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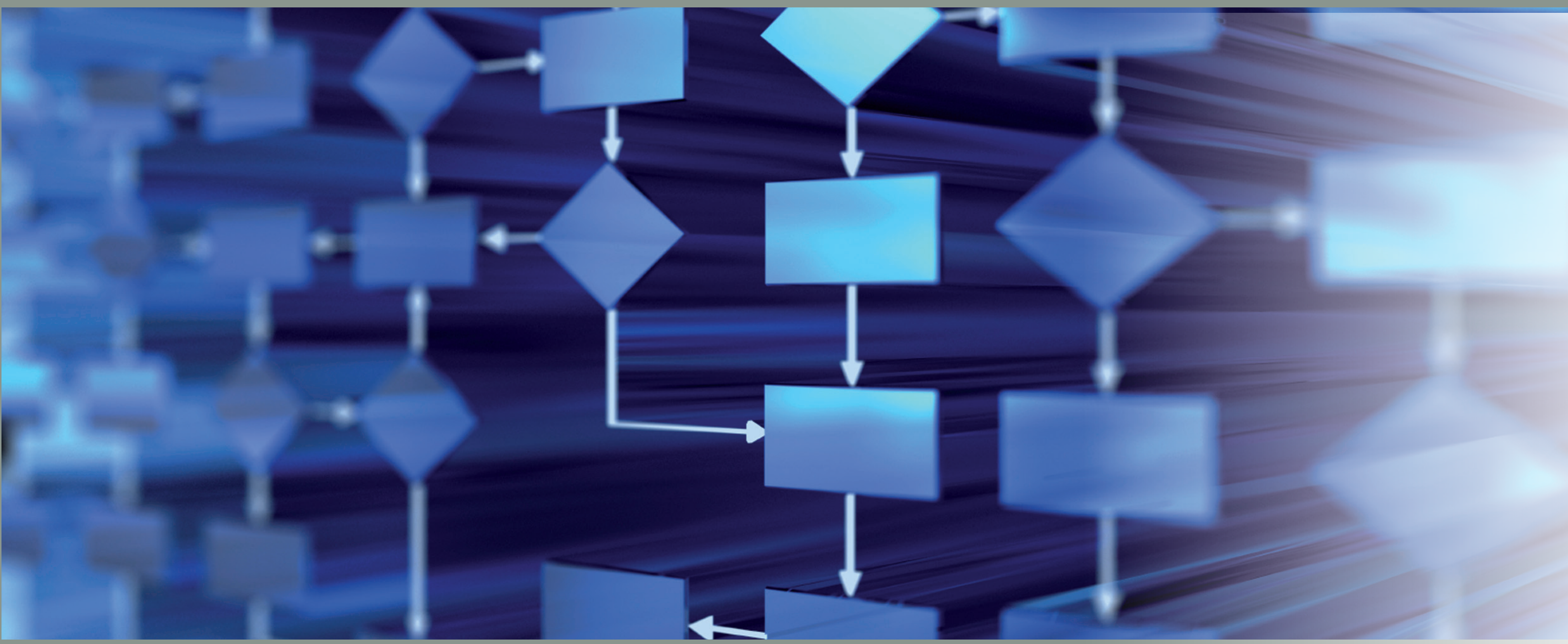
Direction of innovation in developing countries and its driving forces

Xiaolan Fu, Liu Shi



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Direction of Innovation in Developing Countries and Its Driving Forces

Xiaolan Fu[1], Liu Shi[2]

Abstract:

Innovation is a major driving force of long-term economic growth and sustainable development. Direction of innovation matters because technical change is not neutral and hence bears significant social, economic and environmental development implications. This paper contributes to the literature through a systematic examination of the direction of innovation in developing and emerging economies and its driving forces. It shows that innovation in the global South exhibits a vibrant and diverse landscape when we do not confine ourselves with traditional research and innovation indicators. While emerging economies are accelerating their pace in inventive activities in fields such as ICTs, biotech and engineering, low-income countries (LICs) are also found to be active in learning-based, incremental "under-the-radar innovations" (URIs). These URIs that are introduced through international technology transfer and indigenous innovative efforts. Indigenous sources of URIs play a primary role in LICs, contributed by localised learning-by-doing, close interaction with customers and embeddedness in regional production networks and clusters. However, insufficient role of the state, a low science and technology intensity and a lack of university-industry linkage limit the potential of URIs. International technology transfer is another important driver of technical change in developing countries. However, its strengthen varies across countries due to differences in host country policy, absorptive capacity, and the type of foreign economic engagement that they have as well as the inappropriateness of transferred foreign technologies mostly from Global North. Given the status of direction of innovation and its driving forces in developing countries, this report argues that the unfolding 4th industrial revolution poses both challenges and opportunities to LICs. Policy implications are discussed.

JEL Classification: O3, O14, O19, O25

Keywords: *Indigenous innovation, technology transfer, direction of innovation, sources of innovation, government policy, under-the-radar innovation, open national innovation system, 4th industrial revolution, developing countries*

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[1] Professor, Oxford University.
[2] Oxford University.

1. Introduction

Technological innovation is a major driver of long-term economic growth (Romer, 1994). Science, technology and innovation as means for development are also critical forces to address global challenges and implement the 2030 Sustainable Development Goals (SDGs). However, innovation is costly while economic resources are limited. Therefore, not all scientific fields or industries are given the same allocation and priority, which means that innovation has its specific directions. Moreover, direction of innovation matters in the sense that technical progress is not neutral. It is the wisdom of Directed Technical Change theory (Acemoglu, 2002) that technological progress favours capital or skilled/unskilled labour. This factor-biased nature of technical change, together with other contextual factors such as local economic, social, and techno-physical conditions, will affect the appropriateness of an innovation in a specific locality and development scenario (Stewart, 1983; Willoughby, 1990).

1. Therefore, the direction of innovation has significant developmental implications. Firstly, some technological or scientific fields are important for fulfilling certain social-economic missions, such as human welfare and sustainable and inclusive development, but may not receive the resources that are needed because of high costs or public-goods nature of those innovations (Paunov, 2013). Secondly, due to the biased nature of technical change, some innovations, especially those imported or diffused from foreign sources, may not be appropriate or efficient for the countries that imported or adopted them, mostly the developing countries. Hence, the developing countries may use new technologies that are not appropriate to their factor endowment, economic structure, and social and geographical conditions. As a result, these technological innovations will not be widely adopted and the income gap between the developing and developed countries will widen (Fu and Gong, 2011).

Whoever decides which innovation preferences have priority in resource allocation ultimately decides the direction of innovation. Yet, the understanding of the economic forces setting the direction of innovation is much less studied subject than its rate in the economic literature. This knowledge is even more scarce with regard to developing countries because innovative activities in these economies are rarely captured using patents or scientific publications commonly adopted. Given the importance of the direction of innovation and the limited literature of the topic in developing countries, this report aims to fill the gap by examining: (1) what directions of innovation do developing countries engage with? (2) what are the driving forces that shape the direction of innovation in developing countries? and (3) what role do developing countries play in setting the global direction of innovation? The opportunities and challenges presented by the unfolding Fourth Industrial Revolution (4IR), a major trend of technical change in the 21st century, are also discussed in the report given the potentially significant development outcomes.

To carry out this investigation, this report recognizes that firstly, innovation in the developing countries is largely under-the-radar (Fu, 2020) and cannot be captured by traditional indicators such as patent and R&D investment. Nor can it be accurately measured by total factor productivity (TFP) because innovation is however only one of the main factors that affect TFP in addition to skills, management practices, institutions, and entrepreneurship, etc. Therefore, the report adopts a broad definition of innovation according to the Oslo Manual (OECD, 2005). Innovation in the first place can be “the implementation of a new or significantly improved product (good or service), process, a new marketing method, or a new organizational method in business practices, workplace organization, or external relations” (OECD, 2005: 46) in a Schumpeterian sense. Second, for low-income countries (LICs), innovation is not necessarily new to the market or new to the world as a whole but simply novel to these countries or firms in them.

Secondly, innovation is risky, costly and path-dependent, and therefore is largely concentrated in a few developed countries. Those under-the-radar innovations (URIs) in

LICs are in general introduced via two channels: 1) technology transfer from foreign countries, or 2) indigenous creativity, learning and entrepreneurship driven innovation. Therefore, this report examines the drivers of these two origins of innovation separately.

Thirdly, the developing countries are a diverse group, including a few fast-growing emerging economies and a large number of low- and lower-middle-income countries. With rapid development of the former group, their contrast in technological capabilities and resource endowments has been increasing (Lin and Rosenblatt, 2012). This leads to a more nuanced landscape of international technology transfer and appropriateness of diffused innovations. Therefore, this report examines the direction of innovation by considering both the emerging economies and the remaining developing countries in two groups, and it focuses the analysis of the drivers of the direction of innovation on the majority of developing countries.

The remainder of this report is organized as follows. Section 2 gives an overview of the diversified picture of direction of innovation in developing countries. Section 3 briefly explains the importance of direction of innovation by elaborating on directed technical change and appropriate technology theory. Section 4 discusses in detail the driving forces of direction of innovation in developing countries, introduced from both international technology transfer and indigenous efforts. Section 5 analyses the opportunities and challenges faced by developing countries in 4IR. Section 6 summarizes the main findings of this report, puts forward policy recommendations and concludes with discussion on the role of developing countries in setting the global direction of innovation.

2. The nature and direction of innovation in developing countries

Innovation in the developing world, often the outcome of innovation diffusion and adaptation and technology spillovers from developed economies, predominantly has an incremental nature. It exhibits a diversified picture, with a few emerging economies rapidly catching up in science-, capital- and skill-augmented areas, while low-income countries rely more on imported technology which remains small-scale, low-and semi-skilled.

2.1 Direction of innovation in emerging economies

The past decade has seen a divergence between middle-income and low-income economies. A well-known fact is that many countries have made the jump from low-income countries to middle-income countries (Arouri, Boubaker and Nguyen, 2014). Impressively rapid economic growth in Brazil, India and China in the past three decades is changing the landscape of world economy. These countries are catching up fast with global economic frontiers and hence the gap in capabilities and resource endowments is also widening between these emerging economies and LICs.

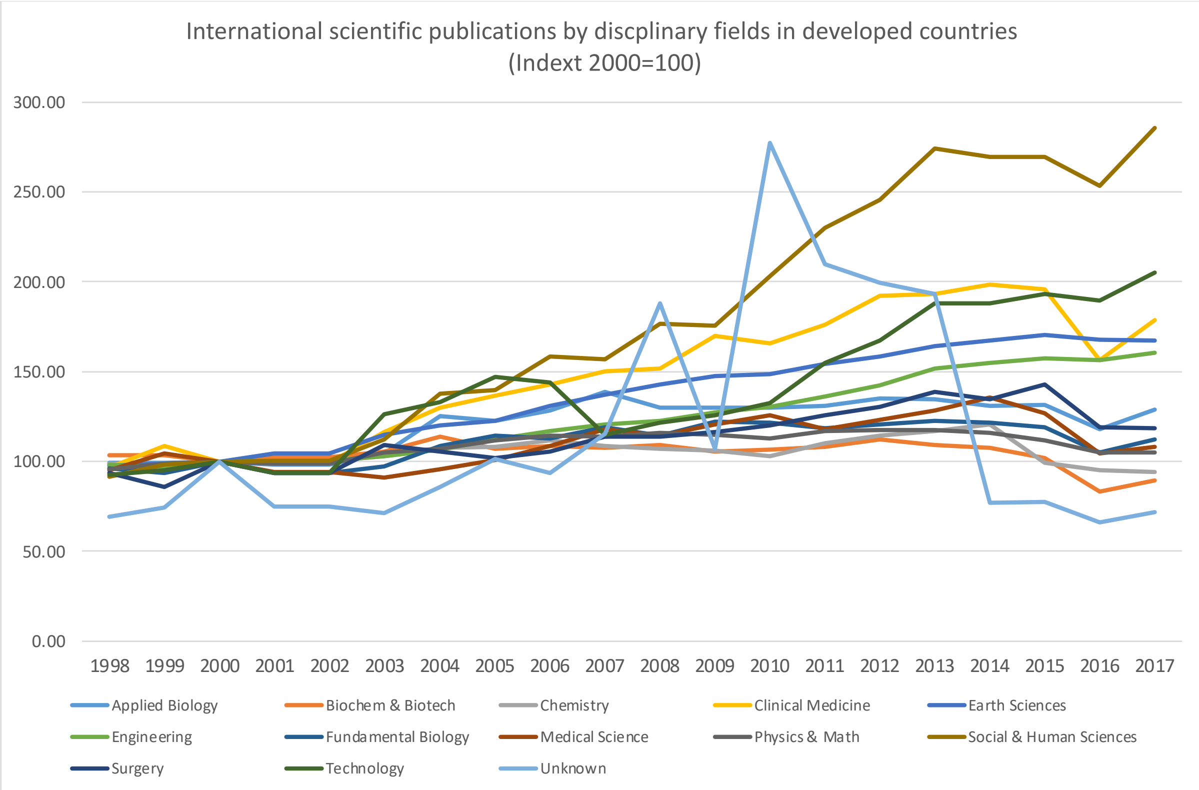


Figure 2.1a: International scientific publications in developed countries

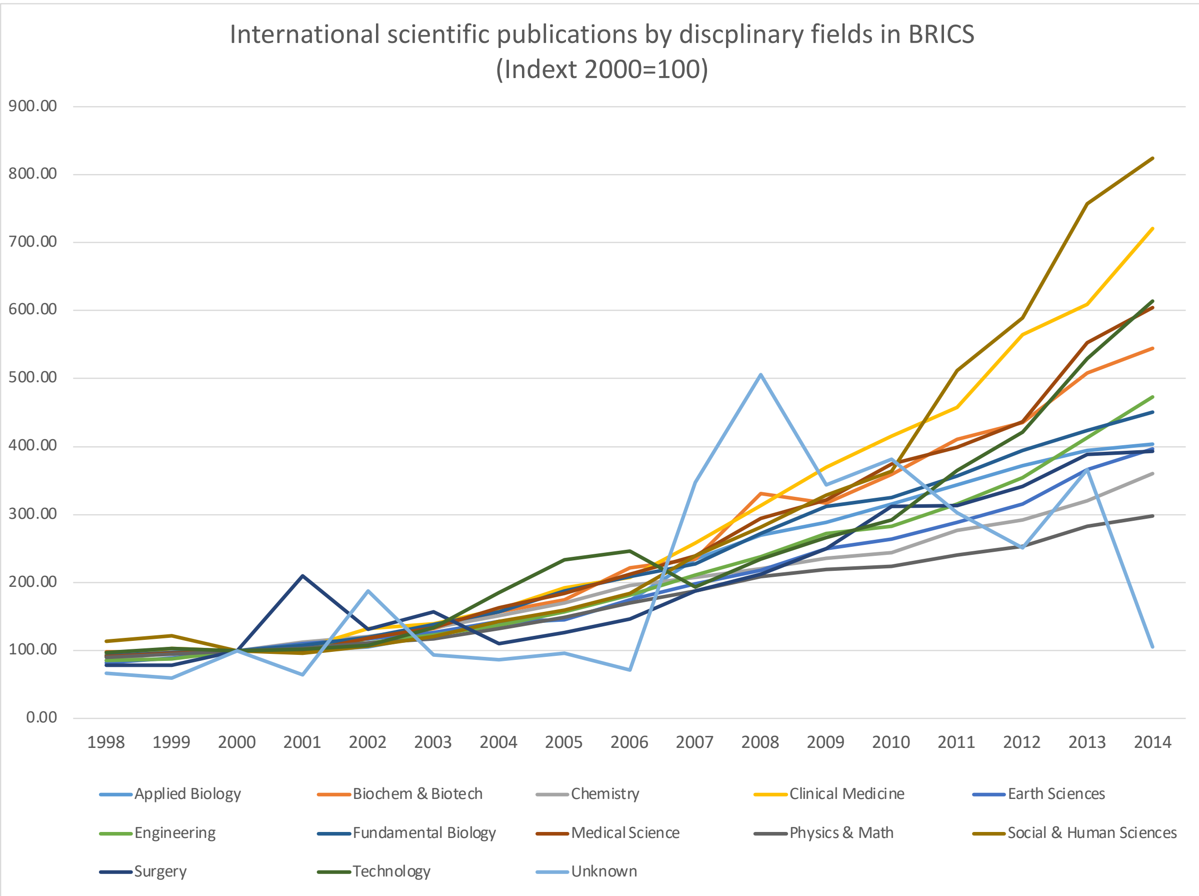


Figure 2.1b: International scientific publications in BRICS

Source: WIPO

This report uses disciplinary and technology fields and industries as rough indicator of direction of innovation, similar to WIPO (2019) and OECD (2020). In terms of scientific publications, taking the year 2000 as the baseline, developed countries and BRICs share some commonalities but more contrasts in terms of fast-growing disciplinary fields of international scientific publications. Social and human sciences, clinical medicine, and technology see high speed of growth in both groups of countries (Figure 2.1a, Figure 2.1b). Whereas developed countries have more rapid knowledge development in engineering and earth science than BRICS, the latter witnessing faster growth in medical science and biochem & biotech. Although the absolute number of scientific publications in developed countries are far greater, the BRICS have exhibited much higher increase rate than developed countries. Putting aside unknown areas, the slowest-growing discipline in BRICS, physics and math, nearly tripled in 2017 compared to 2000. By contrast, the growth rate of the fastest-increasing field in developed countries, social and human sciences, did not surpass 300 percent in 2017 with 2000 as the baseline.

The emerging economies are also heterogenous, with China to some extent more resembling high-income countries than other members within BRICS. The breakdown among BRICS's absolute number of international scientific publications (Figure 2.2a, Figure 2.2b) shows that China alone accounts for the majority of these publications within this group. Taking chemistry as an example, in 2013 it had around 50,000 publications in this field, amounting 2.5 times of the total number in the other four countries.

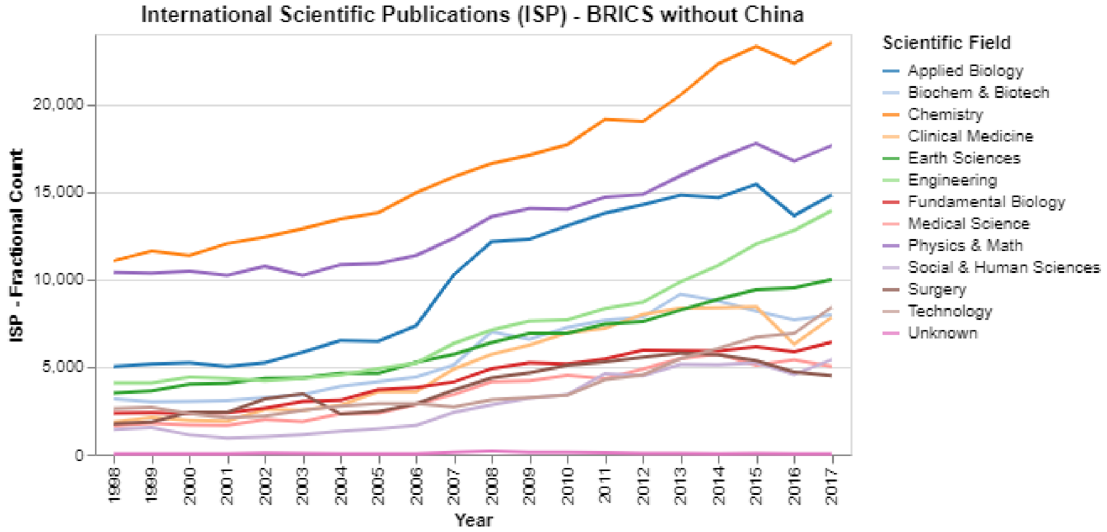


Figure 2.2a International scientific publications in BRICS without China

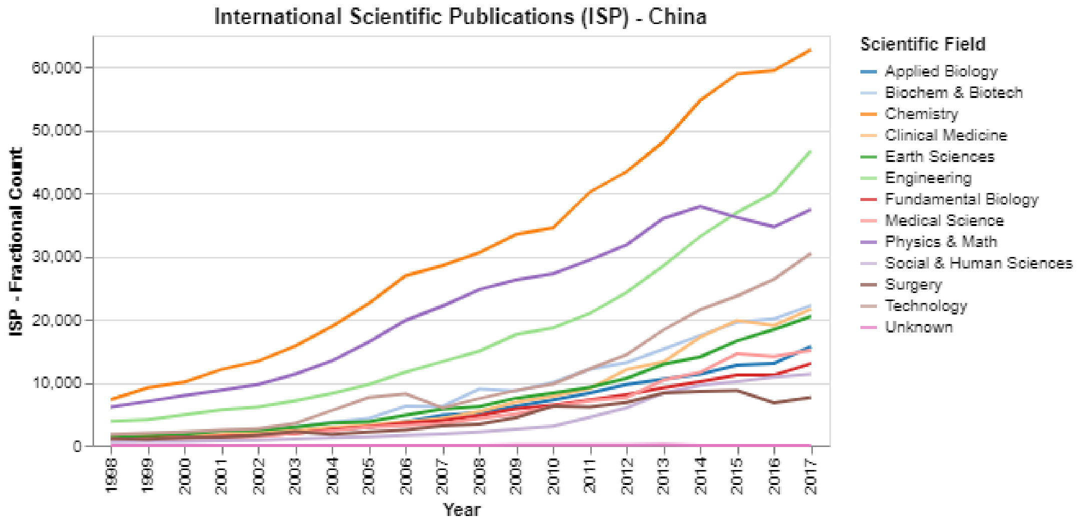
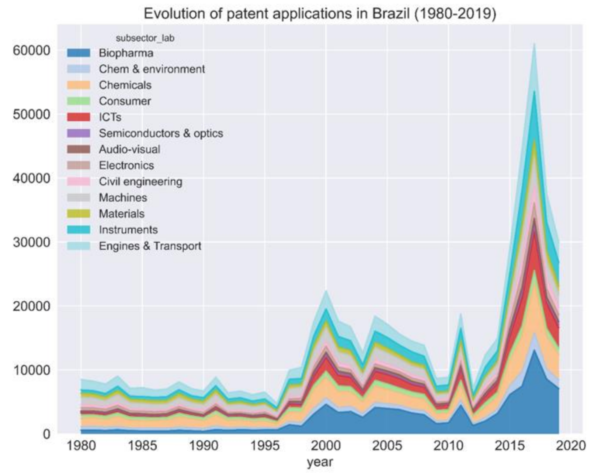
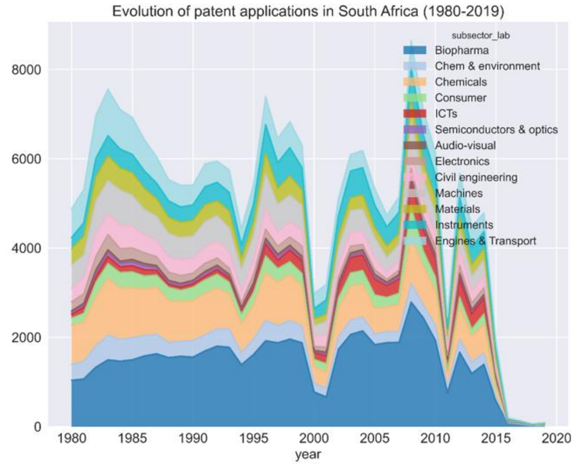


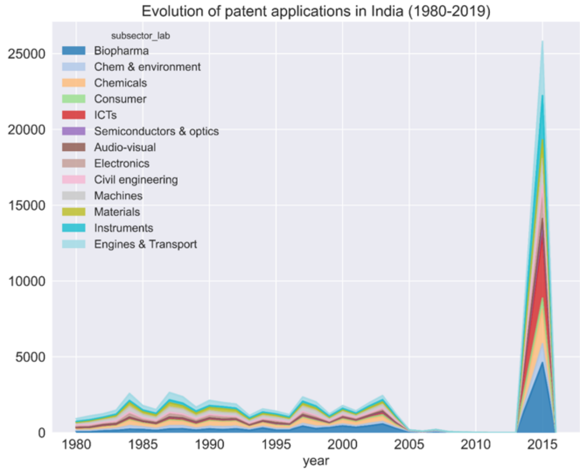
Figure 2.2b International scientific publications in China alone

Source: WIPO

The divergence within emerging economies is also manifested in patenting trend by disciplines (**Figure 2.3)**. China has the most patent applications, which have seen consecutive sharp increases since 2000. Comparing between technological fields, it has a larger proportion of inventions in ICTs, chemistry and environment, semiconductors, etc. Switching to other members of BRICS, South Africa has seen a relatively stable patent application trend during the period 1980 to 2015 with occasional fluctuations. It features inventions in biopharma, chemicals, instruments, engines and transport but fewer in ICT, electronics and machines. The patenting trend in India and Brazil is similar, which was steady and then saw an explosion of inventive activities in 2015. With similar compositions of disciplinary areas for patents, Brazil and India display vibrant inventive activities in biopharma, ICTs, chemicals, instruments and engines & transport, etc. Russia also has steady and intensive patent applications over the years, with a downturn in 2000 followed by a resurgence of inventive activities after 2005. With similarly strong focus on chemicals, biopharma, and ICTs, Russia also puts heavy emphasis on instruments, machines and engines & transport.







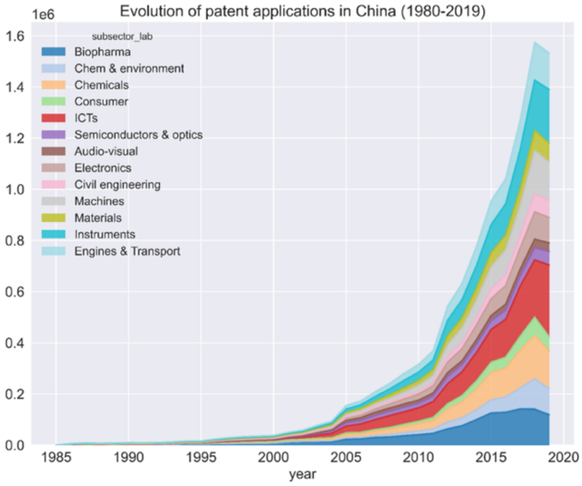


Figure 2.3: Evolution of patent applications in BRICS

Source: WIPO

2.2 Nature and direction of URIs in low-income countries

LICs can hardly be thought of as innovative if they are evaluated using indicators such as patents and scientific publications. According to NPCA (2014), investment in R&D among LICs remained very low in contrast to some OECD economies such as Finland, Denmark and Belgium. Apart from South Africa, Ethiopia and Botswana that had an R&D intensity (ratio of R&D expenditure to GDP) of over 0.5%, other surveyed countries - Mozambique, Namibia, Swaziland and Uganda - reported R&D intensity less than 0.5%. An alternative indicator, TFP, is a measurement that partly reflects the technical change aspect of economy development (Romer, 1990; Comin, 2006). A wealth of econometric analyses demonstrate that African countries have experienced productivity growth and efficiency gains in the past several decades, which could be seen as an indirect indicator of innovativeness, albeit limited, in these countries. For example, based on a panel dataset of 30 countries in Sub-Saharan Africa (SSA) (1999-2011), Noah and Ichoku (2015) find that the marginal source of TFP growth is technical progress. The contribution of innovation, knowledge creation and technical progress to TFP is also confirmed in agriculture (Lusigi and Thritle, 1997) and manufacturing sector (Kruser and Newman, 2018), as well as the growth of ICT industry in Africa (Bollou and Ngwenyama, 2008). Nevertheless, TFP still does not provide an accurate measurement of innovation because other factors such as institutions, human capital, technology transfer, etc., that affect TFP are not included. (Isaksson, 2008; Hou, Fu, and Mohnen, 2021). Moreover, as a residual estimated from statistical analysis, TFP does not provide a direct depict of the nature and pattern of the innovation activities either.

A most recent scholarship put forward the concept of Under-the Radar-Innovation (URI), and from the perspective of URI, firms in LICs are innovative and there is a wide range of creative activities taking place, including significantly improved products and production practices as well as novel marketing and management practices (Fu, 2020). Moreover, an important facet of developing countries is the contribution of economic activities in informal sectors that are rarely captured in traditional indicators. In Africa, the informal sector is about 85.8 per cent of employment by estimation, much higher than the world-average level of over 60 per cent (ILO, 2018). Hence the informal economy is a significant source of employment and consumer demand as well as an avenue for breeding new entrepreneurs and skills.

Evidence from firm-level surveys complemented by in-depth case studies in Ghana and Tanzania shows that firms demonstrated strong resilience in innovation across the board. Despite being located in different parts of the continent, Ghana and Tanzania are both sub-Saharan African economies, similar particularly in terms of economic, institutional and socio-historical structures. They have moved from low-income economies to lower-middle-income group in the past several decades, partly benefiting from implementing STI policy, such as economy recovery program (ERP) and structural adjustment program (SAP), as well as FDI and other economic activities. The informal sector and informal sector activities remain an integral characteristic of both economies, which is also an important constituent in broader developing countries (Fu, 2020). Note that this paper mainly focuses on indigenous firms in LICs, not completely representative of other developing countries such as Latin America and ASEAN, where the strength of national innovation system and openness to global innovation system varies.

URIs in LICs are vibrant, resilient, and multi-dimensional. Taking Ghana as an example, about half of firms introduced new or significantly improved goods or services between 2012 and 2014, and 61 per cent of Ghanaian firms reported being involved in marketing innovation in 2015. Comparing the patterns in formal and informal sectors, formal firms engage more with process, product and management innovations, while informal firms featured management, marketing and process innovation. This suggests that the type of innovation in formal sectors is more technological than that in informal sectors. A breakdown of different dimensions of innovation in formal and informal sectors in Ghana is illustrated below (**Figure 2.4**).

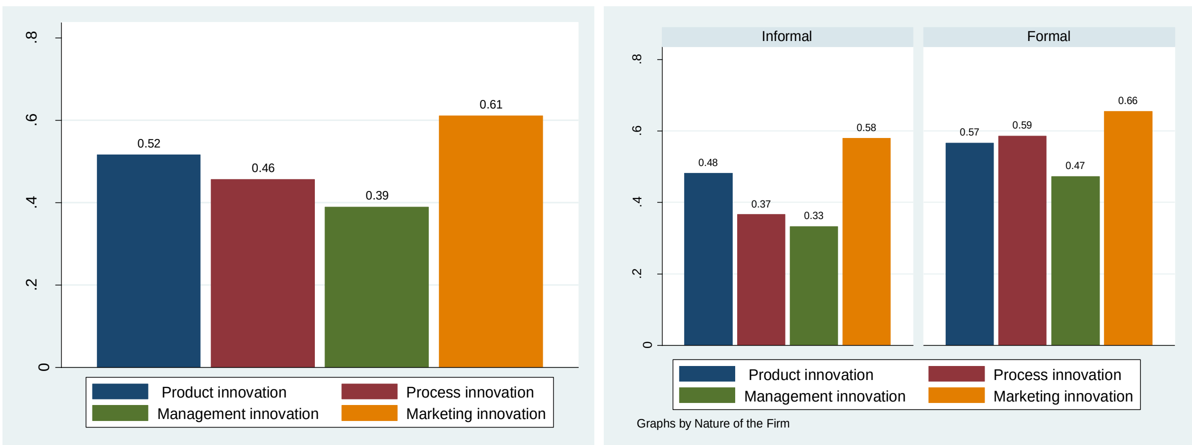


Figure 2.4: Proportion of firms active in innovations, by nature of innovation (left) and by nature of innovation and firm (right) in Ghana 2015.

Source: Fu (2020)

The case study shows that innovation in LICs is mostly imitative and incremental in nature. Innovations are clearly not R&D-based as are those often observed in industrialized countries. The learning-based, incremental nature of URIs mean that they involve limited novelty. In Ghana and Tanzania, most firms conduct product and process innovations that are only new to the firm (**Figure 2.5**), suggesting that firms in LICs mainly adapt innovations from other markets. In Ghana, only 1.8 per cent of firms innovate in products or services new to the world.

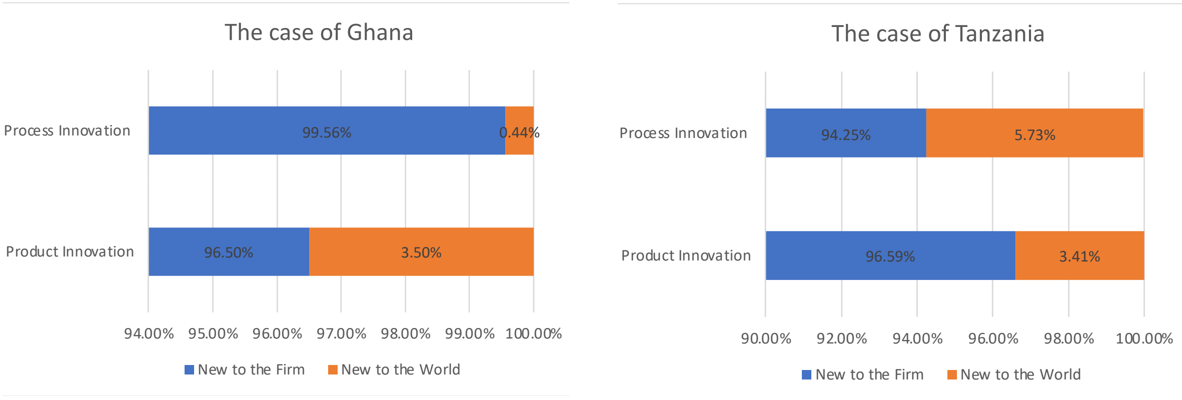


Figure 2.5: Proportion of firm's engagement in new to the firm and new to the world product/process innovation in 2015, by nature of innovation, in Ghana and Tanzania.

Source: Fu (2020)

Notably, URIs are not purely frugal (frugal innovation refers to the process of reducing the complexity and cost of a good and its production). In the case study, two types of innovations are identified -- innovations that address cost savings and innovations aimed at increasing market opportunities. Even though URIs are mostly highly labour-intensive, low-cost innovations, with the majority of them being frugal product or process innovations, or low-cost management or marketing innovations, some of them may also serve the high-income segment in LICs. URI highlights the fact that most innovative activities on the continent are incremental in nature and based on organizational or individual learning and adaptation, practice, or individual creativity. They are often demand-led, learning and non-R&D based, low-cost innovations as a result of the constraints that firms in developing countries face and the responses that they make to survive and grow.

These labour-intensive, low cost and learning-based innovations mostly took place in low-tech manufacturing industries in LICs. Among product innovators in the survey, new to the world innovations were only identified in a very limited range of sectors, such as manufacture of food products, textiles, wearing apparel, wood and products, wood and cork, as well as furniture and other manufacturing (**Figure 2.6**). New to the world product innovators are most frequently spotted in the textile manufacturing industry (5.9%). Switching to process innovators in these sectors, new to the world innovators are even less concentrated. The only sector where innovators with worldwide originality and novelty were identified is the manufacture of food products (0.9%).

Apart from the very limited per centage of product and process innovators who claimed new to the world contributions, all of the rest are innovators that introduced new products and processed new to the firm itself. Manufacturers of beverages, wearing apparel, basic pharmaceutical products, rubber and plastics products and motor vehicles, trailers and semi-trailers are crowded with new to the firm product innovators, with a per centage of them by sector exceeding 60%. All other surveyed manufacturing sectors, except for manufacture of tobacco products, are also hubs of innovators that introduced products new to the firm, albeit less concentrated compared to sectors mentioned previously.

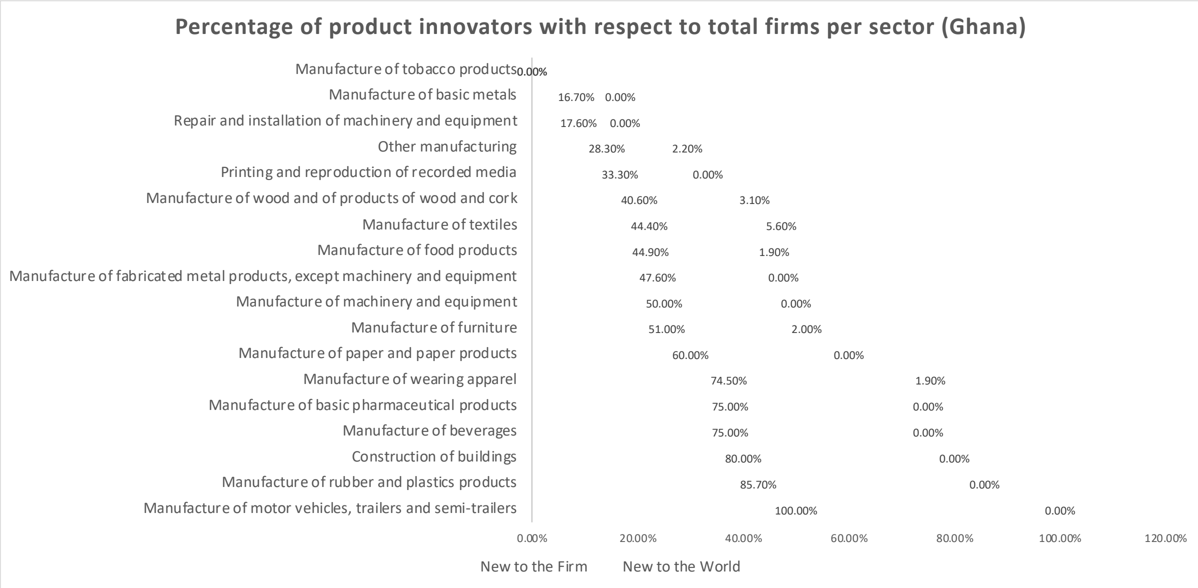


Figure 2.6: Percentage of product innovators with respect to total firms per sector in Ghana

Source: Fu (2020)

Process innovation by sector follows a similar pattern (**Figure 2.7**). 100 per cent of furniture manufacturing firms reported having introduced new to the firm processes. Such frequency was followed by the manufacture of rubber and plastics products, basic pharmaceutical products, construction of buildings and food products, etc., with no less than 60 per cent of firms in the specific sector being new to the firm process innovators. The remaining sectors introduced new processes sporadically to varying extents.

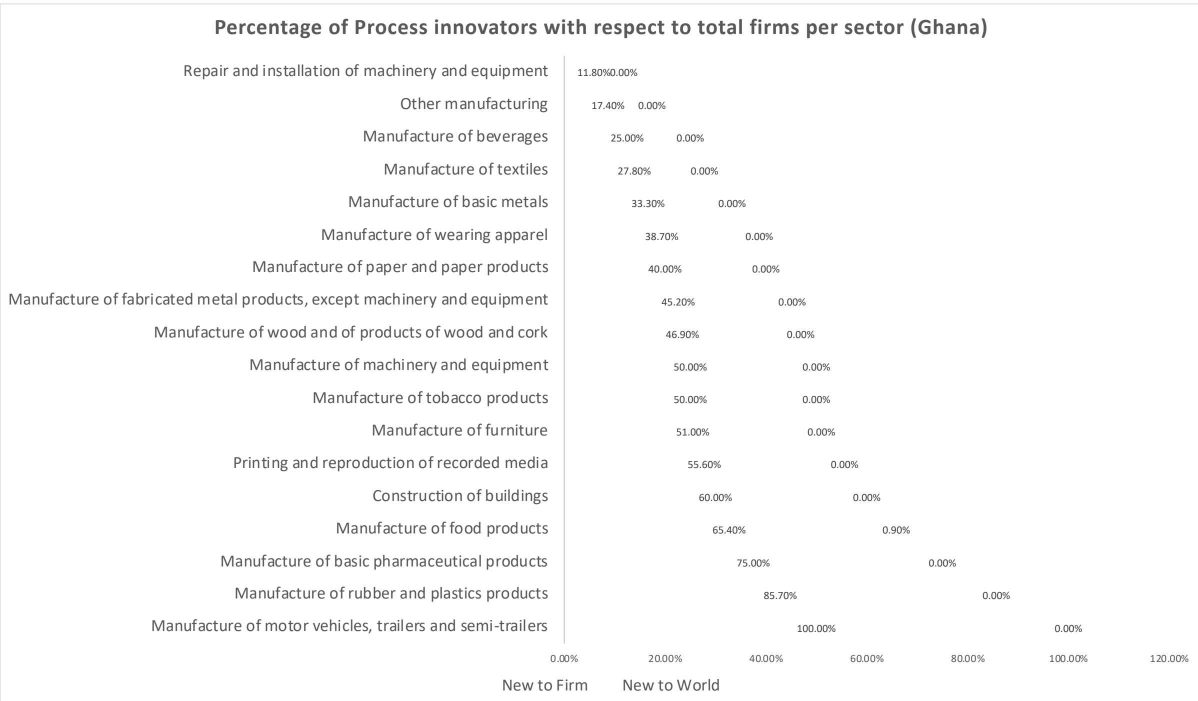


Figure 2.7: Percentage of process innovators with respect to total firms by sector in Ghana

Source: Fu (2020)

3. Appropriateness of technology and the impact of direction of innovation

3.1 Theoretical discussions on determinants of the direction of innovation

Technical change is not neutral but biased, that is, from the perspective of firms, they explore different possibilities along certain directions in favour of others. The determinants of direction of technological innovation have been a major theme in economics research, often overall called inducement of technical change/innovation, which is motivated by two strands of literature differentiating on inducement mechanism.

One inducement mechanism starts with the neoclassical assumption to maximize innovation output or reduce costs and relates the direction of innovation to relativity of factor prices or market size of input factors. Early version has its origin in Hicks, that innovation is directed to "economize the use of a factor which has become relatively expensive" (Hicks, 1932), has been observed in agricultural and energy sector (Popp, 2002). Built upon this early argument, Acemoglu (2002) adds that the market size of input factors also matters, in a sense that technical change is directed to factors that an economy is abundant of. In the long run, the outcome of this induced innovation hypothesis would be that innovation takes the form of labour-augmentation (Funk, 2002).

The other inducement mechanism does not resonate so much with neoclassical assumption but focuses on the micro-foundation generalized from economic history. Observing from the problem-solving process and activities during industrialization, Rosenberg (1969) argues that faced a whole spectrum of possibilities, most firms are "under pressure to undertake actions which promise a payoff in a relatively short time period or with at least most of the constraints imposed by the existing plant" (Rosenberg: p.4). Therefore, technological innovation would then be directed to remove the most restrict constraint. For example, the improvement of automobile engines led to the invention of improved braking systems because problem of increasing speed emerged.

Whatever the inducement mechanisms, path dependence is another source of technical change from an evolutionary perspective. Technical change evolves from earlier technological development and prevailing economic conditions may influence future trajectory of knowledge and technology accumulation (Nelson and Winter, 1982). Path-dependence may lead to technological lock-in in situations of increasing return to scale. This perspective could be integrated with induced innovation argument in the sense that firms or industries may escape from lock-in when change in factor prices or bottlenecks in problem solving cause imbalance to existing economic conditions.

3.2 Importance of direction of innovation and appropriateness of technology

Direction of innovation, determined through varied mechanisms, is no minor issue but has significant consequences for capability building and technological learning and future direction of technological development. Because technological change is a "localized learning by doing" process (Atkinson and Stiglitz, 1969), innovation is a highly contextualized phenomenon. Technologies are specific to particular combinations of inputs (Basu and Weil, 1998) and are applied in specific geophysical, socioeconomical, and technological contexts. This highlights the importance of appropriateness of technologies. For a particular region, appropriate technology (AT) is "a technology tailored to fit the psychosocial and biophysical context prevailing in a particular location and period" (Stewart, 1983; and Willoughby, 1990).

Any society or community has its own needs, values, and demands, which are different across countries or societies. As many technologies, either induced by factor prices/shares or needs to remove constraints, are concentratedly created in developed countries, while in LICs, technologies are often more labour-using and less skill using and small-scale. Technology transfer from developed countries hence may be inappropriate, either too expensive to implement or having limited impact on the economy due to an unfilled capability gap. This can partly explain the increasing income divergence between rich and poor countries and the marginalization of LICs despite that international technology transfer could potentially narrow the income gaps between countries by this technology diffusion.

Specifically, in developing countries that have abundant endowments of unskilled and semi-skilled labour, technologies created there may augment un-skilled labour and be more efficient than foreign technologies, while foreign technology may be less appropriate for labour-intensive low-technology sectors than the indigenous technology at a given time. By contrast, foreign technology from industrial countries, skilled-labour augmenting, will be more efficient than indigenous technology in a technology-intensive sector that uses skilled-labour intensively (Fu and Gong, 2011).

- For example, mobile phones and applications (e.g., M-PESA), with sophisticated technologies and functions reduced to accommodate the less developed skillsets but huge market demand in LICs, is a successful case of North-South technology transfer.
- On the contrary, industrial robots can be widely adopted in manufacturing sectors in US and Europe, but are, however, less applicable to the low-tech apparel sector in Africa due to financial constraints and lack of skilled labour. Moreover, in LDCs with abundant low-skilled labour, it would not be cost-efficient to use industrial robots as an input factor in production.

Considering the stratification of the global economy, technology transfer from middle-income countries may provide greater opportunities for the technological upgrading and industrial catch-up of other developing countries, especially LICs. This is because middle-income countries have accumulated a pool of knowledge and skills, and their factor endowments differ from both industrialized countries and least developing countries. Therefore, they are more likely to generate "intermediate" innovations with medium-level technology intensity than smaller economies with the same degree of capital scarcity (Fu and Gong, 2011).

- For instance, the successful diffusion of low-carbon innovation from middle-income country to LIC, more specifically, the solar grid system developed in India and adapted in Kenya by iterative learning appropriate to differences in social economic status.
- However, technologies from middle-income developing countries can also be inappropriate if important social economic conditions are not met, as proved by the unsatisfactory deployment of Brazilian tractors in Africa, because many African countries are more adapted to solutions for small-scale agriculture.

The direction of innovation in developing countries is important in the sense that it concerns the appropriateness of technologies created in and more frequently, diffused to them, and hence the development consequences in these countries. The nuances in different social-economic conditions and appropriate technology provide multi-tier choices of technology transfer rather than the simple bi-dimensional North-South divide. In **Section 4.2**, the paper will contextualize this diverse picture by means of four case studies to shed light on direction of innovation, how it comes about and the underlying driving forces in developing countries.

4. Drivers of the direction of innovation in developing countries

4.1 Open national innovation system: a model of innovation for developing countries

Openness of a national innovation system (Tybout, 2000; Almeida and Fernandes, 2008) in developing countries is beneficial for international flow of knowledge and technology and facilitates productivity growth, highlighting a path of open national innovation system (ONIS) for capability building in developing countries. An ONIS refers to a national innovation system (NIS) that is opened up to international knowledge, resources and markets (Fu, 2015). In the process, there is a diversity of means of innovation being diffused to developing countries, e.g., trade, foreign direct investment (FDI), migration and licensing (Fagerberg et al., 2010).

FDI as a bundle of technological and managerial knowledge and financial capital has long been a major vehicle for transfer of advanced foreign technology to developing countries (Dunning, 1994; Lall, 1992). It may contribute to capability upgrading and productivity growth in developing countries through three mechanisms. First, as important R&D hubs in the global economy, MNEs are likely to offer training to their local employees to better perform business activities. They also are motivated to transfer technology across borders to share technology between parent companies and subsidiaries (Markusen, 2002). The second mechanism is technology spillovers within the supply chain via backward linkages, where MNEs transfer knowledge for better quality final products, as well as forward linkages where they provide better intermediate materials for their producer customers (Javorcik, 2004). Thirdly, FDI contributes to technological upgrading and improved performance through both demonstration and competition effects (Caves,1974).

International trade is another important source of technological learning for developing countries. Technology transferred through imports of machinery and equipment is embedded in concrete products. Cross country studies on bilateral import data identify imports as important channels for countries to upgrade capabilities and enhance competitiveness (Freeman and Soete, 1997). Under such circumstances, developing countries can make substantial technological learning and reverse engineering efforts to master the technology of designing and producing these advanced machines. In a world of increasing mobility, the flow of personnel, such as technicians, consultants and professionals, brings additional benefit to developing countries. Because human capital constitutes a fundamental determinant of a country's absorptive capacity, an MNE subsidiary and high-skilled returnees contribute in the meantime to the "brain bank" in the developing world (Fu, Hou and Sanfilippo,2017).

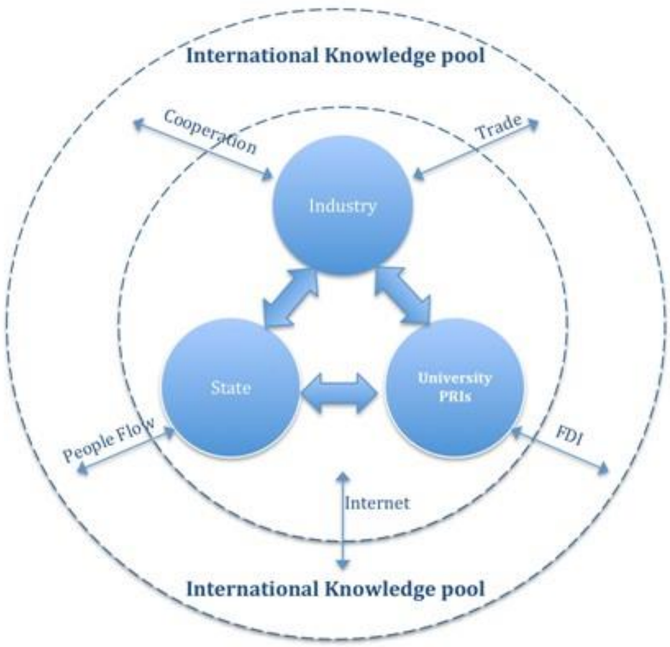


Figure 4.1: Model of an open national innovation system (ONIS)

Source: Fu (2015)

While all developing countries fall into this framework theoretically, their levels of openness and strength of national innovation system (NIS) vary, making relevance of these channels differ from each other. Emerging economies are major destination of FDI from developed countries, such as the BRICS, and integrated deeper into global trade and production networks (Fu, 2015). By contrast, LICs generally attract less FDI and exports from developed countries, but other forms of international flow of technology and knowledge, e.g., migrants and Internet, play a more important role in these economies (Fu, 2021).

Another dimension of variation that matters is the absorptive capacity of developing countries so to genuinely benefit from different forms of international technology transfer and cooperation. Absorptive capacity, defined as the ability of an organization or region to identify, assimilate and exploit knowledge from the environment, is often understood in terms of knowledge gap between foreign and domestic firms and R&D intensity and human capital in local firms (Cohen and Levinthal, 1990). At the country level, absorptive capacity reflects the strength of NIS of a developing country. If technology gap between the sender and recipient economy is large, or the stock of skilled labor and R&D input is low, the positive impact of international technology transfer will be limited. This means that, in practice, countries that have pursued import substitution policies has part of their historical roots of absorptive capacity back in 1980s exhibit higher likelihood of adopting innovation policies and new technologies.

However, as the developing countries exhibit growing heterogeneity in absorptive capacity, countries farther away from global technology frontier such as South-Saharan Africa (SSA) could seize learning opportunities emerging from South-South technology transfer and cooperation. For developing countries, FDI is not an unalloyed blessing; only by accompanying in-house R&D or other types of indigenous innovation effort does foreign technology enhance innovation in practice, according to an empirical study investigating the effect of three types of technological learning (Li, 2011). Moreover, the appropriateness of technology matters because when a huge gap exists between transferred frontier technology and level of absorptive capacity, there would be a lack of linkages between MNEs and the local economy, and foreign subsidiaries may remain enclaves in a developing country yielding limited benefit to the host economy (Fu, 2004). Hence, an effective open national innovation system requires integration into global innovation networks and in the meantime enhances the national innovation system (**Figure 4.1**).

4.2 Drivers of direction of innovation in developing countries: innovations from international technology transfer

In the ONIS of developing countries, both international sources of knowledge and technologies as well as capabilities in the national innovation system contribute innovation that proceeds in a certain direction. MNEs stand at the centre of the global innovation network and global value chain by coordinating the outsourcing of a diversity of economic activities to developing countries while in the meantime acting as the hub of R&D. Local business firms and entrepreneurs engage actively in learning about product, process, management and marketing innovations in response to resource constraints as well as with the strategic intention of competitiveness. In the process, users and market demand constitute a significant source of direction of innovation by adopting these technologies. Besides, the government in developing countries, often with the aim of industrial upgrading and economic competitiveness, plays an important role in implementing policies such as a special economic zones and free trade zones to attract foreign investment.

1) User and demand-driven ICT innovation in Africa: case study on M-PESA

The rapid and large-scale adoption of ICT technologies in Africa constitutes a significant feature of diffusion of innovation on the continent. Despite having the lowest level of infrastructure investment in the world, access to and use of mobile phone technology in Africa has increased dramatically over the past two decades, with over 60 per cent of the population having mobile phone coverage, a process called Africa’s “Mobile Revolution” (Etzo and Collender, 2010). This rapid take up of ICT technology is an excellent example of demand driven innovation. Taking a mobile money application M-PESA as an example (**Box 4.1**), Kenya and the broader sub-Saharan Africa had very low levels of financial development, especially the near absence of a banking system. Mobile technology-enabled financial services hence had vast market demand among African populations. Qualitative studies unveiled that users often kept a balance on their M-PESA accounts, thereby using the application as a rudimentary bank account, or substitute for a formal financial system (Fu and Kingiri, 2020).

Box 4.1 M-PESA's diffusion in Africa

M-PESA, a mobile money application facilitating a variety of financial transactions was first introduced to Kenya in 2007 and gained wide acceptance in African countries. By September 2009, M-PESA had 8 million subscribers and a network of 13,000 agents, with over 3.7 billion US dollars cumulative value of money transferred via the application.

phone service providers and donors piloted new interventions and created revenues for mobile phones to improve consumer and producer welfare in developing countries. Technology side factors, including entrepreneurship and business ecosystem environment, also matter for successful diffusion of the financial digital innovation at the macro-level. Additionally, a pro-innovation facilitative and boundary-spanning role is played by the government such as by the Communication Authority of Kenya (CAK).

2) Diffusion of automation technology shipped from developed countries: case study on South-Africa's apparel industry

Automation, a representative technology in the 4IR, can be widely deployed in developed countries, for example, automobile assembly factories in US, Japan and Europe. Because 4IR innovation is highly concentrated in developed countries, MNEs, especially a handful of technology giants with rich technological and financial resources, are the major drivers of creation and diffusion of such technologies to both middle-income and low-income countries through global trade and production chains. Low-tech and semi-skilled sectors in developing countries, however, find it hard to accommodate these technologies. This is reflected in the very limited adoption of automation technology in South-Africa's apparel industry (Parschau and Hauge, 2020) (**Box 4.2**).

Box 4.2 Adoption of automation technology in South-Africa's apparel industry

The apparel industry is an important manufacturing sector for developing countries, which is projected to experience huge technology unemployment in 4IR. South Africa is one of the few developing countries which is to some extent shifting from a traditional labour-intensive approach and adopting automation technologies in this sector. However, even in this sector the level of automation is lower than generally expected. Although the majority of firms adopt some advanced technologies, even the most automated factories are not equipped with most advanced automation technologies already available, with some operations in sewing assembly still performed manually in these companies.

The decision on whether and how much automation is deployed in factories and production lines is largely left to SMEs in the sector. Support from government in the diffusion of this technology is found to be insufficient. The under-utilization of automation technology in the apparel industry in South Africa resulted largely from financial barriers, i.e., access to capital, consistency and volume of orders, investor confidence, etc. This is especially the case for small firms and informal firms in the sector, which is perceived unattractive because of low margins and profitability. Non-financial factors also contribute to the status quo, including limitations in technologies currently available, skills to operate automation technology and management capability.

3) Network-based mutual learning in South–South transfer of low-carbon innovation: case study on Indian village-scale solar power supply system

South-South technology transfer of low-carbon technology has attracted growing attention because developing countries not only need to drive their (re-)industrialization agenda but also be oriented to sustainable development. From a sustainability transition perspective, low-carbon innovation is the innovation or transition of an entire social-technical system instead of the technology itself (Jacobsson and Bergek, 2011). Therefore, it is often a network of economic forces and actors that contribute to the diffusion of low-carbon innovation to fully accommodate the social, economic, and cultural conditions in destination countries. Because of the system features of low-carbon innovation, the process of technology transfer is inevitably iterative, experimental, and involving significant learning-by-doing. This is illustrated in the diffusion of village-scale solar power supply technology from India to Kenya (Ulsrud, Rohracher and Muchunku,2018) (**Box 4.3**).

Box 4.3 Diffusion of village-scale solar power supply from India to Kenya

One representative example of successful South-South low-carbon technology transfer is deployment of village-scale solar power supply developed in India and diffused to Kenya. The transferred project, solar mini-grids, is a way of using solar photovoltaic technologies at the village scale instead of generally adopted "solar home systems" at household level, better suited to facilitate income generation through collective use of electricity and provision of village services such as IT and TV. This South-South technology transfer project was initiated based on the assumption that solar mini-grids in India might be a promising model and the two countries faced similar challenges in infrastructure provision.

Through iterative, comprehensive learning during the project, the resulting design for Ikisaya, the model eventually successfully deployed in Kenya, differed significantly from models seen in India. A network of forces, both foreign and domestic of Kenya and Brazil, served as drivers of innovation and its implementation in the technology transfer project. Governmental support at the national level in Kenya and community-based and network-enabled learning and implementation of the project were critical in the successful diffusion of village-scale solar mini-grids in Kenya. Taking technology transfer as the adaptation of a social-technical system, joint-learning and experimentation among multiple levels and diversified groups of actors in both "sender" and "recipient" countries are important. Besides, knowledge from the North is still relevant. Work by the University of Oslo funded by the Research Council of Norway is involved in the project in terms of practical planning and implementation and research activities, despite not concerning technological equipment and buildings.

4) Political economic forces underlying South–South agricultural technology transfer: case study on Brazilian tractors' deployment in Africa

Despite the rising share of manufacturing and service industries, the agriculture industry remains a very important sector in many developing countries, especially LICs. Agriculture innovation is a major avenue of innovation in these economies. In recent decades, many middle-income countries have successfully rolled out mechanical farming to boost labour productivity, a so-called “modernization” process of the traditional sector. As an emerging economy with large agricultural economy, Brazil has stood out in recent years as a reference for agricultural innovation for African countries. One prominent case of technology transfer in such a context is the Brazilian tractor, a tropical solution for African countries (Cabral, 2016)

(**Box 4.4**).

Box 4.4 Brazilian solution for African countries’ mechanical farming: tractor versus Matracas

Brazilian tractors are tropical solutions for African countries that hardly considered the appropriateness of the technology to local conditions. With the hope of adapting the Brazilian version of “Green Revolution” to the African context in the framework of South-South cooperation, two types of mechanical farming technology were utilized, tractors and Matracas. One stark contrast between these two types of machinery is that tractors symbolize high-powered mechanized farming while Matracas signals no-till, small-scale conservation farming.

Although they have similar resource endowments and levels of capabilities, it does not mean that technology transferred from middle-income countries to LICs is necessarily appropriate, especially when political economic forces implementing certain strategic intentions of industrial policy intervene in the selection of technologies. To foster the perceived transformation to modernization and turning family farmers into commercial farmers, Brazilian actors and their African counterparts, mainly policy makers and industrial interest groups, instrumentally deployed tractors, which, however, displayed poor suitability to local conditions. The African agricultural sector at that time favoured relatively labour intensive, low skill-using, smaller scale technologies that made use of local materials, resources and knowledge. This meant that Matracas was a better option if appropriateness of transferred technology is sufficiently taken into consideration in policy making and implementation.

5) The role of foreign sources of knowledge in under the radar innovation in LICs

The fact that firms in LICs mainly innovate based on domestic and indigenous efforts and regional value chains outweigh global value chains in their capability building do not supersede the relevance of foreign sources of technology and efforts as drivers of URI. In effect, a considerable proportion of innovations are imported from abroad or result from spillovers emanating from multinational companies (Figure 4.2). This international knowledge is mainly acquired via networks, labour mobility, imports and exports and value chain.

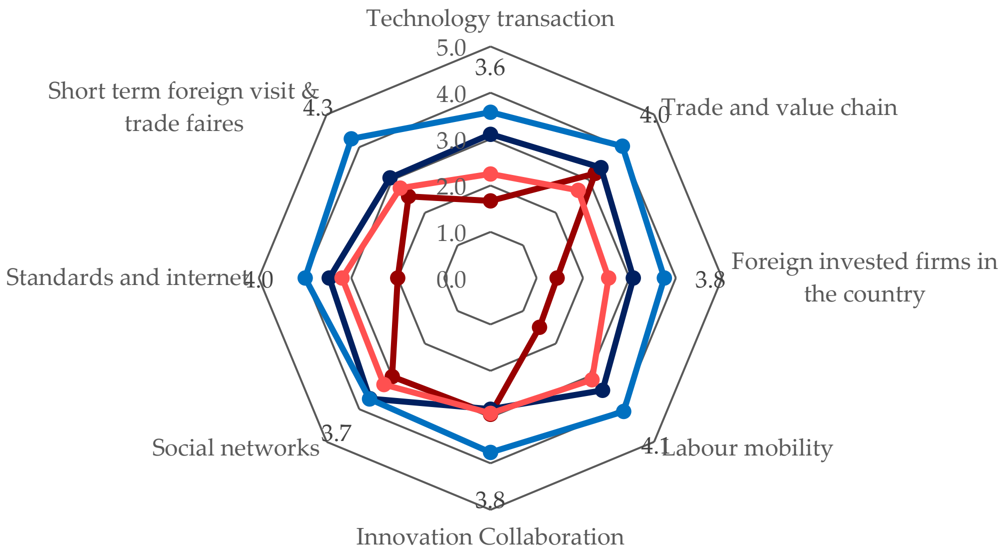


Figure 4.2: Importance of foreign sources of knowledge and innovation for formal (blue lines) and informal (red lines) firms in Ghana, 2015 (1 = insignificant, 5 = crucial, average values).

Source: Fu (2020)

Among various channels of international technology transfer (**Figure 4.2**), trade is a critical channel for local firms to come across and potentially adopt innovation. The global value chain is an additional important channel where formal firms engage with downstream manufacturing sector players to obtain innovation abroad. Besides, spillovers from multinationals are an increasingly relevant source of innovation diffusion from developed countries to LICs. Non-technological innovations are also transmitted via these channels. For example, skilled workers in multinationals often move to another company or start their own business, creating the opportunities for local personnel to access product, process, management and marketing-related practices.

The importance of foreign sources of knowledge differs greatly between formal and informal firms. Overall, for both technological and management innovations, informal firms consider foreign knowledge as less relevant for innovation activities than formal firms, probably because they have little direct access to foreign knowledge. As a result, informal firms source more knowledge from local resources, especially via social networks, value chain and learning-by-doing. By contrast, formal firms tend to engage with foreign firms in a variety of ways including trade, value chain and collaboration. The pattern of how formal and informal firms value foreign sources of knowledge in Tanzania is similar to Ghana, except for some differences in specific channels.

Box 4.5 Innovative adaptations of introduced technologies to fit local needs in Ghana

In the qualitative case study on firms in Ghana, URIs are partly embodied in the innovative adaptions of technologies that originated elsewhere. For example, firm F bought a sewing machine directly from China and they had to modify the engine for it to work with different electric voltage and better manage the blackouts that are frequent in Ghana. In some cases, the modifications can be so radical as to change the original purpose of a device. For example, firm B built a pasteuriser by modifying a metal tank which originally was a water heater and hence had a different purpose.

The innovative use of introduced technologies often result in indigenous technology development that adapt to local conditions (**Box 4.5**). The appropriateness of technology plays a significant role in the successful diffusion process and innovation outcome. Collaborations with formal firms are mainly found in formal firms, which often are closer to the local technology frontier and have the capacity to support such relationships. For example, firms in the food sector have sought collaborations in developing new products by accessing foreign laboratories to test the composition of the product. By contrast, firms in the textile sector benefit from the international initiative of South-South collaborations that focused on process and managerial models.

4.3 Drivers of direction of indigenous innovation in developing countries

As discussed in **Section 2**, URIs in LICs are prevalent in low-tech, semi- or low- skilled manufacturing sectors, mostly new to the firm but rarely new to the world. They are mostly the outcome of creativity by small and medium sized enterprises (SMEs) in response to a variety of barriers. African firms face several difficulties during the innovation process, some of which can even deter firms from engaging in innovation activities. Among a variety of factors, five of them stand out as significant barriers to innovation among firms in LICs, i.e., financial factors, knowledge-related factors such as lack of information on technologies, lack of skills and human resources, market and institutional factors, and factors related to institutional constraints. Under these constraints, firms in LICs achieved URIs largely by drawing knowledge and resources indigenous to the country by means of a localized learning-by-doing process. Local sources, especially skilled workers within the firm, and inspiration and requirements from customers, are important mechanisms by which URIs are materialized in LIC firms. Entrepreneurial ingenuity by creative individuals also contributes to innovations under various constraints.

Due to its imitative and incremental nature, URI is often diffused among firms in LICs. In the process, firms mainly benefit from production networks, value chains and other types of social networks at the regional level, while GVCs play a less important role. The state in LICs facilitates URIs through a portfolio of science, technology and innovation (ST&I) policies, albeit the poor implementation leads to unsatisfactory benefits. University-industry linkage, however, is lacking, which limits the potential of diffusion of URIs in LICs.

4.3.1 Origins and drivers of direction of URIs in LICs

Origins of URIS in LICs

1) Within-country sources outweigh foreign sources

URIs are mostly indigenous and developed in-house within firms in LICs, and foreign sources of technology and knowledge are limited. In the case of Ghana, the vast majority of innovations originated from within the country (**Figure 4.3**). Specifically, in 2015, almost 58 per cent and 56 per cent respectively of informal and formal firms adopted or created innovations with resources and information found in the country. In 2015, these firms also benefitted from South-South collaborations and technology transfer in terms of sources of innovation. This may be attributed to the rationale that adoption of innovations from a country at a similar development stage may be more easily absorbed and adopted by firms with lower technological capabilities. Formal firms appear to be more likely to adopt innovations from abroad, especially from Europe, China and India, possibly because they have stronger capabilities than informal firms.

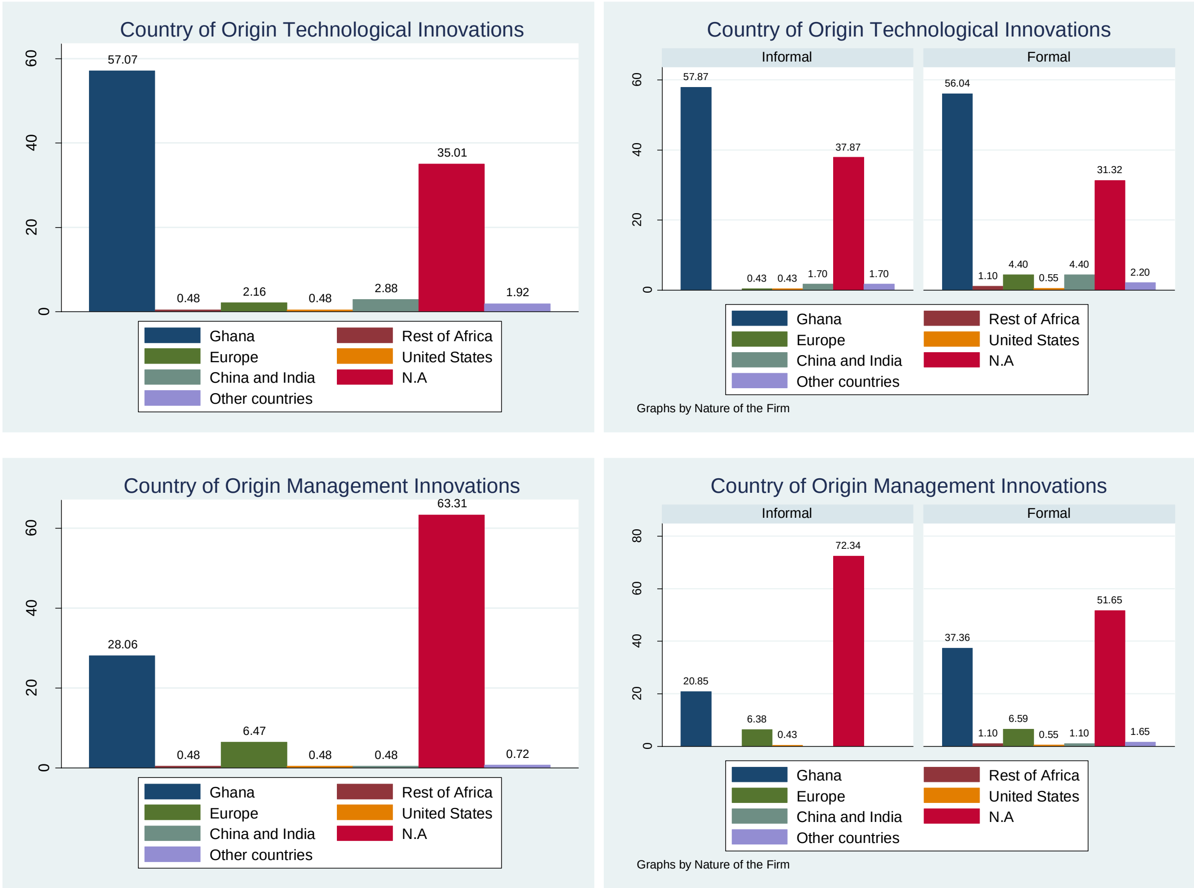


Figure 4.3: Proportion of countries of origin of innovations (left) and by nature of firm (right), of technological and management innovations, in Ghana, 2015. Note: More than one response allowed.

Source: Fu (2020)

For management innovations, most of the firms adopted new management practices that originated within Ghana (28 per cent). A higher proportion of formal firms (37 per cent) adopted within-country management innovations, compared to a 21 per cent ratio of informal firms. Notably, Europe also serves as an important foreign source of new management practices.

2) Local sources of knowledge for URIs

Local information and knowledge external to firms are essential components for drivers of URIs. Four types of them are found to be especially facilitative to URIs in LICs, namely internal to the firm, membership of networks (clusters or associations), market and institutional resources, and other sources including ICTs, conferences and publications (**Figure 4.4**). In Ghana, knowledge sources within the firm are the most important source of innovation for both formal and informal firms and for both technological and managerial innovations. Being a member of networks also brings significant benefits to Ghanaian firms, which can source knowledge and technology from clients, customers, competitors or other enterprises in the same sector, and from other firms within a specific group. Knowledge spillovers from broader networks, especially clusters and associations, also facilitate innovation and its diffusion.

Institutional sources of knowledge, such as universities and public research institutes, together with consultants and private R&D institutes, are additionally valued by Ghanaian firms. For both technological and managerial innovations, formal firms put more emphasis on these sources perhaps due to lack of access to “formal” institutions among informal firms.

It is still worthwhile to highlight the role of other sources of information for URIs, especially general sources such as the internet, and technical sources such as trade fairs, scientific journals and industry associations. The most relevant one is the internet, which holds the potential to overcome the lack of information in low-income countries and lower the cost barrier for users who need to find scientific information.

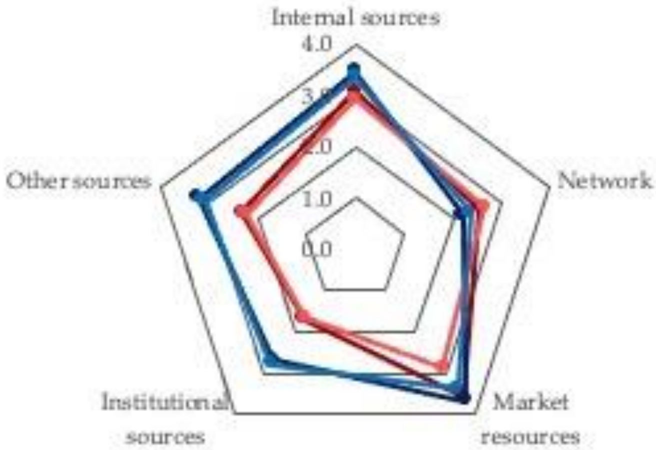


Figure 4.4: Importance of local sources of information for formal (blue lines) and informal (red lines) Tanzanian firms, in 2015 (1 = insignificant, 5 = crucial, average values).

Source: Fu (2020)

- **URIs are mostly in-house learning-based outcomes**

URIs mainly result from indigenous efforts, especially technologies and processes developed primarily within the firm. Most of the innovations appear to be developed primarily within the firm, where internal colleagues comprise the most important domestic knowledge source according to the survey. In Ghana, 63 per cent and 55 per cent of firms respectively developed technological and managerial innovations within the firm. Formal firms exhibited a greater extent of indigenous efforts, with 78 per cent of them reporting to have developed in-house, without external collaboration with other institutions. The reliance on external sources of innovation among Tanzanian firms is even less.

These innovative activities are mostly learning-based rather than R&D-based. Research and Development departments are available only in the larger and formal firms in LICs, and most of firms in these countries need to rely on learning-based mechanisms for innovation. In particular, skilled workers contribute significantly to the innovation process where they find better ways to produce after experiments in a trial-and-error approach, mainly in formal sectors. However, skilled workers are less concentrated in informal firms, which had to rely more on adapting or modifying goods or services originally developed elsewhere. Besides, innovations among these firms are also produced by simply imitating other companies, a common practice when R&D resources are extremely scarce.

- **Customer demand as a major inspiration of innovation**

Among these indigenous efforts, customer demand serves as a major inspiration of URI. The majority of technological innovations in Ghana and Tanzania are modifications to the firms' products in response to customers' requirements, a consistent pattern observed in both formal and informal sectors. Management innovations are also significantly driven by customer requirements. Specifically, the ratio of firms that introduced management innovations and new marketing practices as a response to customers' requirements was 60 per cent for Ghanaian firms and 57 per cent for Tanzanian firms.

Moreover, the market serves as the major source of innovation by offering a strong connection between firms and customers that can be mutually beneficial. Innovations as responses to customer needs and requirements also drive the innovations in process and management practices. For example, in the textile sector, factories and firms can visit local markets for ideas for new styles and products. In the case of a construction supplier, the production of a new product was initiated following a specific request from a large customer, where the supplier invested in new machinery and transferred knowledge gained from producing similar products.

The vast market size in developing countries make the role of consumer demand especially prominent. As discussed in Section. the success of M-Pesa, and more broadly, digital innovations based on ICTs, is greatly accelerated by large volume of consumer demand. In the manufacturing sector, Brazil and India manage to produce automobiles in a cost-efficient way partly because their large market size enables economy-of-scale. Besides, regional disparity and market segmentation provide rich opportunities for firms to experiment and upgrade their capabilities through their interaction with the demand side of economy (Fu, 2015). By comparison, developing countries with smaller market size may suffer disadvantage in terms of diffusion of indigenous innovations and incubating learning opportunities (Sturgeon and Van Biesebroeck, 2011).

Drivers of URI

The firms in Africa, most of which are SMEs, are the major innovators of URIs. The grassroots innovators also contribute to URIs, in particular those low capital-intensive, social-demand-driven URIs. MNEs are drivers of URIs as well, with Northern MNEs contributing more to medium capital-intensive URIs through the adoption of new machineries and equipment in LICs, while Southern MNEs contribute more to labour-intensive URIs by bringing URIs in emerging markets to LICs. A summary of drivers of URIs and routes of knowledge flow are listed in Table 4.1 and Table 4.2 below.

Table 4.1: Drivers of Under-the-Radar Innovation

Drivers	Explanation or examples
Customer demand	Domestic market International market (Exports, GVCs, Regional VCs) Cut cost
Competition to survive	Improve quality New products New management/marketing practices
Entrepreneurship	Both men and women. Women more often seen in low-cost management/marketing innovations
Characteristics of Infrastructure	Forced innovation, e.g., unstable energy supply, so use solar power, or manual operation instead of automation
Inspiration of innovations & knowledge spillover	Both horizontal in the same industry and vertical in other industries
Big change in the industry	Induced innovation, e.g., e-commerce
Regulatory environment, policy push	E.g., grassroots innovation in agriculture to address climate change

Social needs	E.g., NGO driven innovation for the poor
Factor prices	E.g., capital shortage and increase in interest rates. Adoption of more labour-intensive technology from the South.

Source: Fu (2020)

Table 4.2: Routes of Under-the-Radar Innovation

Routes	Sub-routes	Notes
Customer requirement	Domestic customer	
	International customer	
Regional VC/GVC	Quality requirement	
	Training	
Imitation	Without adaptation	
	With adaptation	Learning-based, not lab-based. New player; South and BRICs
On-the-job experiment/trial	Individual creativity	
University-industry collaboration	Commercialization of new technology, or help firms to absorb and make adaptation of acquired external technology	
Technology transfer/spillover	FDI	
	Exports	
	Diaspora	

Source: Fu (2020)

4.3.2 Driving forces of diffusion of innovations within LICs

LIC firms widely adopt open innovation strategies for innovation in response to constraints in financial resources, technological capabilities, and weak institutions. They especially rely on external knowledge search and imitations, collaborating with a range of actors, customers, workers, and other firms to develop and adopt innovations. Imitation of other firms, with or without changes, is a way to become innovative.

1) Formal collaboration and external knowledge search

LIC firms engage to a moderate extent in formal collaboration, mainly with partners in the supply chain and in the same industry. They also use external knowledge search for seeking innovative ideas and technology that can help them improve their product design or quality, production process, or management or marketing practices. Notably, local knowledge is more relevant for innovation outcomes than foreign knowledge, highlighting the importance of appropriateness of knowledge in technological learning.

2) Limited role of Universities-Industry linkage

Innovation literature highlights the pivotal role of universities in knowledge and technology transfer to industry. Moreover, universities are found to play a dual role in the context of developing countries by being the source of radical innovation and more importantly, being the source of incremental improvement and materialization of innovation in collaboration with industries (Fu and Li, 2016). However, such a role of universities is realized far more in low-income countries despite its equal, if not more, importance in developing a knowledge-based economy. Only a small proportion of firms developed or introduced their innovations that stemmed from formal collaborations with other entities. Firms with richer financial resources and stronger absorptive capacity are more likely to engage in formal collaborations, which, however, are quite rare in LICs. The majority of a very limited number of collaborations were initiated by individual action or personal connections, while the presence of governmental initiative was restricted to one third of total recorded collaborations.

There are several reasons underlying the low level of university-industry collaboration in LICs. The first reason, according to evidence from the survey, is that a large proportion of firms does not feel the need or interest to engage in collaboration. Secondly, the lack of collaboration partly results from the fact that firms largely do not have connections with universities or research institutes, despite their intention to get involved in potential collaborations.

3) Clusters, value chains and networks

A diversity of inter-firm networks, both formal and informal, serve as another important source of innovation for firms in LICs. The majority of innovation diffusion in LICs happens within firms' value chain, corroborating literature in LICs that simple forms of clusters and vertical production chains of SMEs allow firms and entrepreneurs to share capabilities in the existing value chain.

In LICs, clusters are often comprised of small and informal firms that together have a greater market power. They are formed initially because of friendship, and then vertical business relationships are established. Clusters benefit member LIC firms in various aspects. In the first place, they constitute the institutions that provide greater support and assistance to informal and formal firms. Clusters especially matter for informal firms in terms of exchange of relevant production and technology information, and a greater collaboration on pricing. Work and resource sharing are also important benefits for clusters members.

Among a variety of mechanisms of inter-firm connection, vertical integration in supply chain provides the avenue for LIC firms to reduce transaction costs, exploit the capabilities of chain members and secure supplies or distribution channels. SMEs are often components of a supply chain in LICs, as part of a network predominantly with a lead firm though retaining independent ownership. Vertical production chains help make existing products cheaper or of better quality as well as contribute to knowledge sharing, whereas they are seldom conducive to novel innovations.

Despite the well-recognized importance of foreign sources of technologies, very few vertical production chains are led by foreign firms in Ghana and Tanzania. By contrast, small and large local firms act as leaders in most vertical production chains which are primarily formed via personal linkages such as family ties. This points to the fact that local sources of knowledge are more relevant for innovation outcomes than foreign ones, perhaps because of a large knowledge and technology gap between these two types of firms and hence local knowledge is more appropriate for LIC firms.

4) The role of the state in diffusion of URIs

Despite the fact that policy intervention is controversial, innovation policy is often justified in terms of public good, the nature of science and technology and a range of failures that discourage innovation activities, such as failures in capability, institution, and the entire innovation system (Laranja et al., 2008). Governments in developing countries gradually adopted science, technology, and innovation (ST&I) policies to support innovation activities and build up a national innovation system (Sithole, 2020). The table below shows the trend of countries in the African Union increasingly incorporating an ST&I policy scheme as instrumental in fulfilling their development visions in the first half of 21st century at the national level (**Table 4.3**). Among these principally "supply-side" oriented schemes, priorities are mainly assigned to building up internal absorptive capacity including research capacity and human resources, as well as enabling an institutional environment such as a research network, or public-private sector connection.

Table 4.3: ST&I policies in selective LICs

Country	Development Vision	S&T Policy	ST&I Policy	STI Policy Ownership
Botswana	Vision 2016 (drafted in 1997)	Science and Technology Policy (1998)	National Policy on Research Science, Technology and Innovation (2011)	Ministry of Infrastructure, Science and Technology
Burundi	Vision 2025 (adopted in 2010)	–	National Policy on Sciencific Research and Technological Innovation (2011)	Ministry of Higher Education and Scientific Research is currently in the process of putting in place the National Commision for Science Technology and Innovation
Ethiopia	Vision 2025 (announced in 2011)	National Science and Technology Policy (1993)	National Science, Technology and Innovation Policy (2012)	National Science Technology and Innovation Council and Ministry of Science and Technology
Kenya	Vision 2030 (launched in 2008)	The Science and Technology Act Cap 250 (1977)	Science, Technology and Innovation Act (2013, Draft National Science, Technology and Innovation Policy (2012))	Presidential Advisory: Parliamentary Committee on Education, Research and Technology; Commission on Science, Technology and Innovation; Ministry of Education, Science and Technology
Malawi	Vision 2020 (launched in 1998)	Science and Technology Act (2003), National Science and Technology Policy (1991 and revised in 2002)	–	National Commission for Science and Technology (under Ministry of Education, Science and Technology)
Mauritius	Vision 2020 (announced in 2008)	–	Draft National Policy and Strategy on Science, Technology and Innovation (2014-2025)	Mauritius Research Council and Ministry of Tertiary Education, Science, Researrch and Technology
Namibia	Vision 2030 (adopted in 2004)	Science and Technology Policy (1999)	National Programme for Research, Science and Technology and Innovation (NPRSTI- period of three years), Draft Innovation Framework Policy (2011)	National Commission on Research Science and Technology
Rwanda	Vision 2020 (revised targets adopted in 2012)	–	National Science Technology and Innovation Policy (2006) revised in Octorber 2014 (not yet approved by the Cabinet)	Ministry of Education
Tanzania	Vision 2025 (in place since 2010)	National Science and Technology Policy Framework (1985), National Science and Technology Policy revised (1996)	Tanzania Science, Technology and Innovation Policy reform (2008-2013) resulted in a review of National Science and Technology Policy into National Science Technology and Innovation policy; revoked COSTECH Act (2000) into new Act (2013); implementation expected in 2015	Ministry of Communcation, Science and Technology
Uganda	Vision 2040 (launched 2013)	–	National Science Technology and Innovation Policy (2009)	Uganda National Council for Science and Technology (operates under Ministry of Finance, Planning and Economic Development)
Zimbabwe	Vision 2020 (late 1980s)	Science and Technology Policy (2002)	National Science Technology and Innovation Policy (2012)	Ministry of Science and Technology Development

Source: Sithole (2020)

Policy interventions and instruments are strongly associated with determinants of innovation in the specific context of developing countries. Attempting to overcome a shortage of financial resources, the Government in Ghana uses direct funding subsidies, a dominant practice in ‘supply-driven’ S&T systems in developing and developed countries, to encourage firms to adopt new technologies, innovate and raise productivity. Both formal and informal firms in Ghana and Tanzania are found to have benefitted from government subsidy and training programs. In line with the participants of training programs, firms that received the subsidized loans responded positively to such financial incentives. The average beneficial rate evaluated by the 23 firms was 3.17 out of 5 among which informal firms tended to take more advantage than formal firms from the cheap rate loans (**Table 4.4**).

Table 4.4: Benefitting from participation in training and subsidised rate loans program for formal and informal firms: (1 = insignificant, 5 = crucial, average values).

	Total	Formal	Informal	Difference
Training opportunities	3.37	3.25	3.46	-0.21
Subsidised rate loans	3.17	3.14	3.22	-0.79

Note: Significance at the 10 per cent, 5 per cent and 1 per cent levels are indicated by one, two and three asterisks respectively.

Source: Fu (2020)

Nevertheless, the quality of policy implementation is far from being satisfactory. The surveyed enterprises regarded most of the issued S&T policies as poorly implemented and ineffective. In fact, the majority of domestic firms seemed not to have successfully benefitted from government's financial support program. In fact, as few as 4 per cent of the entire sample received government subsidized rate loans during 2010 – 2013. Under-delivery of government S&T programs mainly resulted from lack of effective channels to access the information on these policies and programs. Besides, heavy paperwork and bureaucracy of the procedures discouraged many firms from participating. An important issue in the current innovation policy agenda in Africa is hence how to make policies work better for development and innovation.

5. The opportunities and challenges of developing countries in the Fourth Industrial Revolution

5.1 The worldwide landscape of 4IR technologies: a picture of divergence

Amidst the "Fifth Great Surge of Development" (Perez, 2013) featuring fast development and wide deployment of ICT technologies, the 4IR creates tremendous disruptive innovations as well as modifying the innovation process itself. Representative 4IR technologies, such as the Internet of Things (IoT), artificial intelligence (AI), 3D printing and robotics, have transformed and continue to transform the way production is organized, individuals live, and work and economic return is distributed. Unlike previous industrial revolutions, characterized by fusion of breakthroughs in physical, biological and digital realms, 4IR brings about unprecedented technological windows of opportunity that revolutionizes various industrial sectors and provides a basis for a new competitive paradigm (Schwab, 2016).

Despite a surge of 4IR patents in many OECD economies, 4IR technologies embodied in patents are rarely identified in developing countries, except from emerging markets such as China. Moreover, the adoption of these technological innovations is also rather slow in developing countries especially in Africa. Taking the worldwide distribution of industrial robots as an example **(Figure 5.1a**), Africa had the lowest level of shipments, while Asia topped the shipments ranking by region. America and Europe kept their strengthen in the middle and saw a steady growth over the years expect financial crisis. Although Africa enjoyed high growth rates in industrial robot shipments especially after 2000 (**Figure 5.1b**), its stock was still far behind that of the Asia, Europe and America.

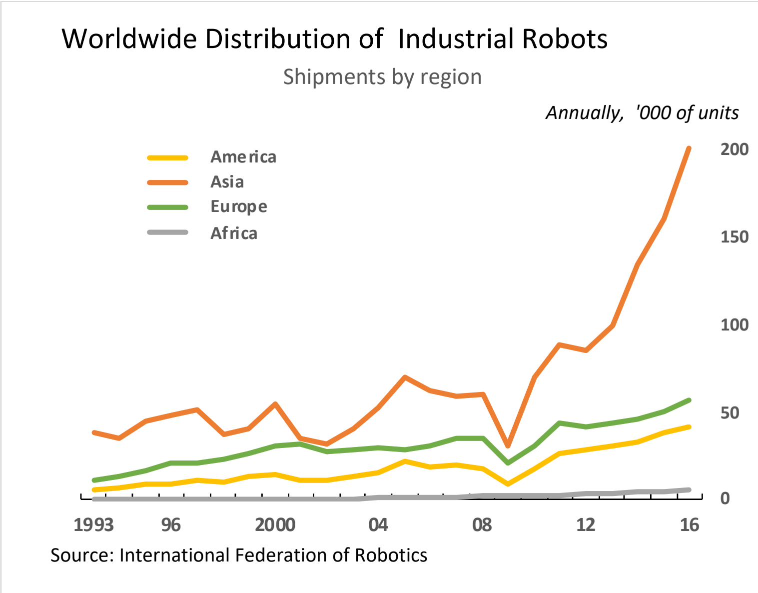


Figure 5.1a: Worldwide distribution of industrial robots

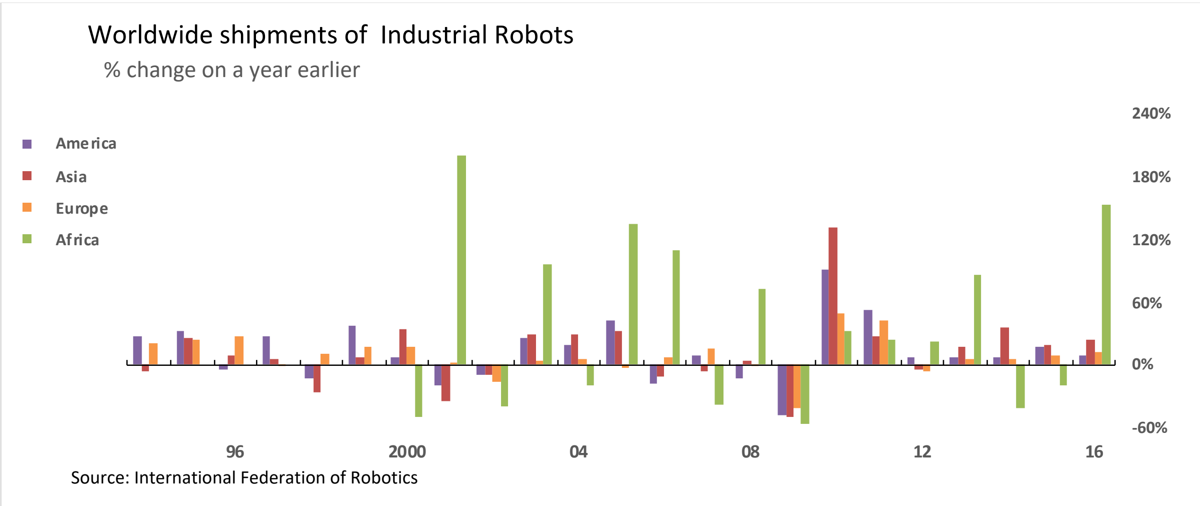


Figure 5.1b: Worldwide shipments of industrial robots (% change on a year earlier)

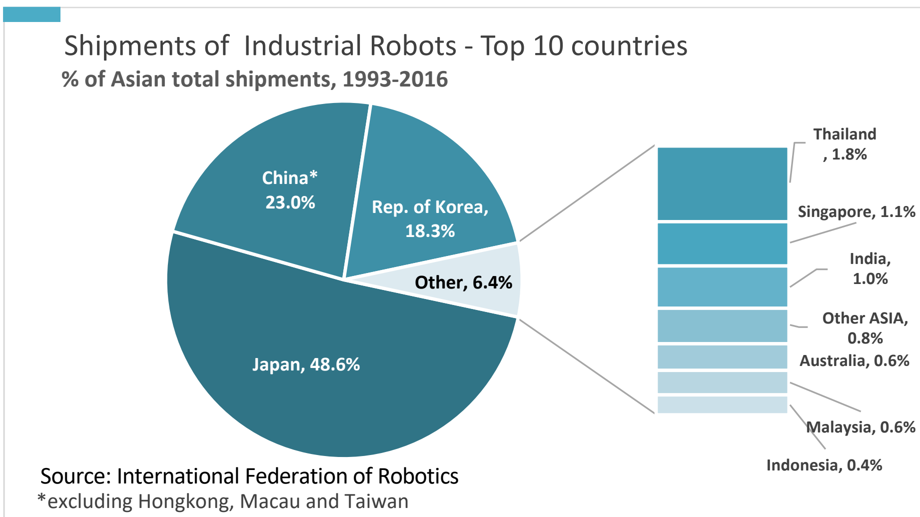


Figure 5.1c: Shipments of industrial robots - Top 10 countries, % of Asian total shipments

Emerging economies are catching up fast. Within Asia, developing countries such as Japan and Rep. of Korea are still the major destinations of industrial robot shipments, together taking up over a half of the region (**Figure 5.1c**). However, China rose as one of the leading markets, representing nearly one-quarter of robot shipments in Asia. Other developing countries such as India and Thailand also have remarkably over 1% of overall shipments in the region.

5.2 Opportunities for developing countries

The surging 4IR provides a diversified range of technological windows of opportunities for developing countries both to achieve technological upgrading and fulfil sustainable development goals (SDGs) in a new development paradigm.

4IR has the benefits of productivity gains by applying digital technologies in a wide range of industrial sectors. Deployment of robots is believed to raise labour productivity when it is applied to tasks they perform more efficiently with a higher and more consistent level of quality than humans. This is supported by an empirical study by Graetz and Micheals (2015) on robot adoption in 17 countries which found that robots raised these countries' annual GDP growth between 1993 and 2007 by 0.4 per cent on average. Based on labour market evidence from a cross-country panel dataset of 74 countries during 2004-2016, Fu et al. (2021) find that adoption of industrial robots is associated with significant gains in labour productivity in developed countries. Besides the adoption of 4IR technologies, the innovation of 4IR technologies is found to boost firm wage levels because of creation of innovative rents in OECD economies (Shi at al., 2020), while the case for developing countries deserves further research.

Moreover, the coupling of the physical and virtual world in 4IR offers the potential of an "on demand" economy. For example, 3D printing means that an idea can be developed and tested digitally, thus allowing innovation, manufacturing and production to skip some costly and time-consuming processes. Reducing fixed costs involved in economic activities, 3D printing makes on-demand production and service provision possible (Manyika et al., 2013). The resulting restructure of global production networks and global value chains brings opportunities of distributed and localized production communities to African countries by lowering the barriers of access to these economic processes.

For developing countries, especially LICs, such effect is potentially more manifest, given that they remain far away from the worldwide technological frontier, with much space for improvement based on low productivity levels and low capital intensity; African countries hence are seeking to leapfrog onto the technological ladder.

5.3 Challenges for developing countries

Although 4IR technologies are promising for developing countries to drive the (re-) industrialization agenda and achieve SDGs using new means, tremendous challenges lie ahead for the potential of these technologies. As indicated earlier in Directed Technical Change theory, the result of technological innovations in 4IR may be mostly biased towards capital and high-skilled labour, which is scarce in LICs compared to developed countries. Specifically, emerging technologies such as AI, automation, and big data analytics, not only require huge capital investment, but also workers that are creative and do not follow repetitive and routine patterns. Such bias between capital and labour, as well as between skilled and unskilled workers, has significant implications for developing countries, which leave leapfrogging in 4IR in question.

5.3.1 Employment effect

A major concern over the labour market consequences of 4IR is technological unemployment, a prediction by economist Maynard Keynes, that “due to our discovery of means of economizing the use of labour outrunning the pace at which we can find new uses for labour” (Keynes, 1933: p. 3). Despite the fact that the debate remains unsettled, as human society is still in the ferment phase of 4IR, existing empirical evidence indeed seems to support the technological unemployment consequences of digital technologies.

A common finding from empirical literature is that routinized occupations, which mainly involve tasks following well-defined repetitive procedures and can easily be performed by algorithms, are especially vulnerable to digital technologies. In the context of 4IR, even some non-routine tasks, such as business analysis, can also be performed by AI. Hence the labour market consequence of 4IR is believed to be far more profound than any previous technical changes. Frey and Osborne (2013) estimated that 47 per cent of US jobs are at risk of being replaced by computerization. The adoption and deployment of automation technology tend to cause even greater disturbance to the labour market. For example, Brynjolfsson and McAfee (2011) argue that such sophisticated technology could make workers redundant in almost every industry and every country. Blue-collar jobs will continue to be automated, and this trend will increasingly spread to white-collar jobs. This renders labour market in developing countries especially vulnerable to 4IR technologies (**Figure 5.2**).

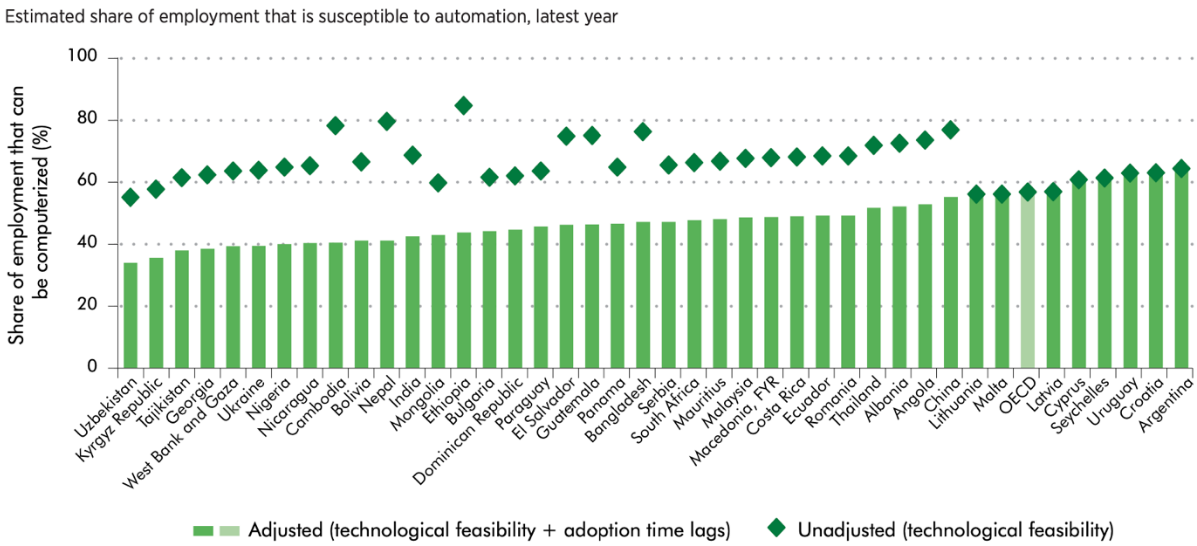


Figure 5.2: Estimations of jobs susceptible to automation in developing countries from a technological standpoint

Source: World Bank (2016)

5.3.2 Distributional effect

Worldwide diffusion of 4IR technologies raises concern of increasing inequality both between developed and developing countries and between different labour groups via a distributional effect. The is partly related to the observed trend that the technological unemployment effect is unevenly distributed in the labour market, posing the threat of job polarization with a structural shift of middle-income workers reallocating their labour supply to high and low ends (Autor and Dorn, 2013). Especially, as middle-income manufacturing sector occupations are more susceptible to automation, low-income sectors attract workers from the middle segment because they require a higher degree of flexibility and physical adaptability. By contrast, middle-income workers find it hard to upgrade their skills in order to enter the high-income segment due to the sophisticated digital competency needed. The resulting “hollowing out” of middle-income jobs in the labour market risks increasing income inequality.

The 4IR featuring digital technology as “general purpose technology” (Brynjolfsson, Rock and Syverson, 2021) could magnify such inequality, as ongoing disruptive innovations favour a small elite group who are well-educated, have access to huge amounts of data and command sophisticated algorithms, or own vast physical or intellectual capital. Compared to developed countries, many developing countries rely on labour-intensive manufacturing sectors as engines of growth, while these sectors are most subject to job polarization.

5.3.3 Industrial re-shoring at the global level

The technological unemployment effect tends only to take place within countries but also occurs between developed and developing countries. According to the United Nations Conference on Trade and Development (UNCTAD, 2016), increased use of robots in developing countries erodes the traditional labour-cost advantage of developing countries, a process called “re-shoring”, defined as “re-concentration of parts of production from own foreign locations as well as from foreign suppliers to the domestic production site of the company” (Kinkel and Maloca, 2009, p. 155). This is because, owing to improved cost-performance brought about by automation, developed countries may re-shore economic activities to regain international competitiveness in manufacturing sectors and cut down job losses in middle-skilled occupations. Sparse empirical evidence shows that moderate industrial re-shoring takes place in developed countries. For example, 4% of 1700 manufacturing firms in Austria, Germany and Switzerland have re-shored some activities, enabled by the use of high-tech automation and digital technology (Dachs, Kinkel and Jäger, 2017). However, it remains to be seen whether 4IR-related re-shoring exceeds new offshoring as technical change progresses.

5.4 Can developing countries leapfrog in 4IR?

Although automation and other 4IR technologies have not spread world-wide on a large scale, the challenge brought about by them for developing countries is rather pronounced. Because 4IR technologies are highly biased towards capital and high-skilled labour and require significant R&D investment, the prospect of developing countries’ leapfrogging could hardly lie in international technology transfer due to low level of technology appropriateness. Nor is it entirely dependent upon indigenous efforts, which are shown to be less R&D related, more learning oriented and can hardly build up competitiveness in the digital era.

Admittedly, typical 4IR technologies such as AI, automation, big data analytics, etc., create alternative paths of leapfrogging through innovative use of these technologies, in a sense like how digital technologies provide substitute for financial infrastructure in ICT paradigm (Soete, 1985). This transforms the process of production and innovation themselves, often accompanied with business model innovations and new marketing practices, an avenue that URIs are good at. The use of drones in drug delivery during pandemic is one example of 4IR technologies being used in developing countries context.

Nonetheless, mere adoption and innovative use of 4IR technologies still make it hard for developing countries especially LICs to leapfrog. Clear limitations of the lack of inputs from modern science and engineering make it difficult for the African firms to catch up with the firms in the industrialized countries which are supported by rapid progress in science and technology. While there is a certain degree of ICT enabled development and innovation in Africa, digital technology could have played a more significant role. Moreover, infrastructure in 4IR have more to do with the fusion of ICT technologies with physical world, e.g., IoTs, instead of ICT itself. To truly seize and exploit this technological window of opportunity, it to some extent depends on pertinent policy making and implementation in developing countries, especially enhancing innovation capacity, overcoming financial barriers, and building digital competency.

6. Conclusions, policy recommendations and the role of developing countries in setting global direction of innovation

6.1 Summary of main findings

This report examines the direction of innovation in developing countries and the economic forces underlying this directionality. Direction of innovation matters because resources are limited and technical change is not neutral, hence it has significant development implications for these countries, which is under-studied in existing literature. The report mainly focuses on URIs introduced via international technology transfer and indigenous efforts. Two groups of developing countries, i.e., fast-growing emerging economies and a large number of LICs, are analysed.

Innovation in developing countries exhibits a highly vibrant and diverse picture. Emerging economies demonstrate intensive inventive activities in fields such as ICTs, biotech, chemicals and engineering. URIs in medium- and medium-high technology sectors are also prevalent in these economies, as is manifested in the rise of the automobile industry and import of machinery in these countries. URIs in LICs are widely found in low-tech, semi- or low-skilled manufacturing sectors such as textile and wood and food products, existing not only in products and processes but also in managerial and marketing practices. These innovations are largely new to the firm instead of new to the world.

International technology transfer and indigenous innovative efforts are the two routes by which URIs are introduced in the ONIS of developing countries. With regards to the channel of technology transfer, MNEs continuously lie at the centre of the global innovation network. They opt to internationalize their R&D and production activities to benefit from other market externalities such as tapping into local technology excellence and shorter cycle-time to commercialize products, with Northern technologies concentrating in medium capital- and technology-intensive sectors, while Southern technologies feature more labour-intensive ones. However, foreign sources of technologies, including MNEs, trade, universities and NGOs from developed countries, are less relevant for URIs in LICs perhaps because of large capability gaps between them. For indigenous sources of URIs, they are largely outcomes of localized learning-by-doing conducted by SMEs in LICs, materialized through close interaction with customers, and created and diffused through embeddedness in regional production networks, value chains and clusters.

State and market forces are two major drivers of the direction of both foreign and indigenous sources of URIs, but the role of universities is underplayed. Specifically, governments in developing countries encourage transfer of URIs through trade policies such as special economic zones, or proactively foster collaborations in fields of low-carbon innovations. In addition, although they are controversial, ST&I policies are increasingly adopted as important tools to enhance indigenous capabilities to innovate. However, perceived benefit among local business is limited due to a lack of effective delivery and implementation of these policies. Market force serves as a strong driver of direction of URIs in developing countries. It provides huge market demand for adoption of certain foreign technologies, for example, ICTs and machinery. Customer requirements also provide inspirations for URIs in LICs through close interaction and mutual learning. The roles of universities and research institutes however are largely absent from the scene. Especially for indigenous URIs in LICs, university-industry linkage is weak, which obscures the role of university in creation and diffusion of URIs in the national innovation system.

The unfolding 4IR opens unprecedented technological windows of opportunity but also presents severe challenges to developing countries. Considering the appropriateness of technology, the 4IR requires heavy investment in R&D and sophisticated high-skilled labour, leaving little room for URIs that are non-R&D oriented, learning-based and incremental in nature. Apart from middle income countries such as China and India that are catching up fast in specific fields, e.g., ICT, AI and big data analytics, the majority of developing countries will find it demanding to leapfrog using URIs.

6.2 Policy recommendations

Several policy implications emerge from the findings of this report.

1) Changing mind-set and supporting innovation in Africa. Increasing evidence has shown the innovativeness of LIC firms. However, innovation in LICs, especially in informal sectors, remains often unrecognized and unsupported. This requires in the first place a change in the mind-set, new thinking and formulation of new policies to recognize and support innovation. For example, policy initiatives should be in place to mitigate the constraints of financial and labour skills that hamper genuine innovative efforts among LICs.

2) Development of open national and firm innovation systems. Developing countries have to build up ONIS that is opened up to international knowledge, resources and markets. The fact that trade, FDI, people flow and the internet have all played some role in facilitating international innovation diffusion at either firm or worker levels, conditional on the level of absorptive capacity, IPR protection, and development strategy of the host countries (eg. Balasubramanayam et al., 1996; Lall, 2002; Fu, 2008; Hu and Jefferson, 2002; Fu and Gong. 2011) suggests that these channels can possibly work in the context of LIC, while there is more to do. Especially, dedication and determination to implementing trade, investment and migration policies are required for a greater level of openness. At the same time, complementary policies in education, upgrading of technology capacity and infrastructure development should be strengthened to enhance the indigenous capability and absorptive capacity in the domestic economy.

3) Enhancing capacity for industrial leapfrogging. URIs are largely learning-based non-R&D and incremental in nature. Given the rapid technical change in the global economy, it is important to develop Africa's capacity in science and engineering and build the necessary research infrastructure in order to keep Africa moving forward together with the rest of the world. This is even more important for innovation leapfrogging. Improving the quality of education, developing the higher education sector and increasing investment in research institutes are important and challenging tasks for African countries.

4) Strengthen university-industry linkage and encourage regional value chains. In developing countries, universities can play a dual role in their national innovation system. On one hand, they serve the traditional role of knowledge creation; on the other hand, through university-industry collaboration, they help firms to assimilate and decipher the transferred foreign technology and make the necessary adaptations for local application. Findings from existing studies suggest the university-industry linkage is still weak in LICs. Government policies should continue to incentivize, support and facilitate university-industry linkage not only using financial policy tools but also combining them with non-pecuniary tools such as project evaluation and talent appraisal.

5) Develop the innovation community through partnership between state and private sector and between domestic and foreign players. The success of M-PESA mobile money transfer service in Kenya suggests that LICs can make an innovative application of modern technology pushed forward by a dynamic local innovation community that involves broad stakeholders in the relevant experimental, entrepreneurial, sectoral innovation ecosystems. In this regard, the private sector should actively engage with the regulatory body. At the same time, government policies and regulation should be responsive and engaging so that they co-evolve with the technological changes to facilitate the progress.

6) Building digital competencies through training, international cooperation and creating an enabling environment. ICTs are tools that facilitate knowledge flow and information exchange. Therefore, it is important for government to prioritize the investment in ICT infrastructure and skills development to facilitate internet knowledge-sourcing in the economy. Moreover, given the rapid development of technology and the 4IR in the world economy and the opportunities and challenges it may present to LICs, it is necessary to prepare societies with adequate digital competencies to understand, adopt, use and create new technologies which are all key to sustainable development in a digital world.

6.3 The role of developing countries in setting the global direction of innovation

6.3.1 Emerging economies are leading the global direction of innovation in specific fields

Emerging economies are changing the landscape of global innovation from a geographical perspective. Among hubs and clusters of inventive activities and scientific publications in the global innovation network, some of them, although the number is limited, are located in emerging markets (WIPO, 2019). It is illustrated in the figure below that China and India contribute to the bulk of innovation agglomeration in Asia except Japan and South Korea. Among the top 10 collaborative hotspots of the world that account for 26 per cent of all international co-inventions, three are located in China (Beijing and Shanghai) and India (Bengaluru).

Innovators from emerging economies are catching up rapidly and even taking the lead in specific areas of technology. Particularly, China is prominent as a hub of inventive activities in 4IR technology. For example, five out of the top 30 AI patenting applicants worldwide come from China. In the group of top 500 universities and public research organizations in the AI field, China is represented by more than 100 institutions (**Figure 6.1**).

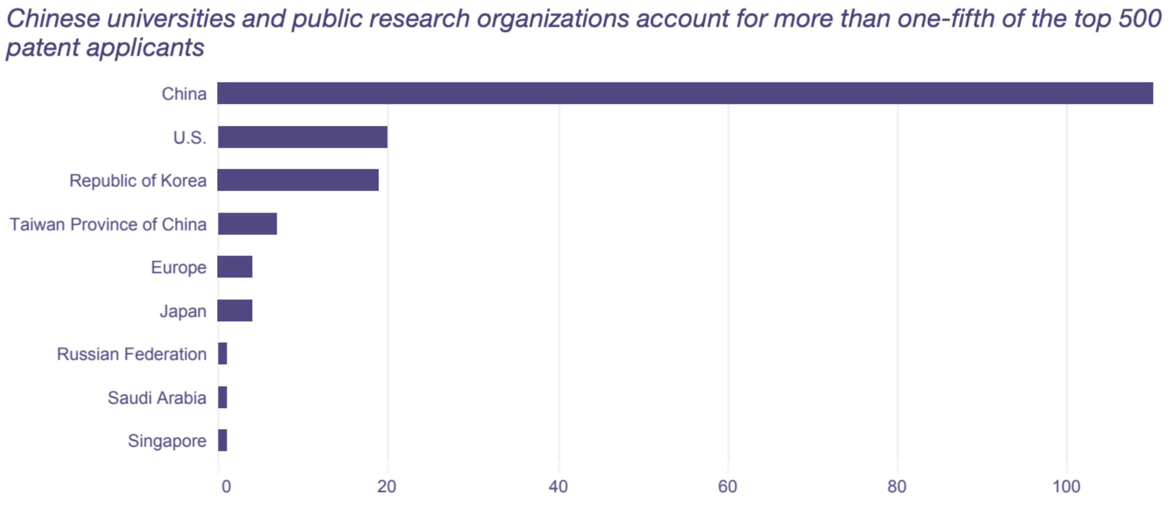


Figure 6.1: Chinese universities and public research organizations account for more than 1/5 of the top 500 patent applicants in the AI field

Source: WIPO (2019)

In the meantime, emerging economies are also emerging as leaders in low-carbon innovation which is an important path towards achieving SDGs. Typical examples include China's dominance in the electric vehicle sector, solar PV cells and solar water heaters, India as one of world's top producers of wind power generation and distribution systems and Brazil's emergence as a leading producer of sugarcane-based ethanol for the transportation industry.

They not only emerge as producers, investors and innovators of low-carbon technologies (LCT), but also affect the direction of LCT by adoption and export of these technologies. In terms of adoption, China alone accounted for 15.9 per cent of total LCT imports in 2016 (Pigato et al., 2020). The export of LCT from emerging economies exhibits an interesting pattern. Although a considerable proportion of these technologies go to high-income countries, South-South LCT trade sees an increasing trend (Table 6.1). According to World Bank (Pigato et al., 2020), no emerging economies or other developing countries are among the major exporters of LCT to high-income economies, China and Mexico rose to top five and represented one-fifth of total share. By contrast, three emerging economies, namely China, India and South Africa, are among the top five exporters of LCT to low-income economies. In both cases, the role of emerging economics has grown, which is more evident in the latter group (**Table 6.1**).

Table 6.1 Top-five economies, by share of LCT exports and income group, 1992, 2002, and 2016

1992		2002		2016	
EXPORTER	**SHARE (%)**	**EXPORTER**	**SHARE (%)**	**EXPORTER**	**SHARE (%)**
Top-five exporters to high-income economies, by share of LCT exports					
Germany	25.2	United States	16.9	China	17.2
United States	22.7	Germany	14.5	Germany	14.0
Japan	18.9	Japan	13.3	United States	10.5
Switzerland	5.8	United Kingdom	6.3	Japan	6.1
Netherlands	4.6	France	5.0	Mexico	4.0
Top-five exporters to upper-middle-income economies, by share of LCT exports					
United States	40.2	United States	34.0	United States	13.9
Japan	28.6	Germany	15.4	Korea, Rep.	13.5
Germany	13.3	Japan	9.5	Germany	10.8
Singapore	3.8	Italy	7.4	China	10.7
Switzerland	2.6	Singapore	4.3	Japan	10.4
Top-five exporters to lower-middle-income economies, by share of LCT exports					
Germany	27.6	Japan	19.9	China	32.8
Japan	21.8	Hong Kong SAR, China	13.0	Korea, Rep.	8.3
United States	20.1	Germany	12.1	Germany	7.7
Spain	3.5	United States	12.0	Japan	7.2
Switzerland	3.3	Italy	8.3	United States	6.3
Top-five exporters to low-income economies, by share of LCT exports					
Japan	33.6	Japan	13.3	China	32.2
United States	22.7	United States	11.0	United Arab Emirates	9.8
Germany	16.7	Germany	10.7	India	9.6
Korea, Rep.	5.4	Italy	9.0	United States	6.5
China	3.3	China	7.3	South Africa	6.0

Source: World Bank World Integrated Trade Solution (database), https://wits.worldbank.org.

6.3.2 LICs are important adopters of frontier technologies and developers of appropriate technologies

Low-income countries that engage less with R&D-based inventive activities are a strong force in setting the global direction of innovation by adoption of frontier technologies as well as appropriate technologies from high-income and middle-income countries. As pointed out earlier, innovation in middle- and low- income countries is mainly under the radar, being incremental, imitative and learning-based. Adoption of innovation by these countries can be partly manifested in the purchase of machinery and equipment, which is the majority of innovation expenditure of firms in manufacturing sectors. This could surpass 60 per cent in middle income countries such as South Africa and Columbia. The so-called 'ICT revolution' in Africa is another case of wide diffusion of technology in the third industrial revolution in developing countries. The diffusion and adoption of ICTs have fundamentally changed the landscape and capabilities of innovation in Africa, with a growing number of start-ups using ICT technologies to explore new entrepreneurial opportunities. LICs also engage in developing appropriate technologies, resulting in applications of digital technologies such as solar-powered lights, cell phones for farmers in Maharashtra, India, and drone delivery of medical supplies in Rwanda.

6.3.3 The importance of diversity in the global innovation system for direction of innovation worldwide

Innovation and its direction have exhibited a highly vibrant and diversified pattern in the global innovation system. This is important for the ongoing and future direction of innovation worldwide, for the reason that appropriateness of technologies may differ significantly from sector to sector and from one disciplinary field to another, therefore such diversity enables countries and firms with heterogenous resource endowments and varied levels of absorptive capacity to be in a better position to benefit from international technology transfer in the global innovation system. Great diversity in the global innovation system also provides abundant opportunities and avenues for collaboration, both within-field and boundary-spanning. This is especially relevant given the growing divergence between emerging economies and LICs, which highlights the prospect of South-South technology transfer and collaboration.

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