logistics.

The Water, Energy, Food Security, Ecosystem Nexus

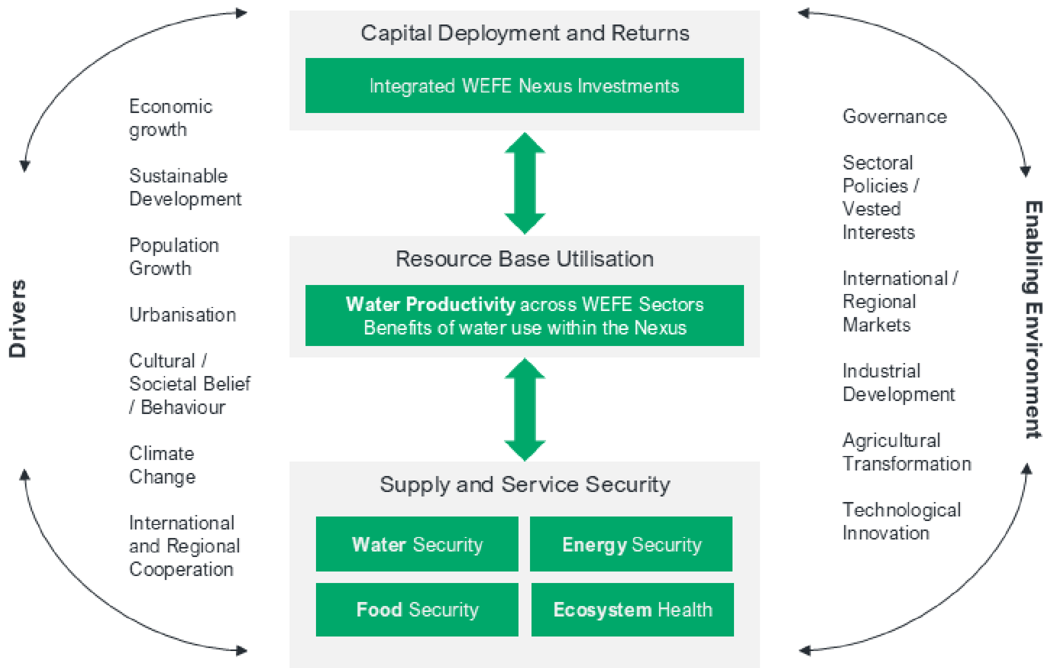
As a result of its stress on interconnectedness and placing water security at its centre, the water, energy, food security and ecosystem nexus (WEFE) is increasingly seen as central to economic greening and growth, especially in the food value chain. Figure 23 provides an overview of some of the most significant linkages and critical causal relationships within the WEFE Nexus.

Figure 23: Multi-dimensional Interlinkages of the WEFE Nexus

Water ↔ Energy	Water is indispensable for energy generation across multiple technologies - powering hydroelectric plants, cooling thermal plants, cultivating crops for biofuels. Energy is essential for water related processes - the treatment and distribution of water, pumping groundwater, and seawater desalination.
Water ↔ Food	Water is the cornerstone of agricultural production and the broader agri-food supply chain, as well as urban life. However, water for agricultural uses may degrade water quality through runoff containing pesticides, fertilisers, or other pollutants. The manner in which water is used in agriculture, rather than the aggregate demand for water is often the driver of trade-offs.
Food ↔ Energy	Energy is a critical component of the food chain, supporting activities such as irrigation, food processing, storage (including refrigeration), and transportation. However, competing land uses can lead to conflicts, for example when land is allocated for large scale energy projects like solar farms, potentially limiting areas available for food production. Agrivoltaics (combining land for agriculture and solar energy), can improve water conservation by reducing water from evaporation (through shade from solar panels) while producing clean energy that decreases reliance on fossil fuels.
Ecosystem Sustainability	Healthy ecosystems underpin the resilience and sustainability of water, energy, and food systems. They provide critical services such as water storage, water filtration, soil fertility, and climate regulation. Unsustainable exploitation of water, energy, or food resources can degrade ecosystems, diminishing their ability to support human and environmental well-being. Preserving ecosystems is therefore essential to sustaining the nexus over the long term.

The WEFE nexus is a systemic approach to natural resource development, management and investment. Figure 24 is a graphic representation of the interconnectedness of the WEFE nexus. Large scale investment solutions developed in isolation within a specific sector or domain may achieve important objectives, but the trade-offs may also have potentially harmful impacts on other systems, as well as competing demands for the same resources between sectors. A systemic and integrated approach that evaluates costs, benefits, synergies, and trade-offs in all aspects of decision making, though resource intensive, could ensure that investments are designed to maximise synergies, minimise resource conflicts between user groups, with long term impacts across interconnected systems.

Figure 24: The interconnectedness of the WEFE nexus



Source: Petrie, B and N. Nattrass (2025), Development of Required Tools and Roll Out of the Sustainable Water-Energy-Food-Ecosystem Security (WEFE) Nexus Initiative in Africa, OneWorld Europe, Brussels.

Optimising synergies and managing trade-offs to ensure sustainable development and to avoid negative consequences of development decisions are core to the nexus approach. The most challenging aspect of nexus based development that it confronts trade-offs and resource constraints without guaranteeing a win-win outcome.

For example, siloed investments might involve building large irrigation infrastructure to increase agricultural yields. While addressing food production and security, this investment may overlook the strain on local water resources, the energy required for water distribution, the ecological damage caused by depleting wetlands or harming biodiversity, or the potential harmful environmental impacts of large scale hydropower.

In contrast, an integrated nexus approach and strategy based on the conceptual framework in figure 24 would start from considering the interconnected drivers at play in any given context and then making a strategic decision about where to focus interventions to optimise synergies. This could involve building solar powered irrigation systems that improve agricultural productivity while ensuring sustainable water use, reduced reliance on fossil fuel imports, and preserving nearby ecosystems. Such an approach to investments would ensure equitable access to increasingly scarce resources, such as water, between sectors, including industry.

The WEFE nexus approach requires considering all the interconnected issues – costs and benefits - but then deciding which drivers to focus on for appropriate strategic interventions

However, some environmental and socioeconomic circumstances cannot support all the water uses desired in this synergistic manner, requiring trade-off decisions. For example, countries facing severe water stress (for example Egypt, which is applying a Nexus approach) may need to choose between water for energy over water for food.

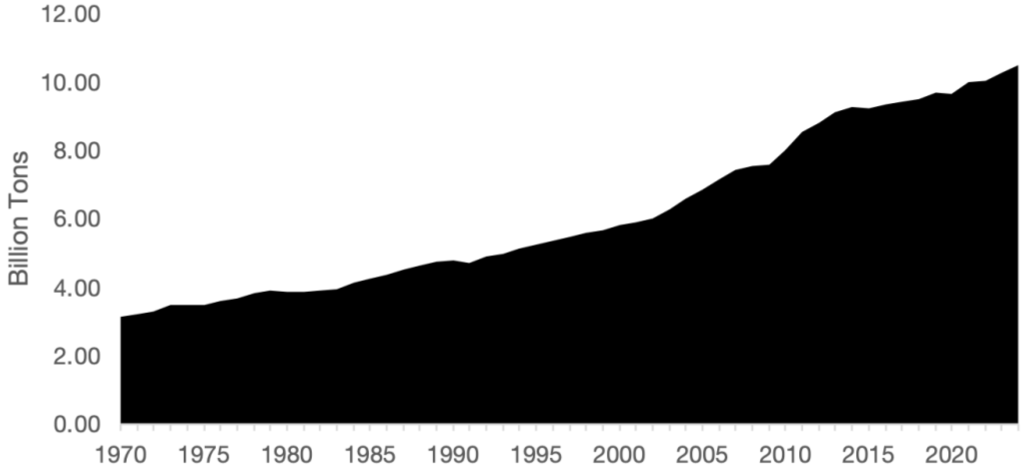
A cost benefit analysis conducted against the nexus drivers identified in Figure 24 may reveal that although food security needs are paramount, these could be met through higher household incomes enabled by enhanced energy access rather than through increased irrigation for food productivity.

In the context of resource scarcity, where water is the primary driver of scarcity, it is critical that the productive use of water is optimised. There is a particular role for the industrial sector and government policy in incentivising the private sector.

Dematerialisation

The human footprint on the biosphere has grown particularly rapidly since The Great Acceleration after 1950. Figure 25 which agglomerates all forms of resource extraction (minerals, hydrocarbons and crops) illustrates that this growth continued without interruption. Between 1970 and 2024, total global material use expanded by more than 340 per cent. 'Without immediate and concerted action, resource extraction by 2060 could surge by 60 per cent from the levels in 2020 which already place an intolerable strain on the earth's fragile resources and environment.[32] A particularly damaging component of the overuse of the earth's resources is the hydrocarbon intensity of production and consumption, since this is the major contributor to global warming and climate change.

Figure 25: World Raw Material Consumption 1970 - 2020



Source: Calculated from https://www.resourcepanel.org/global-material-flows-database

The Circular Economy framework provides an effective architecture for a targeted response and involves concerted and systemic actions in relation to the 'Four R's' – Reduce, Reuse, Recycle and Regenerate. The first of these Rs (Reduce) requires a reduction in the materials intensity of production, not just with respect to energy efficiency but across the range of material inputs. UNIDO has an existing programme addressing this element of dematerialisation. It not only requires changes in production processes, but also materials substitution and the development of new materials. Most importantly, it requires turning as many products as possible into services. Already the provision of music, film and written material has taken advantage of the intangible nature of ICT. The second R (Reuse) challenges the practice imbedded in production, and particularly in consumption, whereby products with a short life span are discarded. Changes in design make it possible to upgrade products (for example, mobile phone upgrades); consumers can adjust their behaviour to avoid single-use packaging and to use refillable containers. The third R (Recycle) requires that when products and components do reach the end of their lives, they are recycled and not discarded. Considerable progress is being made with respect to plastics packaging and in the context of a shortage of critical materials, to the recycling of batteries, magnets and electronic devices. And where there are limits to the efficiency of materials use, where there are constraints to the reuse of products and where recycling has reached its limits, the fourth R (Regeneration) enters the stage with waste being used in efficient processes to regenerate the energy embedded in discarded waste.

Each of these various elements of the circular economy is systemic in nature. The four Rs are interrelated and progress requires a vision and action which threads through each of these domains; changes in production and use cannot be achieved without changes in design; complementary action is required in both the productive economy and in consumption. To a greater or lesser extent, progress in each of these domains is heavily dependent on digital technologies. Design is ICT intensive; coordination between links in value chains depends on the exchange of digital data; and efficiency in production requires ICT based monitoring and machine control.

Circular economy analysis and interventions provide new opportunities

These changes in economic and social organisation offer manifold opportunities for employment growth in manufacturing maintenance, disassembly, recycling and related services. Moreover, insofar as economies transition from a throwaway to a repair-and-reuse structure of production and consumption, these changes are also employment intensive. These opportunities have been widely recognised in high income countries particularly within the EU, and in many respects they require changes in behaviour as much as technology.

Value Chain efficiency

A key neglected area of productive intervention to reduce energy and materials use in low and middle income economies arises from inefficiencies in logistics in many value chains. Take the case of the maize-flour-food value chain. Typically, interventions targeted to reduce materials waste and to increase energy efficiency zero in on a particular link in the chain, often the responsibility of individual firms and ministries. Thus, the Ministry of Agriculture promotes farm storage technologies to reduce postharvest food loss, often in concert with the private sector; the Ministry of Industry and the private sector (predominantly based in higher income economies) will market more energy efficient equipment. All of these innovations are valuable. Yet the primary source of wastage and energy loss may arise along the chain and predominantly in logistics. It is likely (but as yet unmeasured) that the energy loss arising from dirty fuel injectors in diesel trucks more than outweighs the gains arising from more fuel efficient equipment. Similarly, inefficient household cookers lead to a considerable and unnecessary loss of energy and can be relatively easily replaced, and at low expense.

> ***A systemic value chain perspective enables reduction of energy and materials used arising from logistic inefficiencies***

These examples surface the necessity of adopting a systemic value chain perspective to the dematerialisation of production and consumption. A whole chain perspective is required, not just by focusing on all or most of the links in the chain, but also on the interactions between the different links in the system. For example, the containers used to transport materials will often affect the degree of wastage in production; this was one of the primary lessons which the Toyota Production System described in Section 3 above developed in order to improve quality and reduce wastage within Toyota's manufacturing plants. Similarly, Toyota learned that unless complementary changes were made in its supply chain, the benefits arising from improvements in its internal operations would be reduced.

There is no rocket science in this approach to dematerialisation. But what it highlights is the importance of systems wide changes. For example, in the case of energy efficiency in the maize chain, effective improvements require coordinated efforts by a multiplicity of stakeholders (including different Ministries) who have historically acted in isolation. ICTs have an important role to play, not just in the effective control of individual machines, but in controlling the connectivity of vertical and horizontal flows along the chain which are necessary for the individual stakeholders to act in a coordinated and effective manner.

Development and deployment of ICTs throughout the economy

Each of the five paradigms since the onset of the Industrial Revolution has involved the co-evolution of social organisation and production systems, built around a core general purpose revolutionary technology. The determining characteristics of a technological revolution are that it provides manifold opportunities for profitable innovations in process and product, that its cost falls and continues to fall, that it is in unlimited supply and has pervasive uses across economy. Clearly, digital technologies fit these conditions.

Section 6 above provided a few examples of how low cost innovations have been developed to meet the needs of those largely excluded from economic growth. But this is only the tip of the iceberg, and there is considerable scope for many evolving technologies. Moreover, these impacts are not just limited to urban conurbations. To cite a couple of examples, in Rwanda drones have been used to deliver medical supplies to distant rural areas, farmers in Kenya can send photos of diseased leaves to specialised agencies who will diagnose the pest and suggest specialised forms of pest control.

Unquestionably, therefore, there is abundant scope for a large scale initiative (or indeed a series of initiatives) designed to support the innovation and deployment of ICT based products and services across the range of economy and society. But for these opportunities to be grasped, a number of issues will need to be addressed. We cite a few below.

ICT technologies to deliver services and products can be deployed across society to reap major economic and social gains

- *Connectivity*: In most urban areas across the globe, mobile telephones provide access to both vertical communications (with external parties) and horizontal communications (to family, neighbours and friends), although often at too small a bandwidth to allow for data intensive communication. Fortuitously, the gap in the availability and quality of mobile and internet infrastructure between low, middle and high income countries is relatively small, certainly much smaller than in the critical infrastructures central to previous paradigms (such as railways, electricity, roads and fixed line telephony). The narrowness of this gap is a direct consequence of the uneven distribution of infrastructure in Mass Production - the adoption of mobile telephony in high income countries was in part hindered by the legacy of fixed line telephones which had been deployed during Mass Production.

  There are two obstacles limiting the capacity of the excluded to benefit from the systemic gains offered by ICTs. The first is the cost of access; the second is the connectivity problems encountered by people living in distant and often sparsely populated regions. However the rapid deployment of low level earth orbiting satellites can provide the technical potential for both of these challenges to be overcome with appropriate government policies. In future, therefore, it is likely that everyone everywhere *can* be connected electronically. The issue is whether they will be connected.

- *Digital skills*: In previous paradigms the primary global skill divide was between countries. Low income economies suffered from massive skills defaults, which was both a cause and a consequence of their low level of industrial development. In the current era, the primary inequity in the skills relevant to the revolutionary technology are age and gender. The level of digital savviness of the large young populations in many low income countries is astonishing, and in many respects is at least at the same level, and in some cases at a higher level than their peers in richer countries.

- *Entrepreneurship*: As in all countries, new start-ups require support. ‘Headline policies’ in industrial and innovation policies highlight the need to assist firms originating in and spinning out of universities and research establishments in the National Systems of Innovation. A battery of support measures has been developed and since many low and middle income countries possess high levels of skill and are incorporated in globally networked research and innovation programmes, these ‘best practice’ global programmes are in many cases equally relevant to middle income and some low income economies.

  Startups, and particularly digitally based and knowledge intensive startups originating in informal and low income settlements, are less well served in most low and middle income countries. The problems which these startups confront are generally not primarily due to a shortage of entrepreneurship - survival in informal urban settlements has necessitated the development of innovative capabilities. Instead, these startups require business support tailored to the needs of new markets, especially in low income urban clusters and in impoverished rural areas. This business services gap is largely met by NGOS, who are often predominantly foreign funded and managed. A 180 degree reorientation is required in the provision of support for entrepreneurship, from the formal to the informalised sector.

The potential of these start-ups which arose in large informalised settlements should not be underestimated. In Africa, there has been an explosion of digitally based firms originating in informalised urban conurbations, often involving unemployed digitally savvy school and university graduates. Kenya is a case in point[33]. In Indonesia and Malaysia motorcycle ride hailing companies originated in the informal sector and have grown into very large multinational and research based firms.

- *National Systems of Innovation*: Taking advantage of the opportunities opened up by ICTs for employment and industrial growth is of course not limited to the informal sector. In all countries the National System of Innovation (the NSI) plays a critical role in technological development and in skills formation. This includes universities, research establishments, science based government ministries and firms in the producer services and capital goods sectors. So despite the requirement to focus attention on entrepreneurial development and innovation in the informalised and distant impoverished rural sectors, there remains the need to expand and strengthen institutions and activities in the National Systems of Innovation, particularly in the development and application of digitally based innovations.

In summary, as in the case of other interventions, the economy wide diffusion of digitally based technologies necessitates the adoption of a systemic approach, addressing opportunities in the economic and social sphere and benefitting from the systemic interconnectedness of digital technologies.

Renewable and distributed energy

Energy is central to production. By the third and fourth wave electricity generation played a crucial role in providing energy for production and consumption. In these phases electricity generation displayed a number of characteristics: it was produced by the application of various forms of hydrocarbons (coal, oil, petroleum and gas); its generation was concentrated and centralised in large utilities providing the supply for industrial and domestic consumption; and finally its modus operandi was to concentrate on the supply side in managing the system without taking into account patterns of consumption. However, the fifth wave has radically departed from these characteristics signalling a disruptive break in the process of generation and consumption of energy.

The abundant energy required to fuel the fifth wave now being deployed is electricity. But unlike the Mass Production paradigm, electricity in the new wave is increasingly provided by non-hydrocarbons and is being generated locally by renewables such as solar, wind, nuclear, biomass, geothermal and possibly wave power. Although the economic and political power of carbon-based firms and economies is slowing the transition from carbon based to renewable energy, the forces holding back the wider deployment of renewables are fighting a losing battle. Renewables are increasingly becoming the lowest cost source of energy, albeit suffering to some extent from intermittent supply. *Furthermore, renewable energy is no longer dependent on large single utilities but has opened the way for distributed and dispersed forms of generation, especially from solar sources*. Finally, distributed renewable energy is able to take into account consumption as a driver in balancing the systemic relationship between supply and demand. This transition to renewables thus offers manifold opportunities for supporting more equitable and sustainable patterns of growth. These issues are discussed and exemplified in more detail in the case studies in Section 6.

> ***Renewable energy is low cost, distributed and dispersed, and with ICTS balances supply and demand offering opportunities for a new growth path***

Energy can be produced where it is used

Renewable energy brings together generation and consumption

Water based power locked production to the site of the waterfall; production and use were fused geographically. But as steam power, electric power and hydrocarbon based power technologies developed over the 19th and 20th centuries the source of power generation was increasingly separated from its use. But so too was the supply of energy raw materials separated from energy generation. Oil and gas based feedstocks were geographically concentrated globally and the raw material was shipped around the globe in a massive fleet of tankers and long pipelines. The separation of production and use also characterised the intra-country distribution of power. Power stations increased in scale. National electricity utilities became large, centralised monopolies controlling not only energy generation but also through using a national grid infrastructure to distribute power to consumers. This trajectory of increasing scale reinforced the centralising character of the Mass Production paradigm. In low and middle income countries, this effectively cut many potential users off from access to electricity and forced them to use costly diesel generators.

In contrast, with the exception of nuclear, renewables are inherently less scale intensive. This does not mean that there is an absence of scale economies and distribution costs. For example, offshore wind both involves extensive energy transmission. But as a general rule scale is less significant in renewables and at the extreme (solar power, biomass and wind), low cost power can be generated where it is used, reducing barriers to entry for users in distant regions of the country. In this sense, renewables are inherently more inclusive than hydrocarbon, hydroelectric and nuclear power.

There are costs associated with scale

Very large power stations require extensive distribution systems. Construction of this distribution infrastructure is not just costly, but the transmission of energy over long distances involves significant energy loss (between seven and 14 per cent in large hydro schemes.[34] Their large scale requires massive aggregations of finance. The recently completed Great Ethiopian Renaissance Dam cost almost $5bn, equivalent to five per cent of Ethiopia's GDP. South Africa's new coal fired power stations costs have radically escalated due to overruns and corruption and are currently estimated to be around $12bn for Kusile and $9.7bn for Medupi. These massively costly projects lend themselves to corruption and are reinforcing of concentrated economic and political power. In low and middle income economies they also necessarily require the participation of foreign firms and costly foreign equipment and technology. Very large projects such as hydro and nuclear power are also characterised by extensive cost overruns and delays in completion.

Scalability allows for the wider distribution of economic activity.

Very large scale power generation involves a chicken-and-egg balance between supply and demand. Power is generated at a high scale, and unless the large scale plants are substituting for existing power stations, they invariably involve a waste of capacity until demand builds.

By contrast renewables tend to be modular and inherently more scalable, allowing for capacity to be added in proportion to the increase in demand. This adds to the contribution which renewable power can make to the geographical distribution of economic activity, as power supplies can be increased as demand expands. Coupled with their lower capital and running costs, renewable electricity thus involves much lower barriers to entry than hydrocarbon based power. Consequently, they reinforce the attractiveness of a more equitable growth trajectory.

Reducing the negative environmental impact of hydrocarbon based power and large hydroelectric dams

Unquestionably the most important contribution made to more sustainable and equitable growth by renewable power is a reduction in environmental damage. The use of hydrocarbon based fuels leads to massive and environmentally damaging emissions of carbon dioxide and methane. But it is not just in use that hydrocarbons damage the environment. The extraction of hydrocarbons often involves substantial negative environmental impacts. For example the New Horizon blowout in the Gulf of Mexico in 2010 led to massive environmental damage and by 2016 the cleanup cost BP more than $60bn. Transporting oil and gas around the globe adds significantly to carbon emissions, and spillages invariably damage the environment. Large hydro dams also lead to significant environmental damage – not just in the buildup of silt, but also in increased flooding, changes to riverine ecosystems, the disruption of agriculture and the spread of diseases such as malaria.[35]

Renewable energy does not entirely remove the harmful impact of power generation and use. Carbon is embedded in the generation equipment, and although the length of transmission lines are generally much shorter than that involved in large scale fossil fuel and hydroelectric energy systems, large wind and solar plants separate energy production and use albeit to a much smaller extent than in the case of fossil fuel powered energy. Distributed and embedded rooftop solar generation overcomes these limitations. Increasingly it will provide home and commercial alternatives to meet generation and consumption needs.

In summary, the shift from carbon based power and very large scale hydroelectricity provides a major opportunity for a more equitable and sustainable growth trajectory. It makes an overwhelming contribution to the reduction of climate damaging harmful emissions. It lowers barriers to entry and provides lower cost energy. Renewables allow energy production to be located closer to its use, and thus to foster decentralised and smaller scale production. They require smaller aggregations of finance and thus not only reduce barriers to entry but also lower the opportunity and incentives of the centralisation of political power and corruption. Renewable technologies such as solar, wind, and biomass are now deploying very rapidly as a consequence of their economic attractiveness, but they are not the only innovation which will erode the dominance of hydrocarbon based power. Green hydrogen holds potential in some limited uses (truck based transport, steel and cement), and in the long run nuclear fusion offers the prospects of limitless and relatively environmentally benign power. In the medium term, the disadvantages of large scale nuclear fission generation is leading to the development of Small Modular Nuclear generating plants. These are much larger in scale than wind and solar plants, but will produce at a much smaller scale than existing and planned large nuclear plants. These small modular reactors will reinforce the centripetal growth trajectory of the Digital Paradigm.

Renewable energy reduces environmental damage and counters the climate crisis

ICTs have been central to the development and deployment of renewable energy. For example, to be safe solar panels require AC and DC isolators; inverters adjust to variable energy generation; the junction box which allows for the integration of multiple panels is an assembly of electronic components. In wind power, ICTs are critical to the sensors which monitor the yaw of the blades, imbalances in rotors and rotor damage. They are also at heart of the inverters and transformers which feed current into the grid. At a systemic level, the integration of multiple energy sources in the national grid and the control and distribution of electricity depends heavily on electronic control systems. So too do the smart meters in the home and AI enabled thermostats which contribute to energy efficiency.

Making the Most of Commodities

Many, but not all, low and middle income economies are resource rich. The resource rents which economies can earn from their gifts of nature will depend on the economic and environmental viability of extracting raw material deposits and the balance of global supply and demand for the commodities. The capacity of the raw material countries to appropriate resource rents will be determined by the policy regimes providing access to the deposits, the efficiency with which the materials are extracted from the earth, the social and environmental safeguards that are in place and the degree of political stability. These framing conditions are general to all countries, rich and poor alike. The transition to the Digital Paradigm increases the demand for some metals and rare earths such as antinomy, rhenium, hafnium, niobium, gallium and vanadium.

The digital economy demands new raw materials. ICTs improve efficiency of exploration, extraction and processing; and reduce waste. Distributed energy production provides new opportunities for deepening value added and reducing waste and effluent by processing raw materials near the site of mining

The industrial challenge confronting minerals rich economies is how to extract greater value from their gifts of nature. This involves developing and maximising both the upstream and downstream linkages from extraction. With respect to upstream backward linkages, the primary inputs are capital equipment and services. With respect to downstream forward linkages there are a number of stages of value addition. The first is the removal of waste to increase the concentration of the targeted ores. Subsequently the purity level of the extracted ore has to be increased.[36] Typically, the first stage of concentration is done onsite and involves the use of heavy energy intensive machinery. The second stage of processing tends to be more scale intensive and typically a single processing plant will refine ores from a number of plants. As in the case of producing first stage concentrates, refining tends to be very energy intensive. Downstream from concentration, refining and smelting, the ores are then turned into final products which are used throughout industry. Except in the case of countries which have economically attractive raw material deposits, the transformation of refined metals into intermediate and final products tends to occur in foreign economies.

What does the transition to the Digital Paradigm add to these generic opportunities and challenges confronting all commodity producing economies?

- For those economies with deposits which are used in the ICT sector, the demand for their minerals increases substantially. And where the mineral is in short supply and where mining and processing activities have a protracted gestation period, the prices realised for their minerals have risen dramatically.[37] This ICT related expansion in demand provides major opportunities for the extraction of resource rents.

- Since ICTs are a revolutionary technology which affect all sectors of economy and society, their deployment across the economy increases efficiency in the processing of ores. It also increases efficiency in raw material extraction – AI speeds up the search for minerals, and automated mining is rapidly improving both productivity and the efficiency of resource extraction in low grade deposits.

- The development of renewable energy (a sector heavily reliant on ICTs) adds to the capacity of resource economies to maximise the resource rents offered by their mineral deposits. Renewables increasingly provide low cost energy and can substitute for costly and environmentally damaging diesel and electric energy. Insofar as the scale of extraction and processing is related to the cost of energy, the modularity and scalability of renewables provides the capacity to produce low cost energy onsite rather than drawing on costly sometimes unreliable carbon based supplies. It also makes it possible to exploit relatively small deposits which are unviable with existing carbon based energy supplies.

- Refining and processing ores at or near the site of extraction reduces the need to transport (often highly polluting) waste materials across large distances.
- Renewables not only reduce costs but also enhance industrial activity in distant and often sparsely populated regions where most mines are located. Shedding waste at or near the mine site also reduces the environmental costs in processing.

The coupling of renewable power and green steel production in Brazil described in Section 6 is an excellent example of the new systemic opportunities opened up in commodities extraction and processing by the deployment of the revolutionary Digital Paradigm. These systemic gains are not confined to green hydrogen steel but also apply to all 'soft commodities' (agriculture and fisheries), and 'hard commodities' (metals and minerals).

South-South Trade

Productivity and corporate profitability declined in the Mass Production Paradigm after the 1970s (Section 4). In 'normal' circumstances, following the pattern of previous epochs, this would have resulted in the rapid atrophy of those economies specialising in mass production. However, the Mass Production Paradigm's 'life' was extended by deep globalisation and the development of GVCs. Profitability was restored by accessing virtually unlimited supplies of low cost labour in developing economies. The global dispersion of production led to export oriented industrial development and rapid economic growth in a number of north Asia economies, notably in the four 'Asian Tigers' (Hong Kong, Korea, Singapore and Taiwan) and then with a considerable global impact China and South East Asia.

The export dynamism of China and other predominantly north Asian economies was premised on access to external markets, particularly in the US and Europe. However, it resulted in the erosion of manufacturing employment in these final high income countries. It also was in part a cause of low employment growth in other developing economies because China's competitiveness closed off the space for exports from other economies in major global markets and because China's exports to other developing economies frequently displaced domestic manufacturing and employment.

The political consequences of these employment impacts have led to a rapid growth in protectionism. Whilst a number of economies adjacent to China (such as Vietnam and Indonesia) have been able to pick up some of the 'trade space' available as Chinese firms offshore some of their production in order to circumvent trade barriers in the US and other major markets,[38] these opportunities are limited. Trade protectionism is not only aimed at China, but it has severely reduced the opportunities for other countries expanding their presence in GVCs and benefitting from export led growth. Thus, whilst South-North exports will not stop and they may even expand at the margin, they are unlikely to offer the hoped for prospects for much of the developing world.

South-South trade and regional value chains offers growth opportunities for low and middle income countries. Similarities in factor endowments and in consumer incomes and needs provides scope for more employment intensive and inclusive technologies, and smallscale and locally owned enterprises

Over the past decade intra-regional trade had grown more rapidly than inter-regional trade. We have also seen (Section 6) that the character of South-South value chains is often distinctly different to that in which southern producers serve northern markets through their incorporation in GVCs. South-South value chains tend to involve products which are more appropriate to the needs of poor consumers and involve more labour intensive production processes. These regional value chains are not without adverse developmental impacts since they lack the ESG safeguards protecting the environment, child labour and other exploitative working conditions. Nevertheless, the growth in South-South trade offers considerable growth opportunities for low and middle income countries, including the possibility of increased employment and the inclusion of small firms and less educated labour across these regional value chains.

Policy often coevolves with economic logic and it is significant that there has been a growth in trade agreements within the developing world encouraging and facilitating enhanced South-South trade. Perhaps the most significant of these is the African Continental Free Trade Area (AfCFTA) signed in 2018 and beginning implementation in 2021, but which is yet to realise its potential. The AfCFTA includes 43 countries with a population exceeding 1.3bn.

Decentralise Governance

A recurring theme is the analysis of the transition from the Mass Production Paradigm to the Digital Paradigm is the contrast between them with respect to scale and governance. By governance we refer to a constellation of power relations, at the political level (national-regional-local), in institutional design (for example educational and health systems) and within firms and organisations (vertical flows of information upwards and decision downwards). The massification of scale in Mass Production was accompanied by the standardisation of product, service and institutional design, and with top down centralised authority. By contrast, the Digital Paradigm is flexible and provides scope for the customisation of product and service. It not only enables enhanced degrees of horizontal information flows but a greater degree of horizontal and bottom up decision making. The transition to the new paradigm heralds the shift to a more geographically decentralised centripetal economic and social trajectory, which is promoting of more inclusive and sustainable development.

> ***The flexibility of digital processes creates the opportunity for a more decentralised form of governance but this requires restructuring and capacity building of appropriate institutions***

As in all paradigm transitions, this shift in social relations is not a one off change. Institutional routines, values and behaviour are ‘sticky’. They take time to a adjust. Moreover, there is no single set of social relations required to support the digital paradigm. and many possible alternatives exist. Nevertheless, despite this stickiness and variety there are important implications for policy.

There should be a shift in policy formation and policy execution from the centre towards the periphery. This is a matter of degree, dependent on the extent of centralisation in past structures, the size and character of the entities involved, and local circumstances. To a lesser extent it may also involve an enhanced degree of fiscal decentralisation and expenditure. Regional authorities need to be strengthened and especially in the case of policies targeting equitable and sustainable growth in informalised and low income urban communities, strengthened municipal governance is a necessary component of paradigm change.

This shift, in economic geography, in power and in attitudes will take time. However, the central conclusion is that the transition is not an agenda which is fuelled by moral objectives, but by the need for greater social and economic efficiency and the opportunities opened up by the Digital Paradigm. There are economic opportunities for the private sector and its incorporation into visions and policies is a necessary condition for success transition. Just as scale and hierarchy were necessary complements to Mass Production, so decentralisation, dispersion and horizontal and upwards flows of decision making are necessary complements if the potential of the new Digital Paradigm for promoting more equitable and sustainable growth is to be realised.

8. IMPLEMENTATION AND LEADERSHIP

Managing Paradigm Change

- Paradigm changing policies are of a different order to the policies adopted in previous eras. This does not mean that inherited policies are worthless or that existing industries must be scrapped. However, policies required to usher in more equitable and sustainable growth require a different approach and a different set of relationships between stakeholders.
- The new Digital Paradigm is systemic in nature and requires a systemic, integrated response. This involves a combination of economic, social and environmental interventions. No single actor or Ministry can act in isolation.
- Policies are contextual. They will vary between countries, across sectors and over time.
- Policies need to be dynamic and flexible, changing with context and over time
- Policies are a process. Reports and White Papers are less important than developing a common approach with multiple stakeholders

The end of Business as Usual

It is unquestionable that the global economy, regional blocs and individual countries within the global economy, are entering a period of epochal change. 'Normality', 'best practice', 'the rules based order' and other indicators of a relatively stable world order no longer apply. The disruption caused by the widespread introduction of tariffs and the breakdown of a rules based global order in the mid 2020s are not the cause of epochal change. They are instead a symptom.

Consequently, *Business as Usual* is no longer an option.

A successful transition to a new epoch does not occur by accident. It can only follow as a result of purposive action by key actors in the economy and in society. The objective of this Background Report is to suggest a framework which key societal actors can draw on so that destruction and threat can be transformed into creation and opportunity.

Countries seeking to make a successful epochal transition can learn from history. But each epochal transition and each country and each sector within each transition confronts particular challenges. Because of this contextuality, it is not possible to set out detailed policy prescriptions or to identify detailed sectoral transitions to guide countries across the policy spectrum. Moreover, the world is uncertain, and the full potential of the new paradigm is still to be realised.

The new Digital Paradigm is characterised by the reaping of systemic gains across the spectrum of the digital applications which are transforming the economy and society. For this reason the objective of transition cannot be reduced to the adoption of new digital technologies alone, let alone to the adoption of new physically embodied technologies.

Consequently, this Background Report seeks to set out the general principles of the policies which low and middle income countries need to adopt to take advantage of the new opportunities for more equitable and sustainable growth opened up by the transition from the Mass Production Paradigm to the Digital Paradigm.[39] These principles need to be applied to meet the specific conditions of individual countries and sectors. Seven general policy initiatives affecting the economy and society were identified in Section 7 for low and middle income economies (Figure 26):

Figure 26: Policy Initiatives for Low and Middle Income Countries

• Addressing the needs of the mass of the population excluded from the fruits of economic growth, particularly those living in large urban conurbations
• Confronting the environmental challenges posed by climate change
• Developing and deploying digital technologies throughout economy and society
• Taking advantage of the systemic opportunities provided by the transition to renewable technologies
• Making the most of commodities
• Taking advantage of the opportunities opened by south-south trade
• Decentralising production and governance

Beyond Catch-Up

In pursuing this policy agenda, two framing issues are raised for low and middle income developing economies.

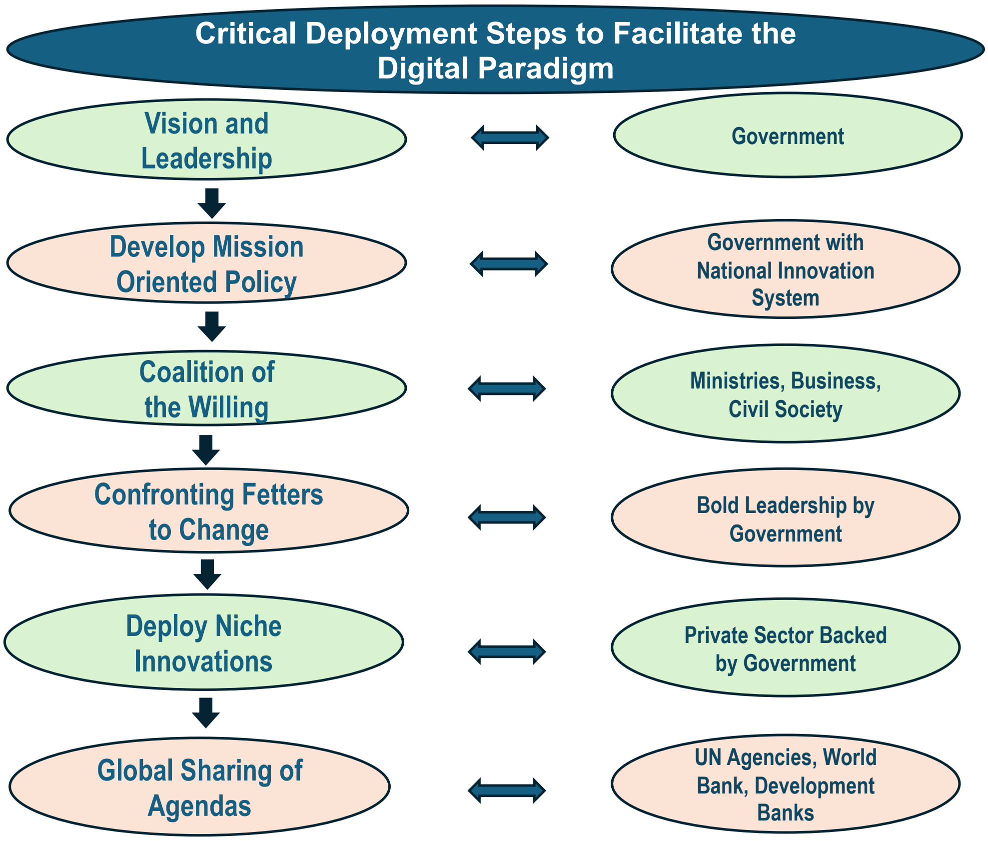
- With respect to the direction of technological change and innovation, high income and low income economies are faced with starkly different challenges. High income countries are characterised by ageing populations and labour shortages. In these economies, digital technologies offer the potential for enhancing productivity change through the introduction of labour saving technologies such as robots. By contrast, low and middle income economies are characterised by a youthful population and a surplus of labour, such that the direction of technological change and innovation needs to be oriented to the inclusion of more people in production and to addressing the unmet needs of the masses of low and middle income citizens.
- There are some advantages to backwardness. These provide opportunities for low and middle income economies to leapfrog over the path travelled by leading economies. Some examples: Given their relatively laggard hardwired telephone infrastructure, developing economies pioneered the use of mobile money leaving many high income economies in their wake. Since each paradigm is accompanied by complementary patterns of behaviour and institutional design, the most advanced Mass Production economies are often saddled with institutions which are not appropriate to the more flexible world of the Digital Paradigm. Highly industrialised economies with carbon intensive industries are hampered by the power of large legacy energy companies in the transition to renewable energy.

Hence at this historical turning point, low and middle income economies face a number of challenges. It is not possible to replicate the south-north export oriented success of China and some other east Asia economies. Even if they were able to do so, this would not solve the problems of exclusion and environmental degradation. And without imposing directionality on the route of technological innovation, digital technologies may exacerbate rather than ameliorate the problems of inequality and exclusion. At the same time, an increasing number of low and middle income economies have developed substantial innovative capabilities with well developed, digitally based entrepreneurial skills, often in the unregulated informal sector and often within a dynamic youthful population.

Business as Usual is no longer possible and for low and middle income economies a new development path has to be pursued in line with their need to increase industrial development and employment

The challenge therefore is to forge a new developmental path (Figure 27), one which does not seek to replicate outdated growth trajectories and to transition to a world which is *Beyond Catch-Up*

Figure 27: Beyond Catch-Up – Forging a new Development Path



The Rocket Science is the easy stage in the innovation cycle

Innovation scholars frequently observe that the 'rocket science', high tech link is the easiest stage of the innovation value chain. The most difficult challenge is the successful deployment of innovation and these challenges are most daunting when innovation involves a combination of technologies, social organisation and lifestyles. This is precisely the challenge raised by the shift from Mass Production to the Digital Paradigm.

Given the heterogeneity of challenges faced by low and middle income countries six critical steps are required to facilitate the deployment of the Digital Paradigm in a direction which fosters more inclusive and sustainable growth.

Vision and leadership are critical

As Roosevelt showed during the Great Depression in the 1930s, and as other political leaders have shown during the period of post war catch up in Asia, Vision and Leadership are critical. This is what might be called the 'Adult' stage of the innovation cycle. Clear and decisive leadership, with the power to allocate resources effectively is the critical factor in enhancing and reorienting a strategy of innovation and growth.

Developing a mission orientation to policy delivery

Each of the epochal paradigms reflect a combination of the technical, the economic, the social and the political. As a consequence the major policy objectives cannot be achieved through actions confined to individual technical disciplines and individual ministries. America's successful experience of landing a man on the moon (and indeed bringing him back!) began with a grand declaration in 1960 by President Kennedy that it would achieve this objective within a decade. This was widely dismissed as fanciful, and unrealistic posturing.

Yet the goal was achieved by assembling a variety of stakeholders, working across the public and private sectors and institutions in the National Systems of Innovation to achieve a common clearly articulated Mission.[40] A similar approach is now needed with respect to the seven general policy areas identified above. In each case it requires. a high level commitment to meeting the objective, and then the assembly of a variety of partners to deliver this outcome. *Too many Missions risks the loss of focus; too few displays a lack of ambition.*

Policy Delivery requires marshalling the coalition of the willing

Since the objective is systemic change – involving a combination of the technical, the social and the political – no one party can achieve the desired result. *Hence coalitions will need to be assembled, not only to deliver the grand Missions, but in individual projects within these Missions.* It necessarily involves collaboration between the private and public sectors, cooperation with institutions in the National System of Innovation (such as universities and research centres) but also within Government. No single Ministry can address a systemic problem; government has to escape ministerial silos. But so too, on a global scale, do the external aid and international agencies need to cooperate in order to underwrite systemic change in developing economies.

Here, too, *leadership is critical*. Within each individual project, some form of leadership is required. Take, for example, the case of addressing the needs of large peri urban agglomerations. Regional and municipal government will be involved; so, too, will service providers, including infrastructural utilities. Education and training are critical, as is health (both as an outcome of enhanced development and as a driver of enhanced development). Individual Ministries have a role to play (for example, Ministries of Industry who support production and entrepreneurship) as do supportive NGOs. No one coalition leader is relevant across the board of challenges – each will be contextual and specific. But the role of leadership is critical to the successful deployment of the Digital Paradigm.

Confronting the blinkers and fetters to change

Sometimes *change is constrained by the lack of recognition of the challenges and the opportunities. Like the blinkers on the heads of horses, vision is restricted*. This obstacle to change can be addressed through a programme of awareness and education, explaining *why* change is needed, *what* change is needed, and *who* should do what and when.

At other times, change is constrained by fetter, the reactionary forces still embedded in the old paradigm and actively blocking change. These represent the interests and power of those parties who gained from the and whose power might be undercut by the transition to a new order. The clearest example of this are those parties who have specialised in fossil fuel energy and who are resistant to, and hold back, the transition to the development of renewables. The problem is not necessarily a moral one – good versus bad – but a genuine reflection of conflicting interests.

Both of these problems need to be addressed, wherever possible with a win-win orientation, but this may not always be possible and then there is a need to confront the problem with honesty and boldness. *Different strategies are required to address these two restraining forces*. Meeting these challenges necessarily requires Vision, Leadership and the capacity to wield economic and political power.

Niche innovations and rapid deployment

Effective change begins with the demonstration of realisable advantages. It is this which makes it easier to confront the blinkers and fetters to change and to move to the rapid deployment of paradigm change. In Section 6 we evidenced ten examples of niche innovations which displayed the potential of the new Digital Paradigm to deliver more equitable and sustainable growth. *A successful policy agenda therefore needs to draw on these positive niche innovations to evidence the potential offered by the new paradigm and then to widen the deployment of innovations as quickly as possible*. This process has been one of the primary drivers of China's recent successful growth, not only in the productive sector but also in the delivery of healthcare.

Sharing agendas and experience across countries

The principles of supporting paradigm change with vision, leadership, mission development, coalition building, overcoming blinkers and fetters, and rapidly deploying niche innovations applies equally at the international level. Some actions (for example with respect to the environment) necessarily require action at the supra-national level. But even when collaboration across national boundaries is not an intrinsic, necessary feature of change, *learning from others is an important source of change.*

A particular role is indicated here for international organisations such as UNIDO, as well as other members of the UN Family and other institutions such as The World Bank, the IMF, Regional Development Banks.

End Notes

[1] In the academic literature this is referred to as the *theory of techno-economic paradigms,* sometimes *as socio-technical paradigms.* In this Report we simply refer to *paradigms*.

[2] Acemoglu D, and S. Johnson, *Power and Progress: Our Thousand-Year Struggle over Technology and Prosperity*, 2024, New York, Public Affairs

[3] UNIDO, *The Future of Industries for Development*, 2025

[4] Abramovitz M (1956), 'Resources and Output Trends in the United States since 1879', *American Economic Review*, Vol 46, pp 52-3; Abramovitz, M., 'The Search for the Sources of Growth: Areas of Ignorance, Old and New' *The Journal of Economic History*, Vol. 53, No. 2, 1993), pp. 217-243.

[5] Freeman C. and C. Perez (1988), 'Structural Crises of Adjustment', in G. Dosi et al (eds), Technical Change and Economic Theory, London, Frances Pinter.

[6] '*[I]n China's most recent and visible industrial achievements - the production of low-cost, competitive quality electric cars, consumer electronics, industrial machinery, high speed trains and robots – some version of kaizen is now at work. And there are reasons to suspect the Chinese iteration may, for a stint, work faster, more disruptively and with more visible results than in the original [in Japan]*' (Financial Times, 30th January 2025).

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[36] In the case of copper which is critical to the digital sector, the first stage concentrates the ore to a level of 20 per cent and then subsequent smelting refines the metal to a 99.9 per cent purity level.

[37] The price of hafnium (widely used in the electronics sector) rose from historic levels of $750/kg to just under $7,000/kg in late 2023 (FT 31st March 2025).

[38] China's share in global exports in 10 labour-intensive sectors fell from 40 per cent in 2013 to 32 per cent in 2018 and have continued to fall further since then. Much of the slack has been taken up by Vietnam and Indonesia.

[39] These policy agendas are specific to the needs of low and middle income countries. There are of course numerous Reports addressing the policy challenges faced by high income economies – see for example, Perez (2026 forthcoming), op. cit; Kaplinsky, 2021, op. cit; Mazzacato, M. (2021), *The entrepreneurial state*, Lawrence and Wishart.

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