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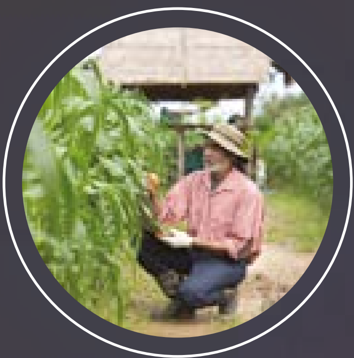
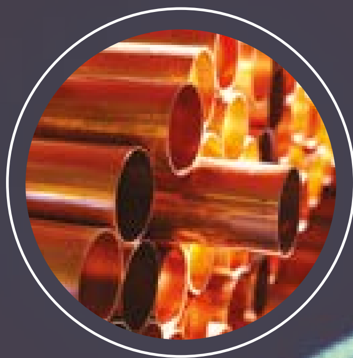
Escaping from the Commodity Dependence Trap through Technology and Innovation



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Notes

Use of the term “dollar” ($) refers to United States dollars.

The term “billion” signifies 1 000 million.

The term “tons” refers to metric tons.

Use of a dash between years (*e.g.* 2000–2001) signifies the full period involved, including the initial and final years.

An oblique stroke between two years (for example, 2000/01) signifies a fiscal or crop year.

References to sub-Saharan Africa in the text or tables include South Africa, unless otherwise indicated.

Acronyms and abbreviations

ASYCUDA	Automated System for Customs Data
COVID-19	coronavirus disease of 2019
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
ICT	information and communications technologies
IT	information technology
MERCOSUR	Southern Common Market
UNCTAD	United Nations Conference on Trade and Development

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Overview

A country is commodity dependent when it derives at least 60 per cent of its merchandise export revenues from the commodity sector. In 2018–2019, about two thirds (64 per cent) of developing countries were commodity dependent compared to 13 per cent for developed countries (see chapter 2). This implies that commodity dependence is particularly a developing country phenomenon. The analysis of commodity dependence has attracted interest from development economists in view of the challenges associated with this characteristic. Indeed, commodity dependence is associated with problems such as slow growth, an undiversified economic structure, low human development, income volatility, macroeconomic instability, Dutch disease, political instability, poor political and economic governance, illicit financial flows, low social development, as well as high exposure to shocks, including those resulting from climate change and pandemics such as the coronavirus disease of 2019 (COVID-19).

Commodity dependent developing countries seem to be locked into this undesirable state. The concept of a commodity dependence trap is used in this report to characterize three different outcomes. The first is a situation where a country is commodity dependent in some reference period and remains dependent over a long time. Zambia illustrates this case. The second situation, illustrated by Nigeria, relates to a country where export diversification characterizes its initial conditions but, over time, the country becomes strongly dependent on one or a few commodities. The third case is that of a country that is initially commodity dependent but, over time, diversifies its export sector and moves out of commodity dependence. Costa Rica exemplifies this case. The experience of most developing countries resembles that of Nigeria and Zambia. Indeed, once a developing country is commodity dependent, it is extremely difficult for the country to extricate itself from this state, as chapter 2 will show. However, as the experience of Costa Rica illustrates, commodity dependence can be overcome. Many illustrative examples of successful cases are presented in chapter 5.

The *Commodities and Development Report 2021: Escaping from the Commodity Dependence Trap through Technology and Innovation* starts by exploring the extent to which commodity dependent developing countries are trapped into commodity dependence and, as a result, how their economic structures are weakened by this situation. What the role of technology could be in helping commodity dependent developing countries to diversify their economies and escape from the commodity dependence trap is then analysed. Policies are proposed to show how countries could diversify their economies, and some opportunities are highlighted to illustrate some benefits that commodity dependent developing countries could derive from digitalization and embracing the current technological revolution. The report concludes with suggestions of key measures at the national, regional and international levels that could help make this transformation possible.

The Commodity Dependence Trap

At any given time, each country should be in one of the following three states: not commodity dependent, commodity dependent, or strongly commodity dependent. In the short run, it is normal that countries move between these three states, depending on factors such as changes in international commodity prices; important discoveries of strategic commodities, such as oil, gold, cobalt and some other minerals; the health of the global economy; development of alternatives to traditional commodities, such as green energy sources; and other factors. When mobility is analysed empirically, the finding is that countries tend to stay in one state for long periods. Most developed countries stay in a state of non-commodity dependence, whereas most developing countries are trapped in states of commodity dependence and strong commodity dependence.

Empirical data based on mobility over the period from 1995 to 2018, and covering 206 countries and territories, shows that there is indeed some mobility between all states even though, by and large, countries seem to stay within one group. On average, half the countries and territories are in a non-commodity dependent state. The other half are in a strongly dependent state (32 per cent of the sample) or in a commodity dependent state (18 per cent of the sample). This information suggests that commodity dependence – and its strong version – only affects half of the countries and territories in the sample, as discussed in chapter 2.

The evidence shows limited mobility out of the non-commodity dependent and the strong commodity dependent groups. During the sample period, 95 per cent of non-commodity dependent countries remained within this group. The proportion of strongly commodity dependent countries that did not move out of the category is 92 per cent. Put differently, the risks that a non-commodity dependent country becomes commodity dependent or strongly commodity dependent are 4 per cent and 1 per cent, respectively. Similarly, the likelihood that a strongly commodity dependent country becomes non-commodity dependent over the 24-year period is very small. There is, however, a 7 per cent chance that such a country will improve, moving from strong commodity dependence to just commodity dependence. Even though this might be considered an improvement, both commodity dependent and strongly commodity dependent countries face the same challenges, only with higher severity for the latter group. Very few countries seem to escape from commodity dependence, and these results seem to be stable over time.

These results suggest that, in a business-as-usual scenario, it would take the average commodity dependent country 190 years to reduce by half the difference between its current share of commodities in total merchandise exports and that of the average non-commodity dependent country. This result illustrates the challenge facing commodity dependent developing countries. Unless these countries take strong action to change the status quo, they will remain commodity dependent for the coming centuries. Doing nothing or not doing enough should not be an option, as commodity dependence will not disappear on its own.

Could higher innovation and technology help commodity dependent developing countries to change their trajectory towards more diversified economies? Econometric analysis shows a strong negative correlation between the state of commodity dependence and several indicators of technology. This suggests that the odds of commodity dependence are strongly associated with low levels of technology. In other words, countries with higher technological capabilities are less likely to be commodity dependent. If the results were to be interpreted as representing causality relationships, they would suggest that, by strengthening their technological capabilities, commodity dependent developing countries may reduce their exposure to vulnerabilities associated with commodity dependence. Indeed, improving the technological ecosystem of commodity dependent developing countries would create opportunities by increasing production outside the commodity sector. Acquiring technological capabilities and adopting institutions that foster innovation and technological development could reduce the dependence of commodity dependent developing countries on commodities and the negative implications of that dependence for economic development.

There is also a positive and statistically significant relationship between commodity dependence and export shares of the three types of commodities: agriculture; minerals, ores and metals; and fuels. The correlation is strongest, though, for countries dependent on exports of minerals. The implication might be that the problems associated with commodity dependence are more entrenched in mineral exporting countries and, to a high degree, countries dependent on fuel exports. One reason could be that extractives (minerals, ores and metals; and fuels) in commodity dependent developing countries are generally enclave sectors dominated by foreign firms investing in high capital activities with little incentive to diversify activities through the creation of backward and forward domestic linkages with non-commodity sectors. For example, as value addition to primary commodities mainly takes place outside the countries where the resources are extracted, commodity dependent developing countries do not benefit from value creation and its attendant advantages, including income generation, job creation, and tax revenue, along the value chain. Commodity dependence also seems to be more prevalent in the least developed countries relative to other countries.

Development of the manufacturing sector seems to be a relevant way of addressing the commodity dependence issue in commodity dependent developing countries. Indeed, industrial production, whether it uses commodities as inputs or not, contributes to product and economic diversification. The experiences of Costa Rica and other countries discussed in chapter 5 show that an economy can indeed be transformed from an extractives-based or agriculture-based to a manufacturing-based production system. Success requires a long time, strong political will and a long-term, realistic development vision, coupled with an ambitious but reasonable implementation strategy.

Commodity dependence, productivity and structural change

Escaping from commodity dependence implies a process of economic structural change narrowly associated with an increase in productivity. As commodity dependent developing countries exhibit lower average labour productivity growth than other country groups, improvements in labour productivity would be a key source of economic growth and overall development process. In turn, diversification and technological development play crucial roles in labour productivity growth. Labour productivity can be driven by productivity growth within individual sectors and/or by productivity-enhancing structural change, namely a reallocation of production factors from sectors with lower productivity, to sectors with higher productivity. In this context, technological upgrading and innovation can be important drivers of within-sector labour productivity growth. Structural change is particularly relevant for labour productivity growth when there are large differences in productivity levels across sectors. These intersectoral productivity differences tend to be highest in low-income countries, where agriculture is typically the least productive sector, but employs large shares of the labour force.

A key question is whether commodity dependence acts as an inhibitor of the within-sector component, the structural change component or both components of labour productivity growth. This is a question of high practical relevance for policymakers in commodity dependent developing countries. For instance, if commodity dependence acts as a drag on growth-enhancing structural change, policy interventions should focus on facilitating the flow of production factors from low-productivity to higher-productivity sectors. But if commodity dependence weighs down sectoral productivity growth, policies that induce productivity growth at the sectoral level need to be strengthened. And if commodity dependence is a drag for both growth components, a policy mix would be needed.

Empirical analysis shows that commodity dependence is associated with low levels of labour productivity, low productivity growth, high volatility of productivity growth and a high frequency of negative productivity shocks. The average annual growth rate of labour productivity in commodity dependent developing countries was 1.5 per cent over the period 1995–2018, lower than in developed countries (1.7 per cent), non-commodity dependent developing countries (2.3 per cent) and transition economies (4.9 per cent). Therefore, combined with a low initial level of labour productivity, slow productivity growth has been widening the productivity gap between commodity dependent developing countries and other groups of countries. Labour productivity growth is also strongly associated with technology development across sectors. Hence, technological upgrading and innovation can play important roles in an increase in productivity and economic diversification.

Commodity dependence can be overcome through the strengthening of the manufacturing sector as a driver of economic growth and productive employment. This would directly and indirectly contribute to the achievement of several Sustainable Development Goals, including Goal 1 on eradicating poverty and Goal 8 on promoting inclusive and sustainable economic growth, employment and decent work for all. The performance of the manufacturing sector is a good indicator of economic development given the strong correlation between the level of manufacturing value added per capita and average income. Commodity dependent developing countries lag substantially behind non-commodity dependent developing countries in terms of shares of global manufacturing employment, with a gap that has widened from 27.6 percentage points in 1995 to 32.4 percentage points in 2017. This points to an important policy challenge for commodity dependent developing countries: how should these countries develop their manufacturing sector? The manufacturing sector continues to expand at the global level and can thus still be an engine of growth for developing countries, including commodity dependent developing countries. Global manufacturing value added has increased both in levels and per capita from 1990 to 2019, even if China, the country with the single largest manufacturing output, is excluded. Nevertheless, commodity dependent developing countries as a group have not industrialized since 1995. Instead, manufacturing shares in employment and value added in commodity dependent developing countries have peaked at significantly lower levels than non-commodity-dependent developing countries and developed countries. Commodity dependence is found to be primarily linked to lower labour productivity growth in the manufacturing sector.

Structural change in commodity dependent developing countries has been characterized by a shift of employment shares away from the agriculture sector. As labour productivity in agriculture remains low in commodity dependent developing countries, any flow out of this sector results in productivity-enhancing structural change. However, employment shares moved primarily towards non-tradable sectors at the lower end of the productivity spectrum, where the potential for future expansion is limited to domestic demand. This raises questions about the long-term viability of this structural change path.

The finding that the link between technological development, human capital and investment, on the one hand, and labour productivity growth, on the other, is not homogeneous across sectors is important for policy. It suggests that, while broad-based investments in technological upgrading, education and infrastructure are likely to yield aggregate productivity gains, their impact can be maximized by considering sector-specific challenges and opportunities as part of the policy approach to addressing commodity dependence. Such targeted measures could, for instance, consist of developing specific skills required for employment in emerging manufacturing and services sectors.

The main message from the analysis of productivity and structural change is that commodity dependence is an impediment to the industrialization of commodity dependent developing countries. However, a positive message for commodity dependent developing countries is that there is ample scope for growth in labour productivity through both its components. The significant distance between productivity levels in virtually all sectors of commodity dependent developing countries and the global productivity frontier represents a significant opportunity for aggregate productivity growth through intrasectoral productivity gains. Similarly, the large productivity differences between sectors in commodity dependent developing countries highlight the potential of structural change to contribute to aggregate productivity growth.

Structural transformation through technological change and innovation

Technological change occurs through different channels: innovation, introduction of a new product (product innovation) or the modification of production methods to increase productivity and reduce costs (process innovation). All forms of innovation trigger shifts in income, consumption, employment and output, resulting in economic structural change. Technological change also affects economic structure through input–output relations between sectors (e.g. change in final product prices due to change in prices of intermediate products). The process of creating new products that replace old ones, and the long-term changes in the economy and society due to the emergence of new technological–economic paradigms, also impact the structure of economies.

Although both process and product innovation can result in structural transformation, in commodity dependent developing countries, process innovation (and the resulting increase in productivity) tends to result in lower prices of agricultural produce or low employment in fuel and mineral sectors. On the other hand, product innovation leads to economic diversification and the emergence of new sectors, creating new opportunities for employment and further gains of productivity through subsequent learning by doing and process innovation. Technology diffusion is strongest in countries with high technologies (the centre) and slowest in the periphery (commodity dependent developing countries), due to differences in pre-existing capabilities, including infrastructure and technological know-how. The centre–periphery differences in technological diffusion also affect structural transformation, with commodity dependent developing countries characterized by slow transformation.

Innovation should be understood as a combination of existing technologies in new configurations or economic activities. Therefore, innovation is path-dependent; it depends on the set of technologies that an economy has accumulated. In turn, technology is not limited to processes within a firm or a farm; it encompasses the whole chain needed to create and bring a product to the market. It includes the following: capital-embodied technologies, such as machines, vehicles, buildings and infrastructure; and labour-embodied technologies, such as business models, operational procedures and know-how. Even though changes in technology, demand and trade patterns are intertwined in complex ways, technological change could be considered the main determinant of structural economic change. It affects demand through changes in income, input–output relations and the substitution or complementarity of products (Schumpeterian creative destruction). Technology also impacts international trade through the effects on relative prices of products in global markets.

Innovation requires the exchange of knowledge among different actors, including firms, research centres, universities, Governments and consumers, the main actors of national innovation systems. Firms (and their entrepreneurs) have the critical role of taking the risk to innovate (bringing a new good or service to the market). Innovators need finance to acquire the resources to innovate. Thus, the decision to innovate depends on many factors, not only the availability of and access to technology.

Among commodity dependent developing countries, countries that are more reliant on agriculture exports usually have a lower technological level, followed by countries dependent on mining and then those dependent on fuels. As argued above, this may reflect the fact that mining and energy projects are more capital-intensive than agriculture, but they are usually in enclave sectors dominated by multinational enterprises. So, they might not truly reflect domestic technological capabilities. Generally, there does not seem to be any systematic advantage or disadvantage in any type of commodity dependence. Most commodity dependent developing countries have similarly low levels of technological development.

Escaping from commodity dependence implies that commodity dependent developing countries embrace new technologies and innovation that can take them into more dynamic sectors. Product space maps (see chapter 4), illustrating the path dependence of innovation, show that the production of some products, including commodities, does not connect easily with other products; they are like dead ends – once a country is in a particular product space, it is difficult to use the capabilities therein to move to another product. For example, the location of Angola on the product space map shows that its capabilities are highly concentrated around petroleum extraction. The country's current technological and productive capabilities may not be easily transferable to production in the digital cluster, for example. On the other hand, machinery and electronics production requires technologies that can be the building blocks of production in many other sectors. Diversification to these products can facilitate further diversification in the future. Hence, for commodity dependent developing countries, diversification into more dynamic sectors might require large "jumps" in innovation to enter clusters that are not necessarily close to countries' positions in the product space. Indeed, some of the technologies needed are not available in an economy and should be learned or transferred from abroad. This would call for government support.

Higher technology is associated with not only higher productivity but also fewer countries that can produce high-technology products. Technology also allows the production of more complex products, so higher levels of technology allow countries to produce and export products of above global average complexity. In this sense, more diversification resulting from higher technology and innovation is also associated with lower competition in export markets. Most commodity dependent developing countries export products at the lower end of the product complexity index (see chapter 4), requiring the least technological capacities. As a result, most commodity dependent developing countries have diversification levels below the global average and face competition from over 82 countries that export similar products. This helps explain why commodity dependent developing countries are stuck in the commodity sector and might need strong support to move out of commodity dependence. Moreover, the process of economic diversification is handicapped by commodity price cycles. When commodity prices are high, commodity dependent developing countries have an incentive to produce more of the same, reducing the motivation to innovate and diversify the economy. On the other hand, when commodity prices are low, the challenge for diversification relates to declining resources, particularly the scarcity of hard currency to import capital goods. Governments' fiscal constraints also prevent them from providing the required complementary infrastructure and quality education to increase the capacity for technological learning and innovation in the context of the economy. Hence, countercyclical fiscal policies are recommended, investing resources from the commodity sector when prices are high into non-commodity sectors, as did Indonesia, or capturing more revenue by adding value to the commodity as Oman has done (see the discussions in chapter 5).

Being commodity dependent need not be fateful. Viet Nam is an example of a country that has successfully diversified its economy. Three decades ago, this country was at the same development level as the world's least developed countries. Viet Nam has succeeded in increasing its technological and productive capacity to industrialize further and expand production from agriculture and low value added manufacturing such as garments to production in the digital cluster. Between 2005 and 2018, the country increased the share of its high-technology exports in total merchandise exports from 6 to 35 per cent, while the share of exports of primary resources fell from 52 to 22 per cent of total merchandise exports. The push for industrialization began in the 1990s, with an industrial and trade policy that merged import substitution measures and export subsidies to promote an export-driven growth strategy, supported by strong foreign direct investment. Other policies have also contributed to the country's productive development, including the establishment of export processing and industrial zones, the development of urban infrastructure and education. As chapter 5 shows, there are several successful cases that may provide useful lessons for commodity dependent developing countries.

Enabling technological transformation

As discussed above, technological transformation in developing countries, including commodity dependent developing countries, goes hand in hand with economic transformation. What are the enablers of technological transformation, to shift from the status of being a commodity dependent developing country to having a more diversified economy? Structural change should be thought of as a meso-economic process that encompasses production composition effects, intrasectoral and intersectoral linkages, market structures, the functioning of factor markets and the underlying institutions. The set of policy interventions required to support technological transformation are determined by the mix of short- versus longer-term objectives in terms of productive capacity enhancement, as well as the diversification path chosen by a country. Market failures and government failures often act as constraints to this process.

Diversification away from commodities production could follow different paths. Often recommended is a shift towards manufacturing, usually characterized by higher productivity. Such a shift may operate either by means of promotion of sectors and products unrelated to the set of commodities produced or through the exploitation of forward linkages within a process of vertical integration. Vertical integration can also operate by exploiting linkages to backward products or services. Diversification could also be through the promotion of production of other commodities. Another important source of diversification is quality upgrade of the set of commodities currently produced, as discussed in chapter 3. A diversification strategy needs to account for the type of commodity a commodity dependent developing country would be diversifying from: is it a point-source natural resource (minerals and energy commodities) or a soft commodity? Abundance in point-source natural resources is usually associated with higher rents relative to soft commodities. Such rents could provide part of the resources needed to fund a diversification strategy, as the case of Indonesia, discussed in chapters 2 and 5, illustrates.

Technological transformation requires access to technology and a conducive framework for its transfer. This is particularly important for commodity dependent developing countries that acquire technologies from abroad. Accessibility refers to both cost and technical know-how. Commodity dependent developing countries generally have limited resources to access the expensive technologies needed to produce more complex products. Even when financial resources are available, as in the case of some countries endowed with strategic resources, commodity dependent developing countries may not have the skills needed to exploit those technologies. Indeed, the capacity of entrepreneurs and workers to introduce and adapt new and better production processes is the basis for technology adoption. Training is therefore an integral part of a successful technological transformation strategy. Furthermore, as firms are major actors in a successful technological transformation, they should be allowed to operate in an environment that helps the process. For example, removing excessive administrative procedures, support with filling the skills gap and provision of human and physical capital, as well as introducing relevant institutional reforms, are prerequisites for technological transformation. Encouraging foreign direct investment can help fill some of the gaps given that it is one of the channels for technology transfer and technical know-how.

Effective technology transfer should lead to local innovation, at least in the medium term. This might require the creation or reinforcement of national innovation systems. The existence and effectiveness of an institutional framework able to coordinate the various actors engaged in innovation and learning – research and development centres, universities and technology schools, extension services and the innovating firms themselves – would be necessary. In addition, investments may have to be redirected over the long term towards new capabilities and to an ambitious educational strategy that supports these processes. Over time, success relies on the accumulated technological knowledge and production experience of the managers and production workers of the firms involved in a process.

Infrastructure is a core enabler of technological transformation. For example, having reliable power is a basic condition for technological transformation. However, firms in many commodity dependent developing countries have only intermittent access to power, and many are forced to invest part of their capital in power generators, diverting resources that could have been invested in technological upgrading. Reliable access to the Internet has also become critical to unlocking the possibilities offered by digital technologies. Again, as chapters 2 and 4 show, commodity dependent developing countries lag on this metric. Where resources are limited, infrastructure development can be directed to the promotion or reinforcement of geographical clusters of firms expected to foster technological transformation. Trade integration can also significantly enable technological upgrading through an increase in productivity resulting from a better allocation of resources. Trade integration might lead to the adoption of more advanced technologies if these make firms more competitive, and if the firms benefit from wider regional markets to the extent that the benefits outweigh the costs of technology acquisition. This was the case with Argentinian firms that were able to take advantage of lower tariffs in Brazil after the establishment of the Southern Common Market (MERCOSUR).

There are other enablers that depend on the type of commodity dependence and/or the diversification path followed. These are referred to as vertical enablers. Countries amply endowed with point-source natural resources should be able to mobilize public funding more easily thanks to the rents they derive from their extractive activities. In these countries, a specific challenge could be the management of natural resource windfalls. In countries depending on the agriculture sector, increasing productivity might be the most important challenge to overcome. The small size of farms in many commodity dependent developing countries dependent on agriculture may also make technology adoption very difficult. The promotion of effective technology adoption could thus be based on market and institutional features that would allow some mutualization of investment efforts. Farmer-to-farmer information diffusion can also be a cost-effective approach for improving smallholders' practices and profits. In addition, technology adoption and eventually diversification may be facilitated by participation in global value chains.

With respect to implementation of policies towards technological transformation, several examples are provided to show that, through technology and the other factors discussed above, commodity dependent developing countries can indeed diversify their economies and move away from commodity dependence. They can diversify by fostering forward linkages, as did several fuel-export dependent countries that have expanded their export baskets by moving into value added products that are energy intensive. Oman is a good example. The country expanded its production to refined fuels, such as gasoline or kerosene, and assorted petrochemicals, including alcohols, fertilizers and plastics; or products that are energy-intensive (for example, aluminium), even though most non-energy inputs are imported (for example, alumina and bauxite). Government intervention played a central role in the process. Other developed countries, such as Norway, pursued a model based on strengthening backward linkages. This led to the development of both service and industry activities with a high tradability potential. Norway set up a very innovative oil and gas industry with substantial linkages, creating a Norwegian model of petroleum exploration. At the same time, it accelerated a manufacturing industry supporting the sector.

Intersectoral horizontal diversification is another approach where diversification is towards sectors that are not directly linked to the prevalent commodity, pushing an economy beyond its current comparative advantage. For example, Indonesia succeeded in reducing dependence on oil through countercyclical spending and investment into agriculture first, and later into processed and semi processed goods. In Botswana, the close relationship between the Government and the private sector in the diamond sector has also significantly contributed to the country's success. A partnership between the Government of Botswana and a South African diamond conglomerate is an illustration of a successful private–public partnership. Through this relationship, Botswana has been able to integrate its diamond sector vertically, with the polishing and cutting of diamonds now taking place in the country.

As an example of countries dependent on soft commodity exports, Thailand illustrates how new technologies can be used to produce higher quality and more competitive fresh organic vegetables and fruits. The so-called smart agriculture business is growing rapidly across the world. Also, the production, distribution and processing of agriculture output in producing countries are fundamental components of forward production linkages. In many commodity dependent developing countries, cotton provides a good example: edible oil is extracted from cotton seeds, while textiles and medical cotton are derived from cotton lint. There is also a list of cotton by-products, including briquettes and boards, that can be produced out of cotton stalk. All these transformations can easily take place in commodity dependent developing countries producing cotton. In all successful examples, the Government played a pivotal role by putting in place the instruments that allowed the private sector to thrive, in many cases in joint ventures with the Government.

Opportunities from technological revolutions

What is the role of new technologies in the structural transformation of commodity dependent developing countries? New technologies are essential for the technological upgrade of traditional production sectors in commodity dependent developing countries, as well as for diversification into other sectors. There are technologies that trigger new technological–economic paradigms – the cluster of technologies, products, industries, infrastructure and institutions that characterize a technological revolution. Arguably, the developed world now lives through the mature phase of the digital revolution's deployment period, characterized by the Internet, mobile connectivity and the so-called Web 2.0 technologies (e.g. applications, social media, cloud computing, big data, etc.). This technological–economic paradigm has resulted in an increasing share of global value chains in global production, reduced communications and transaction costs, and the emergence of electronic commerce (e-commerce), among other changes. However, while the digital revolution has already reached a mature phase in developed countries, it is still in an installation phase in many commodity dependent developing countries. The existence of these technologies does not guarantee their applicability in the context of low-income commodity dependent developing countries. Major factors that limit the deployment of these frontier technologies include failure to build the required information and communications technology (ICT) infrastructure and skills, to implement the necessary institutional change, and a lack of investment due to the scarcity of financial resources, as discussed above.

To assess commodity dependent developing countries readiness to take advantage of current revolutions, it is important to first understand where they stand in the technology landscape. Some of the elements of previous technological–economic paradigms are still being implemented in different economic activities in commodity dependent developing countries. For example, in many of these countries, mechanization (first technological revolution) has not reached most of the farms, large shares of the population lack access to electricity (third technological revolution), many production sectors have not been able to take advantage of economies of scale and become internationally competitive (fourth technological revolution), and the digital revolution (fifth technological revolution) has been limited to the use of mobile phones and digital platforms. In many commodity dependent developing countries, universal access to electricity has not yet been achieved, and the network of roads, highways and ports is still weak (which places them in the fourth technological revolution). Most commodity dependent developing countries still have a weak infrastructure of high-speed, fixed Internet connections, such as fibre optic and broadband, or high-speed mobile connections. Digital and frontier technologies also require technological literacy and skills, which may be lower in most developing countries. The development of skills to use digital technologies requires people to be exposed to these technologies and engaged actively in "learning by using", which is challenging in low-income commodity dependent developing countries with a large share of the population that is illiterate. Hence, commodity dependent developing countries are less prepared to adopt and adapt these technologies than developed, transition and non-commodity dependent developing countries. Commodity dependent developing countries that rely on agricultural products are less prepared than commodity dependent developing countries that depend on the energy and mining sectors.

Nevertheless, the current (digitalization) and emerging ("Industry 4.0") technological revolutions will change commodity sectors and related global value chains and will have a significant impact on commodity dependent developing countries. Even though commodity dependent developing countries are not ready to deploy Industry 4.0 technologies, there are ways of taking advantage of them. First, commodity dependent developing countries will benefit through increasing demand for their primary commodities that are fuelling digitalization and the adoption of a wide range of frontier technologies, from renewable energy to the Internet of things and big data. These commodities include lithium, cobalt, manganese, graphite, nickel, aluminium, copper, silver, bauxite, iron, lead and rare earth elements. Some of these strategic commodities, such as cobalt, lithium and copper, are found in large quantities in commodity dependent developing countries. Demand for some of those commodities could increase by 1 000 per cent by 2050. This growing demand should serve as an economic opportunity for those countries that are home to major reserves of these commodities.

Another opportunity relates to possibilities offered by frontier technologies to extract new commodities that were not economically extractable before. For example, advances in biotechnology, such as biorefining techniques, have facilitated the sequential extraction of the major components of red algal biomass as commodity products, such as pigments, lipid, agar, minerals and energy-dense substrate (cellulose). The large-scale marine macroalgae production, mainly for human consumption, has given rise to their consideration as a non-lignocellulosic feedstock to produce renewable fuels. However, making biofuel from algal biomass economic requires the co-production of additional useful biochemical components unique to algae. This might form the basis for starting new ocean-based biocommodities, reducing the dependence on the terrestrial resources for food, feed, energy and chemicals. There are also new technologies for the extraction of lithium that may revolutionize the way lithium is harvested, minimizing water use and speeding the recovery process. This will significantly reduce the environmental footprint of lithium extraction as observed today. New technologies may also make some lithium deposits in countries such as the Plurinational State of Bolivia economically viable.

It is also expected that frontier technologies, including drones, robots, blockchains and the Internet of things, will lead to profound transformations of global commodity chains, resulting in continuous reduction of transaction costs, increasing efficiency and profitability, and enhancing transparency, traceability and reliability. Frontier technologies can also optimize transactions' effectiveness and transparency, minimize costs in processing data and help forecast commodity prices more accurately. Furthermore, frontier technologies can help improve the resilience of commodity sectors to climate change and strengthen their contribution to sustainable development. Smart water management, precise environmental monitoring and enforcement, and enhanced weather and disaster prediction and response are just some examples of the potential of frontier technologies to support the battle against climate change. Moreover, the adoption of cost-efficient solar photovoltaic cells may bolster energy security and support commodity sectors in remote areas that are not connected to national power grids, while reducing the traditional deleterious effect of energy production on climate change. There is also potential for blockchain to reduce the carbon footprint of commodity sectors. For example, a global low-carbon tea project in Kenya (see chapter 5) attempts to formulate a resilient and low-carbon tea value chain using blockchain technology. While increasing trust among consumers and retailers, tea promoted as a "carbon sink" could not only fetch higher prices but also give growers potential access to carbon markets, creating economic incentives for small-scale tea producers.

Frontier technologies offer economically viable alternatives to costly investment in infrastructure related to traditional technological paradigms. An example of the potential for leapfrogging frontier technologies is the development of decentralized renewable energy systems. Low-cost, high-efficiency solar panels are available for household rooftop solar installations and village-level micro- and mini-grids. The cost of these panels has fallen by a factor of more than 100 in the last 40 years, and by 75 per cent over the past 10 years, dramatically improving their affordability and thus widening access to energy particularly in rural areas. Digitalization of trade and logistics-related documents, an area where firms in developed countries already have valuable experience, is another potential area of interest. Moreover, technology-enabled efficient payment systems, critical for international trade, are already benefiting from emerging technologies. Early adopters in commodity dependent developing countries can place themselves in a good position to reap the benefits of new technologies. At the institutional level, digitalization and frontier technologies also offer Governments an opportunity to build national capacity in the provision and regulation of digital services. The UNCTAD Automated System for Customs Data – ASYCUDA – is an illustrative example.

It is important to note that, at the global level, funding is available for digital and frontier technology solutions in e-commerce and global value chains. At the current stage of Web 2.0 technologies, in which the technology is more mature, finance is looking for profitable applications related to digitalization and e-commerce. These are becoming less available in developed countries. Thus, innovators in developing countries could tap into these idle resources to finance digital innovation. Most particularly, commodity dependent developing countries could access these resources to invest in digital platforms that allow them to take advantage of digitalization of commodity-based operations to become more efficient and competitive, as discussed in chapter 6. Some structural factors, such as the coming into force of the African Continental Free Trade Area, may be an incentive to attract funding for these technologies in Africa given the large size of the regional market. Moreover, the key role of China in commodity value chains and its position of leadership in many of the new technologies associated with Industry 4.0. can help in spreading them in commodity dependent developing countries and other developing countries.

To benefit from these opportunities, commodity dependent developing countries will need to overcome many challenges. Among them are fast demographic growth, which might offer stronger incentives to use more labour than technology; the large technological gap that characterizes commodity dependent developing countries; the lack of economic diversification, particularly into the manufacturing sector that can absorb more sophisticated technologies relative to the commodity sector; the dearth of public and private resources to fund research and innovation; and limited access to ICT infrastructure and digital skills. In this regard, to promote structural transformation through economic diversification and technological upgrading, commodity dependent developing countries could consider pursuing a strategy of innovation in three steps: promotion of economic diversification towards more complex products, starting with those close to their position in the product space; promotion of implementation of the digital revolution (current technological–economic paradigm) to lay the ground for deeper diversification; and preparation for the implementation of Industry 4.0 and trying to enter into possible value chains related to this paradigm. This strategy should be guided by national development plans, as well as countries' development objectives and priorities.

As discussed throughout the report, taking full advantage of the opportunities offered by technology and innovation will depend on several factors. Key among them will be the level of commitment of the leadership and Governments of commodity dependent developing countries to foster technology and innovation as a way of moving out of commodity dependence. Another important factor will be the role of the international community in accompanying commodity dependent developing countries in this endeavour. In this regard, it will be essential that international public and private partners of commodity dependent developing countries facilitate technology transfer and participate in commodity dependent developing country efforts towards building the physical, human and institutional capabilities required for the adoption and domestication of the relevant technologies. As chapter 2 emphasizes, if nothing is done, the technological and development gap between commodity dependent developing countries and other groups of countries will only continue to widen.

CHAPTER

1

Background

1. Background

A country is commodity-dependent when it derives at least 60 per cent of its merchandise export revenues from the commodity sector.[1] Trade data shows that roughly 53 per cent of all UNCTAD member States were commodity dependent in 2018–2019. According to the State of Commodity Dependence 2021 (UNCTAD, 2021), commodity dependence is most widespread among developing countries. In 2018–2019, 64 per cent of developing countries were commodity dependent compared to 53 per cent for transition economies and 13 per cent for developed countries. Therefore, even though commodity dependence is found in all three country groups, the issue is primarily a developing country and, to some extent, transition economies phenomenon. Moreover, the prevalence of commodity dependence does not seem to improve over time. If anything, commodity dependence increases over time. In 2008–2009, 60 per cent of developing countries were commodity dependent, 4 percentage points lower than for the period 2018–2019. Over the same period, commodity dependence increased also in transition economies from 47 per cent to 53 per cent, and in developed countries from 10.5 per cent to 13 per cent, even though the absolute number of commodity dependent countries is much lower than in developing countries.

Commodity dependence is not simply about being dependent or not. The extent to which a country is commodity dependent matters. A country deriving more than 80 per cent of its merchandise export revenues from the commodity sector is more exposed to the challenges of commodity dependence than one that derives 60 per cent. In this regard, the analysis of commodity dependence in chapter 2 distinguishes between commodity dependence, where commodity exports represent between 60 per cent and 80 per cent of total merchandise exports, and strong commodity dependence, where the share of commodities in total merchandise exports is greater than 80 per cent.

The analysis of commodity dependence is important for two major reasons. First, commodity dependent developing countries seem to be in a trap: once a country is commodity dependent, it is difficult to develop a productive sector out of commodities and export non-commodity products. If countries were able to move in and out of commodity dependence seamlessly, being commodity dependent would be a less serious issue. Hence, trying to understand how countries could get out of the commodity dependence trap is relevant for development policy.

The second justification for the relevance of the analysis of commodity dependence is that this status is associated with many socioeconomic challenges. As documented elsewhere (for example, UNCTAD and the Food and Agriculture Organization of the United Nations (FAO), 2017)), relative to non-commodity dependent countries, commodity dependent developing countries suffer from unpredictable export revenues due to high commodity price volatility; declining terms of trade over the long-term; macroeconomic instability due to high trade and budget deficits (van der Ploeg and Poelhekke, 2009) and unstable exchange rates. Moreover, overvaluation of the exchange rate following commodity discoveries or commodity price booms has led to Dutch disease in many commodity dependent developing countries. Dutch disease renders non-commodity exports, particularly manufacturing exports, less competitive, making the affected country even more reliant on the export of a single commodity or a limited number of commodities.[2] For example, chapter 3 shows that, between 1995 and 2017, the average share of manufacturing in the total value added of commodity dependent developing countries declined from 11.5 per cent to 10.4 per cent.

1 The 60 per cent threshold was formally derived through a quantile regression by Nkurunziza, Tsowou and Cazzaniga, 2017.

2 Dutch disease is a situation whereby increasing external flows associated with a major discovery and exploitation of a new commodity, such as oil, results in the overvaluation of the domestic currency, making a country's traditional exports less competitive. For example, the manufacturing sector in many African commodity dependent developing countries was more vibrant in the 1960s and 1970s than it has been recently, before the discovery of oil and certain minerals from the 1960s through to the 1980s. Indeed, the share of manufacturing in GDP was highest in 1990, at 15.3 per cent, and declined steadily thereafter (UNCTAD and United Nations Industrial Development Organization, 2011).

Macroeconomic challenges associated with commodity dependence have led to difficulties for households and firms. For instance, due to macroeconomic instability in commodity dependent developing countries, firms operate in a difficult economic environment, resulting in low profitability. Commodity dependent developing countries that depend on agriculture commodities suffer from low producer prices, negatively affecting household incomes and aggregate demand in countries where most of the population lives in rural areas. Commodity dependent developing countries are also less integrated into commodity value chains. In fact, the role of most commodity dependent developing countries is limited to the production of a raw commodity, with all value adding activities taking place outside.[3] This may explain why commodity dependent developing countries that produce strategic commodities, such as oil and cobalt, remain some of the poorest in the world, even though the commodities they produce generate billions of dollars for other value chain participants, such as importers, refiners, retailers and so on.[4]

Commodity dependence has also been associated with a high level of political instability. Research has shown that the contest over the control of rents generated by natural resources has led to civil wars in many commodity dependent developing countries (for example, Collier and Hoeffler, 1998). In an econometric study of the determinants of civil wars, Collier and Hoeffler established that the probability of civil war is at its highest, 0.27, where natural resources represent 26 per cent of the gross domestic product (GDP). Beyond this threshold, the risk starts to decline as countries get more and more resources to invest in the security apparatus. There is also a nascent body of literature associating commodity dependence with high illicit financial flows (for example, Lemaître, 2019, and UNCTAD, 2016).

The literature has also shown that commodity dependence is associated with poor governance and low social development. For instance, a higher share of point-source natural resources – fuels and minerals – tends to have a negative effect on the quality of institutions (Bulte et al., 2005) and on governance (Isham et al., 2005). Moreover, commodity dependence is linked to both lower social development (Carmignani and Avom, 2010) and lower human development (Nkurunziza et al., 2017). Furthermore, a higher share of commodities in exports is linked to lower non-resource export diversification (Bahar and Santos, 2018). Also, commodity dependence is associated with lower aggregate labour productivity (Csordás, 2018).

Commodity dependent developing countries are also vulnerable to shocks, including shocks related to climate change. Indeed, commodity dependence has been shown to amplify the negative effects of climate change, as documented by a recent UNCTAD report. Of the 40 countries most vulnerable to climate change, 37 (92.5 per cent) are commodity dependent developing countries (UNCTAD, 2019). Moreover, most recently, the coronavirus pandemic has highlighted the vulnerability of commodity dependent developing countries to an international health shock. A simulation analysis carried out by UNCTAD and the Commonwealth Secretariat assessed the impact of the pandemic on commodity exports from Commonwealth countries, the majority of which are commodity dependent developing countries. The results of the study (Ali, Fugazza and Vickers, 2020) show that, compared with business-as-usual, commodity exports to Australia, China, the United States of America, the United Kingdom of Great Britain and Northern Ireland and the European Union[5] were expected to fall by between $72 billion and $98 billion in 2020, representing an export loss of 16.5 per cent to 23.8 per cent relative to the benchmark.

3 In countries reliant on the extractive sector, even production is controlled by multinational enterprises that own the capital and technologies used to extract the commodities

4 For many commodities, including soft commodities, such as coffee and cocoa, commodity producers get a very small share of the final product's consumer price. For example, the share of the coffee consumer price accruing to producers is less than 5 per cent (UNCTAD, 2018).

5 The European Union from February 2020, with 27 member States, after the departure of the United Kingdom.

The discussion above illustrates the vast literature analysing the deleterious effects of commodity dependence on economic and human development, the channels through which these effects are mediated and the vulnerability of commodity dependent developing countries to different types of shocks. This report builds on this literature to offer an analysis of the extent to which commodity dependent developing countries are trapped in a state of dependence and what they should consider doing to break away from it. Most particularly, the discussion in this report focuses on the potential role technology and innovation could play to extricate commodity dependent developing countries from commodity dependence.

As reflected in the subtitle, "Breaking out of the commodity dependence trap through technology and innovation", this report contributes to the understanding of economic development challenges that face commodity dependent developing countries by attempting to answer four questions. First, taking as given that commodity dependence hampers development, as explained earlier, to what extent are commodity dependent developing countries trapped in the commodity dependence state? Second, if commodity dependent developing countries are trapped, could technology and innovation help them to break out of the commodity dependence trap? The term technology here has two distinct but complementary meanings. The first meaning relates to knowledge and processes that can be used to extract, process, trade and use commodities more efficiently. The second meaning refers to the fact that appropriate technologies help to allocate resources in a way that fosters economic transformation and diversification. While technology in this report should be analysed from a positive perspective – how it could help commodity dependent developing countries to reduce their dependence on commodities – the discussion should also highlight the challenges that commodity dependent developing countries may face if they fail to adopt some of the major technological advances in the third and fourth technological revolutions. Problems could include increased inequality, falling farther behind the productivity frontier, failure to adapt to the effects of climate change, worsening governance, and security issues.

The third question is, if technology could help commodity dependent developing countries to become less reliant on the commodity sector, what would be the institutional requirements that would allow this process to take place and be successful? Factors that could explain the limited use of modern technologies in commodity dependent developing countries include poor infrastructure, dearth of investment owing to scarcity of financial resources, lack of skilled workers and unfavourable institutional environment. Low productivity and high production costs, low quality and standards of production, child labour and environmental damage could be among the consequences of the technological gap in commodity dependent developing countries.

Fourth, what could be the role of digitalization and new technologies associated with the fourth technological revolution in upgrading the technological landscape in commodity dependent developing countries? For example, if economically viable, adopting technologies that allow commodity dependent developing countries to internalize the commodity value chain by adding more value to natural resources within their economies would create new economic activities and generate jobs and revenues, while contributing to structural change and economic diversification. The question of how technology will affect commodity trade is also relevant. For example, wider adoption of e-commerce can help producers to sell directly to consumers, reducing the number of intermediaries, which could generate more benefits for commodity producers.

Based on empirical analysis, the research in this report provides some answers to the questions above. First, transition analysis confirms that commodity dependent developing countries are indeed trapped in a commodity dependence state. Unless there is strong action at the highest political level in commodity dependent developing countries to do things differently, the analysis shows that they will remain trapped for centuries. Second, econometric analysis suggests that technology and innovation could, indeed, help commodity dependent developing countries to diversify their economies and become less dependent on the commodity sector. This could strengthen productivity growth, which has been stunted in commodity dependent developing countries. Technology and innovation could lead the way to economic and structural transformation in commodity dependent developing countries. Third, a careful product space analysis shows some non-commodity products that commodity dependent developing countries could indeed start to produce, competitively, helping to diversify their export basket. Fourth, the analysis shows that there are available technologies from the third and fourth technological revolutions, as well as digitalization, that could help commodity dependent developing countries to move out of the commodity sector trap. Fifth, producing more technologically advanced goods would imply access and adoption of new technologies, as well as embracing innovation. This would require international cooperation.

To enable commodity dependent developing countries to escape from the commodity dependence trap, there needs to be stronger cooperation between commodity dependent developing countries and their trading partners, as well as development partners, in terms of technological acquisition and domestication. Hence, a conducive framework for technology accessibility and technology transfer to commodity dependent developing countries is needed at the international level. With respect to commodity dependent developing countries, they would need to initiate or strengthen their institutional capacity to absorb and domesticate new technologies. It is, therefore, clear that finding an answer to the ills of commodity dependence afflicting commodity dependent developing countries is not just the responsibility of this group of countries. Left alone, as has been the case in the recent past, they will not succeed. Commodity dependent developing countries will succeed only if the countries that benefit from the status quo, generally from the developed world, heed and support commodity dependent developing countries' political decisions and actions to break out of the commodity dependence trap.

The analysis is carried out in five substantive chapters, in addition to an overview and a background chapter and a concluding chapter. In chapter 2, entitled "The commodity dependence trap", the existence of a commodity dependence trap is explored and the relationship between commodity dependence and technology identified. Using empirical data, transition analysis is applied to measure the likelihood that a commodity dependent developing country breaks away from commodity dependence. The analysis particularly shows why breaking from commodity dependence is difficult. It requires strong political will and long-term commitment, with adequate human, financial and institutional resources. Using several technology indicators, suggestive evidence is provided in the chapter that the adoption of some relevant technologies, as well as innovation, may help commodity dependent developing countries to build a productive sector beside the commodity sector, diversifying the economy and reducing these countries' strong dependence on commodities. This analysis will pave the way for discussions in the subsequent chapters.

Under the title "Commodity dependence, productivity and structural change", in chapter 3, trends are explored in labour productivity and structural change in commodity dependent developing countries. As a potential long-run driver of rising real incomes in developing countries, labour productivity growth is an important development indicator that is firmly rooted in the Sustainable Development Goal framework. Improvements in labour productivity across sectors and productivity-enhancing structural change are key determinants of economic diversification and economic growth in commodity dependent developing countries. Against this background, in this chapter, the patterns and trends of labour productivity are analysed across groups of countries and sectors, showing the difference in productivity levels and growth of commodity dependent developing countries relative to other groups of countries. Empirical results show that commodity dependence is associated with low levels of labour productivity, slow productivity growth – particularly in the manufacturing sector – and a high frequency of negative productivity shocks.

Hence, breaking away from the commodity dependence trap can help spur economy-wide labour productivity growth, for which there remains a large potential in commodity dependent developing countries. It is argued that, to realize this potential in commodity dependent developing countries, it is necessary to strengthen broad-based drivers of productivity growth, such as technological upgrading, but also to use targeted measures to remove sector-specific obstacles for productivity growth. For example, technological upgrading and innovations that spur productivity growth need to be enabled and promoted through the development of adequate infrastructure, including digital infrastructure.

In chapter 4, the discussion focuses on how technological change and innovation could foster economic diversification and structural transformation in commodity dependent developing countries. Under the title "Structural transformation through technological change and innovation", the recent economic complexity literature is exploited to present stylized facts related to technological change, diversification and structural transformation. The distribution of the export product complexity of commodity dependent developing countries shows the technological capabilities available in those economies and finds that commodity dependent developing countries are indeed very far from the technological frontier. Given that commodity dependent developing countries have made minimal gains in terms of technological development, large jumps in product complexity (see chapter 4) are needed to close the technological gap from which they are suffering. This will require strong government intervention to build absorptive capacity and put in place the required conditions to introduce higher-technology productive systems in the economy. Seen from a different perspective, the large technological gap between commodity dependent developing countries and other groups of countries is an indication of the substantial opportunity the former could take advantage of to increase their technological capabilities. Information on countries' product space (see chapter 4) highlights some of the products commodity dependent developing countries could produce if they adopt technologies that are within their reach.

The title of chapter 5 is "Enabling technological transformation". Two main issues are the focus of the chapter. First, what are the enablers of technological transformation in the context of a commodity dependent economy? What would a successful implementation strategy consist of? To address the first issue, in the chapter, different diversification paths are first discussed. Horizontal diversification may be undertaken within the commodity sector and by expanding into the non-commodity sector. Vertical diversification can be achieved through quality upgrading and by developing backward and forward linkages. To achieve these objectives, there are horizontal enablers or general enablers that are independent of the nature of the diversification path pursued. These include infrastructure, entrepreneurship, skills development and the capacity to fully appropriate technological innovation. Trade integration could also play an important role, as it can increase productivity through improvements in resource allocation. In addition, there are enablers that are specific to the type of commodity a country is dependent on. For example, a major constraint in countries endowed with point-source natural resources may be poor management of natural resource rents. In these countries, adopting technologies that strengthen the management of natural resource rents maybe a key enabler. In contrast, countries dependent on agriculture may need to address issues of productivity, particularly where the small size of firms prevents them from adopting technologies that address this constraint. The second focus of the chapter is to provide specific examples illustrating how several commodity dependent developing countries have been able to successfully use technology to diversify their production and escape the commodity dependence trap.

In chapter 6, titled "Commodity dependent developing countries and technological revolutions", how technological revolutions have impacted or could impact commodity dependent developing countries is discussed. Indeed, technological revolutions offer the possibility of new combinations (innovations), sometimes leading to new technological–economic paradigms. The current (digitalization) and emerging (Industry 4.0) technological revolutions are expected to change commodity sectors and related global value chains, with a potentially significant impact on commodity dependent developing countries. Even though commodity dependent developing countries may not be ready to deploy Industry 4.0 technologies, there are ways of taking advantage of them. Harnessing these technologies could help commodity dependent developing countries to diversify and structurally transform their economies. For example, every technological revolution has been associated with specific commodities, with the current Industry 4.0 fuelling industries, such as renewable energy, robots, drones and the like, that rely on commodities including cobalt, lithium, rare earths and so on. Commodity dependent developing countries have an opportunity to gainfully play a bigger role in the value chains of these strategic commodities. Digitalization has the potential to drastically reduce transaction costs associated with commodity trade, enabling commodity dependent developing countries to become more efficient and capture more value out of their commodities. Moreover, blockchain technologies can increase transparency in commodity value chains, helping to increase product information, accountability and risk management and fostering responsible consumption and production.[6] By increasing traceability, blockchain can also link consumers and producers more directly, potentially increasing the intangible value of a product. Product traceability made possible by blockchain can also help to differentiate "high quality" from "low quality" products, allowing price differentiation that benefits producers who invest in the production of high-quality commodities. Should commodity dependent developing countries miss these opportunities, they will be left behind and remain trapped in commodity dependence and underdevelopment.

Chapter 7 concludes by briefly offering a summary of lessons learned and suggesting some policy actions that commodity dependent developing countries could pursue to successfully use technology to alleviate the strong dependence on commodities.

6 One example of how blockchain can increase transparency in commodity markets may be found in Pisani M, 2021, Harnessing the potential of blockchain technology for sustainability and transparency in cotton value chains, presented at the twelfth session of the Multi-year Expert Meeting on Commodities and Development, Geneva, 9 February. Available at https://unctad.org/system/files/information-document/cimem2_2021_9_Feb_Maria%20Teresa%20Pisani.pdf. See also United Nations, Economic and Social Council, 2021, Harnessing blockchain for sustainable development: prospects and challenges, E/CN.16/2021/3, Geneva, 4 March.

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CHAPTER

2

The Commodity Dependence Trap

2.1 Introduction

Whether commodity dependent developing countries are trapped in their state of commodity dependence is explored in this chapter. The persistence of dependence is documented, and some potential drivers of the phenomenon are highlighted. Identifying the correlates of commodity dependence could inform policies seeking to enable commodity dependent developing countries to break with commodity dependence. More specifically, how countries move in and out of three states is measured in this chapter. These states are: non-commodity dependence, a state that characterizes countries that derive less than 60 per cent of their merchandise exports from the commodity sector; a state of commodity dependence for countries deriving between 60 per cent and 80 per cent of merchandise export earnings from the commodity sector; and a state of strong commodity dependence for countries deriving more than 80 per cent of their merchandise export earnings from the commodity sector. As noted in chapter 1, Background, if countries moved in and out the three states seamlessly, commodity dependence would not be a serious issue. The problem arises if countries get stuck in one of the two commodity dependence states, given the negative outcomes associated with dependence.

In theory, any country may be in any of the three states at any given time. However, if some countries are found to stay in a specific state over a long period of time, this might indicate that they are trapped. Therefore, for this chapter, an empirical analysis was carried out with three objectives. First, using mobility analysis, data from 1995 to 2018 and covering 206 countries and territories shows the average proportion of countries that are in each of the three groups. This highlights the level of short-term mobility. The shortcoming of short-term analysis is that countries could be in a specific group due to factors that are not necessarily associated with dependence, for example short-term shocks to export prices. Taking this into account, the second objective is to determine the distribution of countries in the three groups after all short-term movements have taken place.[7] This is key to the concept of a commodity dependence trap, particularly if the ultimate objective is to assess to what extent countries are trapped in the two states of commodity dependence. The third objective is to identify some correlates of commodity dependence, highlighting technology indicators.

Empirical results show that commodity dependent countries seem to be trapped in a state of dependence but the consequences of this are more important for commodity dependent developing countries, as explained throughout this report. The implication is that, if they do nothing, time by itself will not get them out of the trap. They will remain commodity dependent and continue to suffer from the negative consequences associated with it. Strong action is therefore needed to change the status quo. Most particularly, strengthening technological capabilities of commodity dependent countries is highlighted as one key avenue that could enable commodity dependent developing countries to move away from commodity dependence.

In section 2, illustrative cases of countries trapped in commodity dependence are discussed by briefly presenting the examples of Zambia and Nigeria. Costa Rica is used to illustrate a country that was able to escape from commodity dependence. The methodology used to measure mobility, both in the short term and the long term, is briefly discussed in section 3. Empirical results of mobility are also presented. In section 4, the correlates of commodity dependence are identified, based on the results of an econometric probit model. A conclusion is provided in section 5.

2.2 The commodity dependence trap: A tale of three country trajectories

The concept of a commodity dependence trap in this report is used to characterize three different outcomes. The first is a situation where a country is commodity dependent in some reference

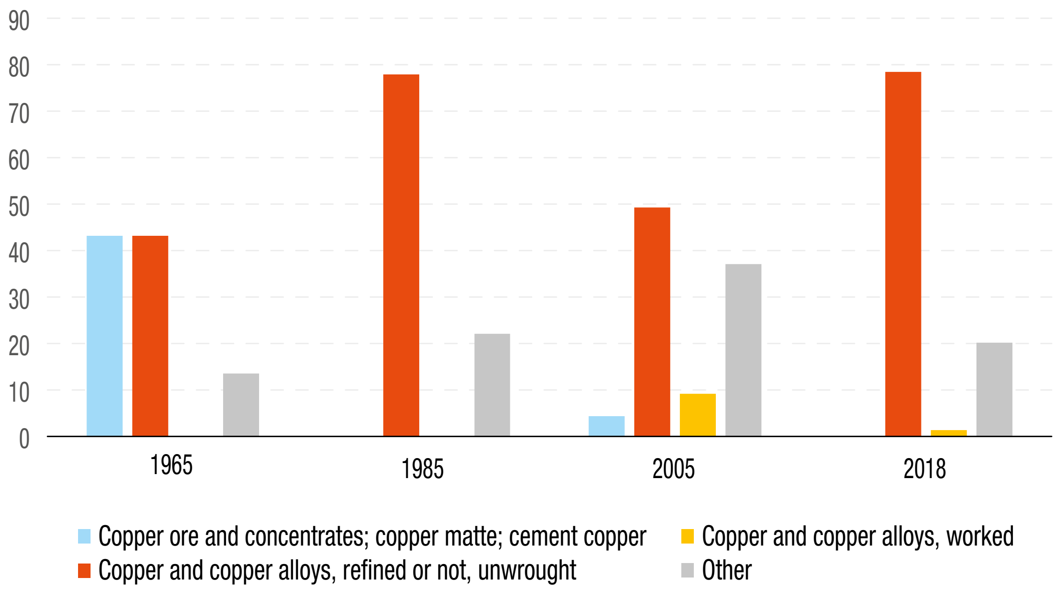
7 The technical term for this is ergodic distribution.

period and remains dependent over a long period. Zambia illustrates this case. The second situation, illustrated by Nigeria, relates to a country where export diversification characterizes its initial conditions but, over time, the country becomes strongly dependent on one commodity. The third case is that of a country that was initially commodity dependent but, over time, diversifies its export sector and moves out of commodity export dependence. Costa Rica exemplifies this case. Data from the Atlas of Economic Complexity[8] for the three countries over the period from 1965 to 2018, which spans more than half a century, reveals three different trajectories that summarize the experiences of most developing countries.[9]

In 1965, copper ore and concentrate, and copper alloys, represented 85 per cent of the net merchandise exports of Zambia. Twenty years later in 1985, the composition of the country's export basket had hardly improved, with copper and copper alloys, refined or not, and unwrought representing 77 per cent of the country's merchandise exports. By 2005, merchandise exports were still dominated by copper-based raw materials, accounting for about 60 per cent of the total. In 2018, the export concentration of Zambia around copper had worsened, increasing to almost 80 per cent of total merchandise exports (figure 2.1 (a)).

Whereas Zambia has remained dependent on the same commodity for more than half a century, Nigeria was relatively diversified in 1965 but became more and more dependent on one commodity over time (figure 2.1 (b)). In 1965, even though Nigerian exports were dominated by primary commodities, the export basket was diversified with cocoa beans, groundnuts, and palm nuts and kernels, representing 15 per cent, 13 per cent and 10 per cent, respectively, of total merchandise

Figure 2.1 (a) **Zambia: Main merchandise exports in 1965, 1985, 2005 and 2018**
(Percentage of total mechandise exports)

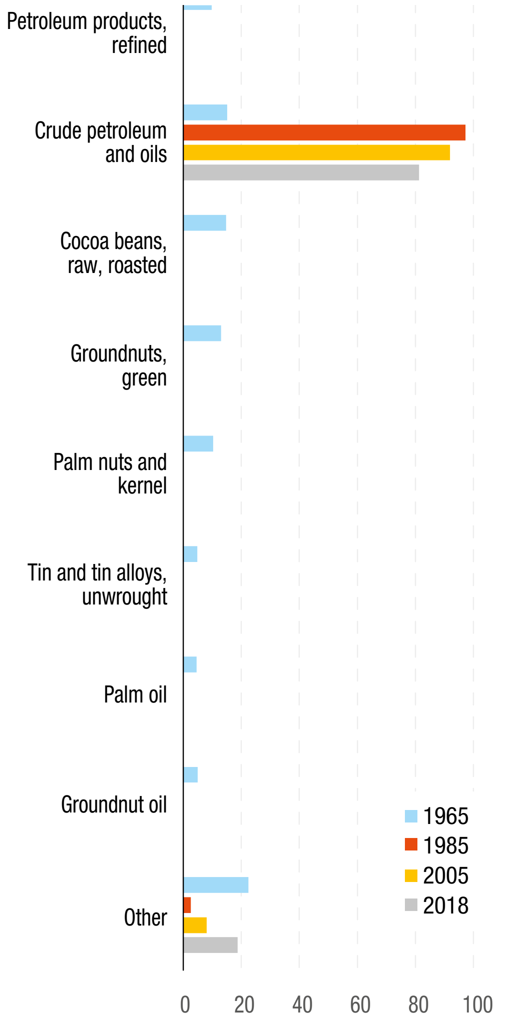


Source: UNCTAD, based on data from https://atlas.cid.harvard.edu/explore?country=247&product=undefined&year=2018&productClass=SITC&tradeFlow=Net&target=Product&partner=undefined&startYear=undefined (accessed 11 May 2021).

8 Available at https://atlas.cid.harvard.edu/.

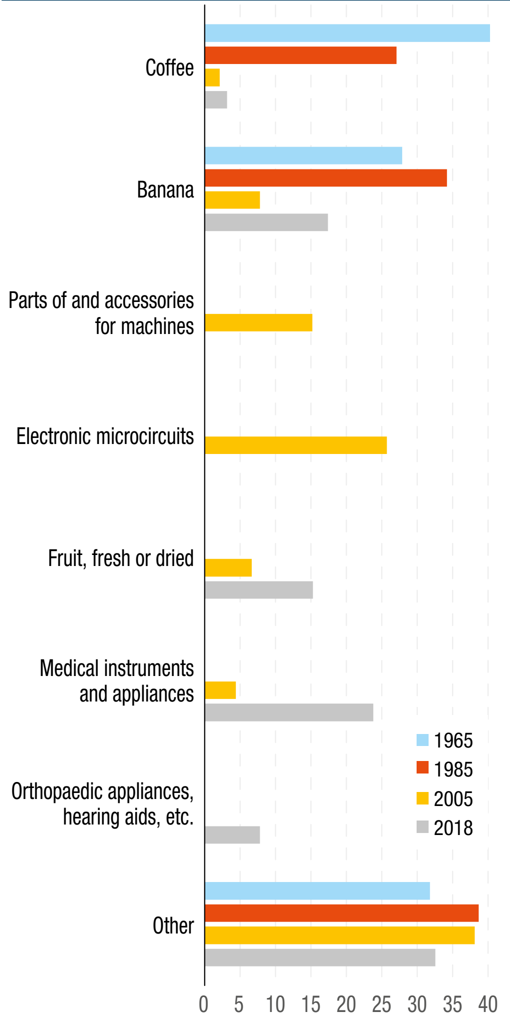
9 To access disaggregated data from before 1995, the United Nations standard international trade classification, revision 4, was used. Export shares are calculated using gross trade flows. Data in figures 2.1 (a) and 2.1 (b) are derived using the 4-digit level of disaggregation. However, in the discussion, sectoral level data at 1 digit are also used to show more aggregated information.

Figure 2.1 (b) **Nigeria: Main merchandise exports in 1965, 1985, 2005 and 2018**
(Percentage of total mechandise exports)



Source: UNCTAD, based on data from https://atlas.cid.harvard.edu/explore?country=159&product=undefined&year=2018&productClass=SITC&tradeFlow=Net&target=Product&partner=undefined&startYear=undefined (accessed 11 May 2021).

Figure 2.1 (c) **Costa Rica: Main merchandise exports in 1965, 1985, 2005 and 2018**
(Percentage of total mechandise exports)



Source: UNCTAD, based on data from https://atlas.cid.harvard.edu/explore?country=52&product=undefined&year=2018&productClass=SITC&tradeFlow=Net&target=Product&partner=undefined&startYear=undefined (accessed 11 May 2021).

exports. The country also exported palm oil, groundnut oil, and tin and tin alloys, unwrought. Crude petroleum and refined petroleum accounted for 15 per cent and 10 per cent, respectively, of total merchandise exports. Twenty years later, in 1985, the country was exporting almost a single commodity, crude petroleum, which accounted for 97 per cent of total merchandise exports. In 2005, at 92 per cent of total merchandise exports, crude petroleum was still by far the major export of Nigeria. By 2018, the picture had changed only slightly, with crude petroleum still accounting for 81 per cent of total merchandise exports (petroleum gases represented an additional 12 per cent).

Costa Rica followed a different, more successful trajectory. In 1965, the export base of Costa Rica was dominated by coffee and bananas, representing about 68 per cent of total net merchandise export earnings (figure 2.1 (c)). Overall, food commodities represented 83 per cent of total merchandise exports. Twenty years later, in 1985, these two commodities were still the country's dominant exports, accounting for 61 per cent of total merchandise exports. Even though food commodities made up 76 per cent of total merchandise exports, there was a nascent manufacturing sector, which contributed about 15 per cent to total merchandise exports, against only 7 per cent 20 years earlier. Thereafter, the country embarked on a diversification drive to the extent that, by 2005, the country's export basket had dramatically changed. In 2005, the main exports were electronic microcircuits, with a share of 26 per cent of total merchandise exports, followed by parts of and accessories for machines, with a share of 15 per cent. The share of the food sector had dropped to only 24 per cent of the total. By 2018, other sectors that had developed included the medical instruments and appliances, and orthopaedic instruments. Interestingly, the traditional food sector remained important, as banana and fruits represented an important share of exports. This contrasts with the case of Nigeria, suggesting that diversification is not about adopting new products while abandoning traditional ones.

In fact, the reconfiguration of exports in 2018 shows the food sector regaining importance, mainly because there were more food commodities exported. Among the most important ones, in addition to bananas, were fruit, fresh or dried, including avocados, pineapples and mangoes; edible products or preparations; fruit and vegetable juices; fruit, prepared or preserved; and bakery products. This illustrates that diversification is not just about adding value to primary commodities or only producing more sophisticated goods. While Costa Rica diversified into more sophisticated goods, it also increased the number of products exported within the commodities sector. This highlights the point that, even when a country remains commodity dependent, it is better off relying on a larger basket of products, as Nigeria was doing in 1965. Currently, as a price taker, the total reliance of Nigeria on exports from the energy sector exposes the country much more to the vagaries of international oil markets.

Zambia, Nigeria and Costa Rica illustrate three different trajectories of commodity dependence. Costa Rica illustrates a successful case of export dynamism, from a highly concentrated base to more product and sectoral diversification. The country owes its success to a combination of factors, including the adoption of a long-term plan for economic and export diversification, macroeconomic stability, openness to foreign direct investment, proximity to a large export market and health and education policies that fostered human capital development (UNCTAD and FAO, 2017). Zambia and Nigeria, in contrast, are two different illustrations of the commodity dependence trap. For more than half a century, Zambia has made limited progress in terms of economic and export diversification away from copper. Nigeria, in turn, had the opportunity to maintain a relatively diversified export sector or even develop it further. Instead, commodity dependence worsened over time.

There is literature claiming that economies more reliant on point-source natural resources such as Nigeria and Zambia may be more prone to the natural resource curse than those relying on sparsely distributed agricultural commodities. One major transmission channel may be that point-source natural resources are more prone to predation by incumbent politicians and rebels (Collier and Hoeffler, 2004). The latter may capture those resources either at their extraction site or at any choke point when they are moved for export, causing instability and economic decline. This might help explain the contrast between Costa Rica and Nigeria and Zambia.

The negative relationship between point-source natural resources and the resource curse might not be generalized (Alexeev and Conrad, 2011). Indeed, when revenues from natural resources are used to develop other sectors and hence contribute to diversifying the economy, commodity dependent developing countries avoid the natural resource curse. Indonesia, for example, derived 71.5 per cent of its merchandise export earnings from the oil and gas sector in 1980. Fifteen years later in 1995, the contribution of the fossil fuels sector to total merchandise exports had been reduced to only 22.2 per cent of total merchandise exports. This was the result of massive investment of revenues from the fossil fuels sector in non-commodity sectors, diversifying the economy. By 2018, oil and gas accounted for 10 per cent of total merchandise export earnings. The exports have been diversified into products such as coal, coke and briquettes; iron and steel; road vehicles; vegetable oils and fats; metalliferous ores and metal scrap; apparel and clothing; and electric machinery.[10]

The discussion of the three country cases above, as well as that of Indonesia, points to one of the main issues addressed in this chapter: when observed over a long enough period, an initially commodity dependent country may move out of commodity dependence. Costa Rica, and Indonesia to some extent, illustrate this case. Zambia and Nigeria, in contrast, seem to be trapped in a state of commodity dependence.

The following section briefly presents the methodology used to measure mobility, followed by empirical results. Given that most developing countries, which constitute a large share of the sample, are commodity dependent, knowledge of the likelihood that a country can escape from dependence may inform policy towards structural transformation and export diversification, as discussed in detail in chapter 5. Before calling on commodity dependent developing countries to diversify their economies, it is important to first understand the extent of the challenge that they face, helping in turn to understand why they have been stuck in commodity dependence for such a long time.

2.3 Measuring mobility between commodity dependence States

The first part of the empirical analysis relies on transition analysis, using a methodology adapted from Nkurunziza (2015). The second part uses regression analysis to uncover some correlates of commodity dependence.

A brief discussion of the methodology

Observed at any specific time, any country can be classified in one of the three states defined above: the country may be not commodity dependent, commodity dependent or strongly commodity dependent. Allowing for a long period of time, countries may move between the three states. After all, the old debate about the need for commodity dependent developing countries to diversify their economies implies moving from a commodity-dependent to a non-commodity dependent state. Costa Rica achieved this over several decades. However, many commodity dependent developing countries remain commodity dependent even when they are observed over a period spanning half a century, as Zambia and Nigeria illustrate. These countries seem to be trapped.[11]

Mobility is analysed with a transition matrix. This is a tool used to determine the probability that a country in a reference period remains in the same group in the next period or moves to some other state. The unit of observation in this chapter is one year, but when results are presented, mobility is aggregated over a 24-year period, corresponding to 23 potential annual transitions, from 1995 to 2018. The 24-year period is dictated by data availability. It is long enough to study short-term mobility but not long enough to conclude that some countries may be trapped. Hence, the short-term distribution of countries in the three states is used to derive a long-term

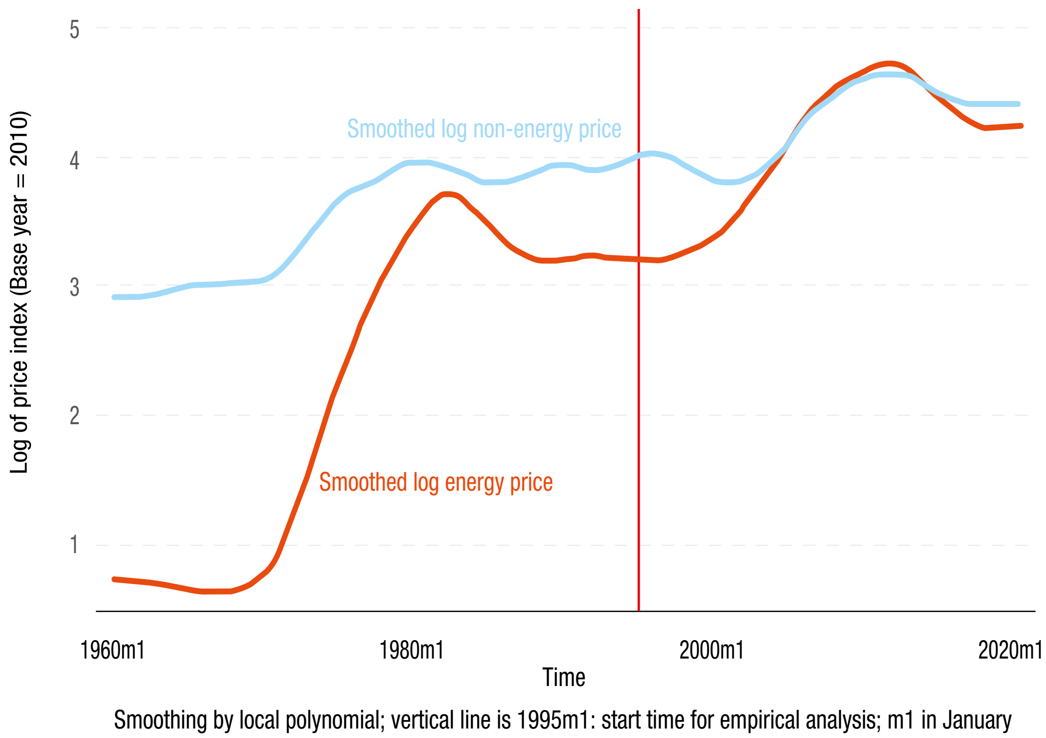
10 Based on data from the Atlas of Economic Complexity, available at https://atlas.cid.harvard.edu/explore?country=103&product=undefined&year=2018&productClass=SITC&target=Product&partner=undefined&startYear=undefined (accessed on 18 January 2021).

11 Strictly speaking, the statistical concept of a "trapping" state in the analysis of dynamic systems means that once a country is in this state, it is impossible for it to move to any other state (Robert and Casella, 1999). In this chapter, unless otherwise specified, the concept is used to represent situations of very slow mobility, with probability close – but not equal – to zero.

or equilibrium distribution.[12] Indeed, the analysis of commodity dependence dynamics requires a relatively long period of observation given that the economic transformation process leading to export diversification takes decades, as illustrated by the case of Costa Rica. Moreover, regression analysis is used to probe the potential role that technology and innovation could play to help commodity dependent developing countries move out of the commodity dependence trap.

The sample period is from 1995 to 2018, with 4,944 observations or country-years (24 years for each of the 206 countries and territories). The 24-year period captures different phases of the commodity price cycle. Between 1995 and 2002, commodities prices were low, corresponding with a declining phase of the price cycle that had started in the early 1980s (figure 2.2). The period between 2003 and 2011 was characterized by a commodity price boom, with commodity prices increasing manyfold over a few years. Between 2012 and 2018, commodity prices were declining, even though they remained higher than their levels before the commodity boom of the 2000s. Indeed, before presenting empirical results of mobility, it is worth discussing first commodity price trends, considering that commodity dependence may be a function of prices, at least in the short term. For example, during the last commodity price boom, the number of commodity dependent developing countries increased from 110 in 2005 to 118 at the end of the boom in 2011. Thereafter, the number declined (Nkurunziza et al., 2017).

Figure 2.2 **Commodity prices: A sixty-year perspective**



Source: UNCTAD, based on the World Bank commodity price index, using 2010 as the base year.
Note: Data smoothing by local polynomial. Vertical line is 1995m1, start of sample used in empirical analysis.
* Sixty years, from January 1960 (1960m1) through July 2020.
** For all years, m1 indicates that data covered is from month 1 (January) of the year.

12 A formal discussion may be found in a background paper prepared for this chapter: Nkurunziza JD, 2021, The commodity dependence trap. Background paper prepared for the 2021 edition of the Commodities and Development Report, UNCTAD, available at https://unctad.org/webflyer/commodities-and-development-report-2021.

Decomposing commodities into fuel and non-fuel groups of commodities, figure 2.2 illustrates commonalities and differences in the behaviour of the price trends for both groups. The major common factor is that prices follow the same long-term trend. Prices have tended to increase, stabilize and decline at the same time. This finding implies that, over a long enough period, the markets for energy and non-energy commodities are fundamentally affected by the same major factors, namely supply and demand. This strong correlation suggests that, while diversification within the wider commodity sector may help, to some extent, only diversification out of the commodity sector could be an answer to the deleterious effects of commodity dependence. The manufacturing sector is identified in chapter 3 as being the sector towards which commodity dependent developing countries should strive to diversify. In other words, even though some types of commodities might face idiosyncratic challenges – for example, climate change may have a much stronger impact on agricultural commodities than on minerals, ores and metals – the major challenges facing the commodity sector are the same. Many of these challenges are highlighted in chapter 1.

But there is a major difference between the two types of commodities, as illustrated by figure 2.2: the amplitude of price changes. Energy commodities experience much stronger price changes than non-energy commodities. For example, because of the commodity price boom of the 1970s, the energy price index increased by more than 1 350 per cent, from 3.4 to 49.50 between January 1973 and December 1980. Over the same period, the non-energy commodity price index increased by 114 per cent, from 27.07 to 57.87. Unequal increases in prices were again recorded during the commodity boom of the 2000s, with energy prices increasing by 552 per cent between January 2002 and July 2008, while non-energy prices increased by 189 per cent over the same period. Energy markets have also been characterized by sudden and drastic price drops, shattering exporting countries' economies.

High price volatility is indeed an intrinsic characteristic of energy markets. Between June 2014 and January 2015, oil prices dropped by more than half in just six months. In June 2014, the energy price index stood at 131.48, but it had fallen to 63.10 by January 2015, less than half its value six months earlier. Countries that had planned spending based on an oil price of $112 per barrel in June 2014 faced the challenge of substantially cutting their budgets to adapt to a price that had reached $45 by 13 January 2015. The brutal effect of commodity dependence was strongly felt by oil-export dependent countries across the world, including Angola, the Islamic Republic of Iran, Nigeria, Saudi Arabia and the Bolivarian Republic of Venezuela. Commodity dependence is harmful not only as price shocks are destabilizing, but also as the relatively short periods of high commodities prices are followed by much longer periods of depressed prices, as illustrated by figure 2.2. This information may help to understand why commodity dependence might manifest itself differently in relation to the type of commodity on which a country depends. Econometric results seem to confirm this hypothesis (UNCTAD, 2019).

Empirical results

The empirical transition matrix in table 2.1 summarizes aggregate mobility of 206 economies, both developed and developing, which represents almost all countries and territories in the world.

Table 2.1 provides three sets of information. First, the last row is a summary measure of mobility, showing the average proportion of countries in each of the three states after mobility has taken place over a period of 24 years. On average, over the sample period, half of the countries were in the non-commodity dependent state. The other half were in the strongly dependent state (32 per cent of the sample) and the commodity dependent state (18 per cent of the sample). This summary information suggests that, while a widespread characteristic, commodity dependence – and its strong version – only affect half of the countries in the sample. Second, the fact that all elements of the table are non-zero, even though some are small, implies that there is indeed mobility across all states.

Table 2.1 Commodity dependence: Mobility across three states, 1995–2018
(As an average)

	Non-commodity dependent	Commodity dependent	Strongly commodity dependent
Non-commodity dependent	0.95	0.04	0.01
Commodity dependent	0.13	0.75	0.12
Strongly commodity dependent	0.01	0.07	0.92
Annual average proportion of countries	0.50	0.18	0.32

Source: UNCTAD, based on UNCTADstat database.
Note: Values are interpreted as probabilities.

The third set of information relates to values of the table, interpreted as probabilities. Starting with the two extreme values of the diagonal (in the table): there is evidence of limited mobility from the non-commodity dependent and the strongly commodity dependent groups. During the sample period, 95 per cent of non-commodity dependent countries remained within this group. The proportion of strongly commodity dependent countries that did not move out of the category is 92 per cent. Another way of interpreting these findings is that the risk that a non-commodity dependent country becomes commodity dependent or strongly commodity dependent is 4 per cent and 1 per cent, respectively. Similarly, the likelihood that a strongly commodity dependent country becomes non-commodity dependent over the 24-year period is very small. But there is a 7 per cent chance that such a country improves from strong commodity dependence to just commodity dependence. Even though this might be considered as an improvement, this information needs to be put in context as both commodity dependent and strongly commodity dependent countries face the same challenges, only with higher severity for the latter group.

The value in the middle of the diagonal suggests an almost equal likelihood that a commodity dependent country becomes non-commodity dependent (probability of 13 per cent) or strongly commodity dependent (probability of 12 per cent). On average, three quarters of commodity-dependent countries remain in the same state, over the sample period. This result suggests that, a priori, while some countries graduate into the non-commodity dependence category, an almost equal number fall into the worse state of strong commodity dependence. The implication is that relatively few countries can escape from commodity dependence.

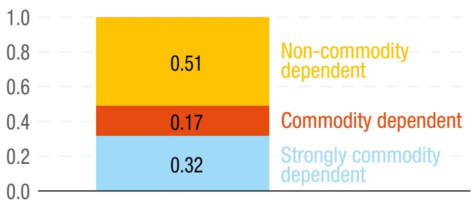
One question is whether a period of 24 years of observation is long enough to properly capture the transition processes occurring across all commodity dependence states. In other words, could transitions captured in table 2.1 be the result of short-term analysis of a phenomenon that requires a longer period of analysis? Indeed, it might be argued that commodity dependence is correlated with commodity price cycles that are generally longer than the 24-year sample period. Hence, it is important to analyse the evolution of commodity prices over a longer time span to ensure that what is captured by the transition matrix may be considered as representing a general pattern of mobility.

To answer this question, it is important to establish that the distribution reflected in table 2.1 does not change over time. Following the methodology discussed in detail in Nkurunziza (2015) and briefly exposed in a background paper,[13] the long-term distribution of countries in the three groups (see figure 2.3) is almost the same as the short-term distribution reflected in table 2.1.

Moving from short-term to long-term analysis (figure 2.3), there is a small change in the proportions of countries in the non-commodity dependent and the commodity-dependent categories, from 50 per cent to 51 per cent, and from 18 per cent to 17 per cent, respectively. This finding suggests that

13 Ibid., available at https://unctad.org/webflyer/commodities-and-development-report-2021.

Figure 2.3 **Long-term distribution of countries in the three states**
(As an average)



Source: UNCTAD, based on table 2.1 of the present report).

commodity dependence as characterized by data in the sample depicts a stable distribution of countries in the three states. This is consistent with the examples of Zambia and Nigeria which show that, for close to 60 years, the countries have remained not only commodity dependent but also dependent on the same commodity. This confirms that commodity-dependent and strongly commodity-dependent countries are indeed in a trap.

Another way of ascertaining the difficulty of emerging out of the dependence trap is to determine the time it would take a commodity dependent country to become non-commodity dependent, given mobility as observed between 1995 and 2018. Considering that only 1 percentage point of countries moves from commodity dependence to non-commodity dependence between the short-term and long-term analyses, and if no strong action is taken to accelerate mobility, it would take the average commodity dependent country 190 years to reduce by half the difference between its current share of commodities in total merchandise exports and that of the average non-commodity dependent country.[14] This result illustrates the challenge facing commodity dependent developing countries. Unless they take strong action to change the status quo, they will remain commodity dependent for the coming centuries. This seems to be the trajectory that characterizes Zambia and Nigeria, as well as most other commodity dependent developing countries. Doing nothing or not doing enough does not seem to be an option as commodity dependence will not disappear on its own.

Could technology be one of the disruptive factors that could help commodity dependent developing countries to change their trajectory towards more diversified economies? The experience of Costa Rica shows that an economy can indeed be transformed to become more diversified. As mentioned earlier, success requires time, strong political will and a long-term, realistic development vision, coupled with an ambitious but reasonable implementation strategy (UNCTAD and FAO, 2017). The remainder of the chapter identifies some correlates of commodity dependence. This information may provide potential entry points towards economic structural transformation and diversification.

2.4 Correlates of commodity dependence

Correlates of commodity dependence are identified based on available data. Most particularly, given the report's specific interest in technology, this section presents the results of a simple probit econometric model regressing commodity dependence on several indicators of technology, and other control variables.

2.4.1 Discussion of the variables

Five indicators of technology are used (see the descriptive statistics in table 2.3). First, the share of a country's population using the Internet captures the deployment of ICTs within an economy. The Internet provides greater access to information, reduces production costs and allows far greater connectivity between people, firms and other economic agents, ultimately leading to higher productivity.

14 Ibid., available at https://unctad.org/webflyer/commodities-and-development-report-2021.

The second variable is the speed of the Internet. This captures the quality of ICT deployed in a country. Indeed, productivity improvements result from not only accessing the Internet, but also having Internet connections that work well and at speeds that facilitate transactions without interruption. The Internet creates so many opportunities that it is has become a vital economic resource in modern societies. The Internet permeates economic and social life to such a degree that it is now at the root of the digital divide (Aydin, 2021) between those who have access to it and those who do not.

Third, high-skill employment as a percentage of the working population is an indicator that measures the quality of human resources available in a country. Indeed, measures such as the employment-to-population ratio do not account for the fact that many jobs, particularly in developing countries, are low skilled and contribute little to export and economic structural transformation. High-skill employment, on the other hand, is associated with technological innovations that commodity dependent developing countries might need to adopt to create new products and reduce their strong dependence on commodity exports.

Fourth, the number of scientific publications on frontier technologies (research and development publications) is considered as a good proxy of technological activities taking place within an economy. The higher the number, the more technologically advanced an economy is.

Fifth, high technology manufactures exports as a percentage share of total merchandise trade measures the share of technologically sophisticated goods that are exported by a country. As primary commodities are less sophisticated exports, moving out of the commodity dependence trap implies that commodity dependent developing countries need to upgrade their productive systems to produce manufactured goods and services that are more sophisticated.

All five technology indicators show the capacity of a country to produce and export goods and services with a high technology content, unlike commodities that embed a low level of technology.[15] Put differently, countries displaying high levels of technology indicators are less dependent on the commodity sector for their exports. Technology and innovation enable them to diversify exports into high-value goods and services that are less prone to the negative shocks that afflict primary commodities. Therefore, improving technology and innovation in commodity dependent developing countries is expected to help them diversify into high-value exports and increase as well as stabilize export earnings.

In addition to technology and innovation indicators, other control variables, all sourced from the UNCTADstat database, are included as correlates of commodity dependence (table 2.3).[16] These are the shares of fuels, minerals and agriculture exports in total exports. These are expected to capture the fact that commodity dependence may be a function of the commodity sector a country depends on, as discussed earlier (see also UNCTAD, 2019). High shares of energy and minerals in total merchandise exports tend to be associated with strong commodity dependence. In many developing countries, energy and minerals sectors concentrate the bulk of investment, particularly foreign direct investment, translating thus into highly concentrated economic activity.

Sectoral allocation of employment may potentially be related to commodity dependence if a large share of employment is in a sector producing the commodity (or commodities) on which a country depends. Another way of analysing dependence is to probe the sectoral contribution to value added in an economy. High value added shares indicate the importance of a sector to an economy. For example, in commodity dependent developing countries, value added is generally generated

15 As explained earlier, extractives in commodity dependent developing countries may display high levels of technologies, but these are not embedded in the domestic economic system; they are instead controlled by multinational enterprises that operate enclave projects.

16 A detailed discussion of many of these variables and why they matter for commodity dependence and economic structural transformation is found in chapter 3.

Table 2.2 Descriptive statistics of the variables included in the econometric model

Variable	Mean	Median	Observations
Dummy variable for commodity dependence	0.52	1.00	4 944
Share of fuels exports in total merchandise exports	0.17	0.05	4 675
Share of minerals exports in total merchandise exports	0.08	0.02	4 764
Share of agriculture exports in total merchandise exports	0.26	0.18	4 770
Share of employment in industry	19.67	20.14	4 392
Share of employment in services	50.42	52.02	4 392
Share of value added in agriculture	12.58	8.38	4 378
Share of value added in industry	26.60	24.81	4 366
Share of value added in services	53.25	53.56	4 188
Dummy variable for least developed country status	0.23	0.00	4 944
Internet users (share of population)	0.52	0.55	474
Internet speed, in megabits per second (mean download speed)	0.50	0.46	316
High-skill employment (% working population)	0.39	0.37	474
Research and development publications (no. of scientific publications on frontier technologies)	0.40	0.38	316
High-technology manufacturing (% total merchandise trade)	0.56	0.56	474

Source: UNCTAD, based on data from the International Labour Organization, International Telecommunication Union and the UNCTADstat database.

in low-technology and low-skilled primary and services sectors, suggesting that exports would also tend to be low-skilled and low-technology, which is the case for commodities. Finally, a least developed country categorical variable is introduced to proxy for three dimensions of a country's level of development. This variable captures a country's income level, human assets and economic vulnerability.[17] The status of least developed country implies that a country faces development problems that may add to the negative effect of commodity dependence, making development even more challenging. Such countries require more attention than non-least developed countries (Gore and Kozul-Wright, 2011). In this chapter, the variable "least developed country" takes a value of 1 if a country is a least developed country and a value of 0 otherwise.

Technology indicators cover only a few years, between 2015 and 2018, and slightly fewer countries, depending on which indicator is considered.[18] Despite this reduction in the sample size, there is no reason to consider that the relationship between technology and commodity dependence was different during the period not covered by the data – before the period 2015–2018. It is assumed that the period covered is representative of the full sample period. Indeed, the empirical results show that these indicators reflect the expected relationship between commodity dependence and technological development.

17 See UNCTAD, 2017, *The Least Developed Countries Report: Transformational Energy Access*, What are the least developed countries? (United Nations publication, Sales No. E.17.II.D.6, New York and Geneva), pp. v and vi.

18 Some variables, such as Internet speed and research and development publications, cover only two years and 158 countries each.

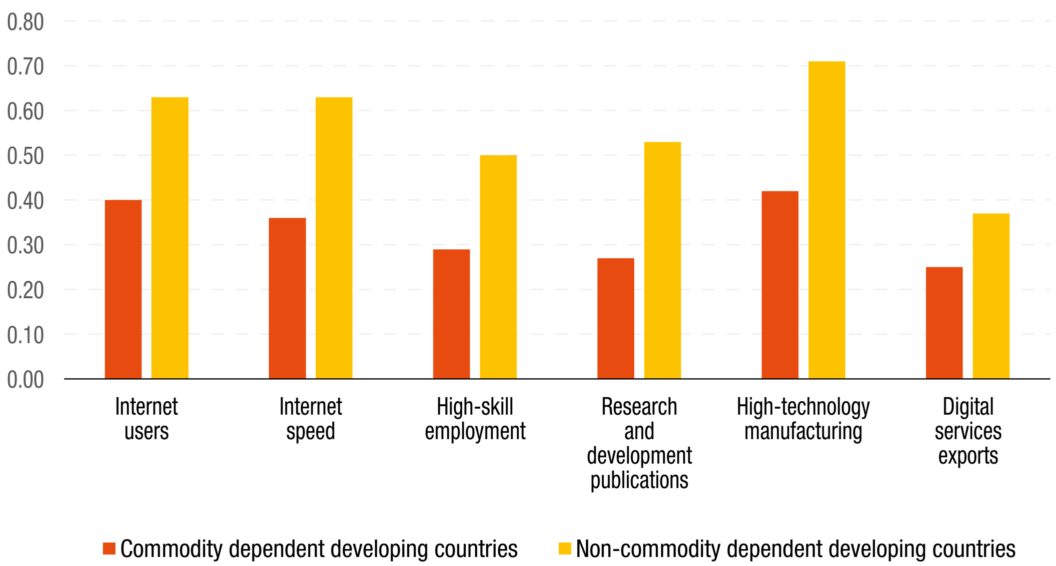
2.4.2 Empirical results

Econometric results[19] suggest a number of interesting findings regarding commodity dependence and its correlates. First, all the technology variables are strongly and negatively correlated with commodity dependence. This suggests that the odds of commodity dependence are strongly associated with low levels of technology. In other words, countries with higher technological capabilities are less likely to be commodity dependent. Figure 2.4 illustrates the strong and negative correlation between commodity dependence and the level of technological development, across all indicators of technology.

If the results were to be interpreted as representing causality relationships, they would suggest that, by strengthening their technological capabilities, commodity dependent countries may reduce the vulnerabilities associated with commodity dependence. Indeed, improving the technological ecosystem of commodity dependent countries would create opportunities by increasing production outside the commodity sector. As chapter 4 shows, weak technologial ecosystems in commodity dependent developing countries coexist with the least sophisticated and low-value product baskets. Acquiring technological capabilities and adopting institutions that foster innovation and technological development, as argued in chapter 5, could reduce the dependence on commodities of commodity dependent developing countries and the negative implication of that dependence for economic development.

There is also a positive and statistically significant relationship between commodity dependence and export shares of the three types of commodites. This means that the problem of the commodity dependence trap is not limited to some type of commodity on which a country depends. However,

Figure 2.4 Technology level in commodity dependent developing countries and non-commodity dependent developing countries



Source: UNCTAD.

19 See Nkurunziza JD, 2021, available at https://unctad.org/webflyer/commodities-and-development-report-2021.

the odds of commodity dependence are not uniform across commodity types. The correlation is strongest for countries dependent on exports of minerals. The implication might be that the issue of commodity dependence is more entrenched in mineral exporting countries and, to a great extent, fuel export-dependent countries. One reason could be that extractives in commodity dependent developing countries are generally enclave sectors dominated by foreign firms that have little incentive to create backward and forward domestic linkages with non-commodity sectors (Hansen, 2013). As value addition to primary commodities takes place outside producing countries, the latter do not benefit from value creation and its attendant advantages, including income generation, job creation and tax revenue, along the value chain.

Other results suggest that development of the industrial sector would be a relevant way of addressing the commodity dependence issue. Indeed, industrial production, even when it uses commodities as inputs contributes to product and economic diversification. Finally, the least developed country variable indicates that the least developed countries are more affected by commodity dependence than other countries. If the relationship were to be interpreted as causal, that would mean that, other things being equal, the odds of being commodity dependent are between 2.7 and 5.0 times higher for a least developed country than for a non-least developed country.[20] Commodity dependence seems to be positively correlated with other vulnerabilities embedded in the least developed country variable discused above.

2.5 Conclusion

The main objective of this chapter was to document the level of commodity dependence and determine whether countries are trapped in a state of commodity dependence. The next step was to identify the correlates of commodity dependence in order to offer insights into possible pathways towards escaping from the dependence trap.

Empirical analysis confirmed that commodity dependent countries are indeed trapped in a state of dependence. The likelihood that a (strongly) commodity dependent country becomes non-commodity dependent is very low, as shown in table 2.1. This finding seems to hold even when allowing for a long time period, implying that, if the countries concerned do not take strong action to change the status quo, they will stay commodity dependent for a very long time.

Econometric results seem to confirm the hypothesis that technology and innovation could play an important role in helping countries escape from the trap. However, this process of change appears particularly challenging for countries dependent on the extractive sector. In this regard, fostering the development of a technology ecosystem in commodity dependent developing countries that encourages production of more sophisticated goods would be appropriate. Defeating commodity dependence will require that commodity dependent developing countries put in place the right physical and institutional infrastructure that allows this technology ecosystem to thrive.

The message about the potential positive role that technology and innovation can play in enabling commodity dependent countries to escape from the dependence trap is key to this report. This finding lays the ground for further discussions in subsequent chapters.

20 These values are based on the smallest and the largest coefficients of the econometric models, namely the models with research and development publications and Internet use, respectively. Given that the coefficients cannot be interpreted as elasticities, the values are obtained as $e^{1.01} \approx 2.74$ and $e^{1.62} \approx 5.05$.

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CHAPTER

3

Commodity Dependence, Productivity and Structural Change

3.1 Introduction

The connections between commodity dependence, labour productivity trends and structural change in commodity dependent developing countries are analysed in this chapter. Improvements in labour productivity are a key source of economic growth and thus closely linked to the overall development process in low-income and middle-income countries. In particular, labour productivity growth can be a long-term driver of increased real wages and improved living standards in developing countries. The importance of labour productivity growth in the development process is reflected in the inclusion of a related indicator under Millennium Development Goal 1 on eradicating extreme poverty and hunger and in its inclusion in the Sustainable Development Goals framework: target 8.2 aims to "achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high value added and labour-intensive sectors" and indicator 8.2.1 is the annual growth rate of real GDP per employed person, as noted in resolution 71/313 of the General Assembly. Diversification and technological development play crucial roles in labour productivity growth.

The growth of economy-wide labour productivity can be driven by productivity growth in individual sectors and/or by productivity-enhancing structural change, that is, a reallocation of production factors from sectors with lower levels of productivity to sectors with higher levels. Either of these components can also have negative impacts on aggregate labour productivity. In this context, technological upgrading and innovation can be important drivers of within-sector labour productivity growth. Structural change is particularly relevant to labour productivity growth if there are significant differences in productivity levels across sectors. Such differences tend to be greatest in low-income countries, in which agriculture is typically the least productive sector but employs a large share of the labour force.

Starting from the observation that commodity dependent developing countries exhibit lower average levels of labour productivity growth than other country groups, a key question addressed in this chapter is whether commodity dependence acts as an inhibitor to the within-sector component, the structural change component or both components of labour productivity growth. This is a question of significant practical relevance for policymakers in commodity dependent developing countries. For example, if commodity dependence is a drag on growth-enhancing structural change, policy interventions should focus on facilitating the flow of production factors from low-productivity to higher-productivity sectors. However, if commodity dependence weighs down within-sector productivity growth, policies that induce such growth at the sectoral level need to be strengthened. Finally, if commodity dependence is a drag on both components, a policy mix will be needed.

As shown in this chapter, commodity dependence is associated with low levels of labour productivity, slow productivity growth, high volatility in productivity growth and a high frequency of negative productivity shocks. The link between commodity dependence and stunted productivity growth is particularly strong in the manufacturing sector. Furthermore, there is a strong association between technology development and labour productivity growth across sectors. Overcoming commodity dependence can strengthen the role of the manufacturing sector as a driver of economic growth and productive employment, which can, directly and indirectly, contribute to the achievement of the Sustainable Development Goals. Technological upgrading and innovation can play important roles in the diversification process.

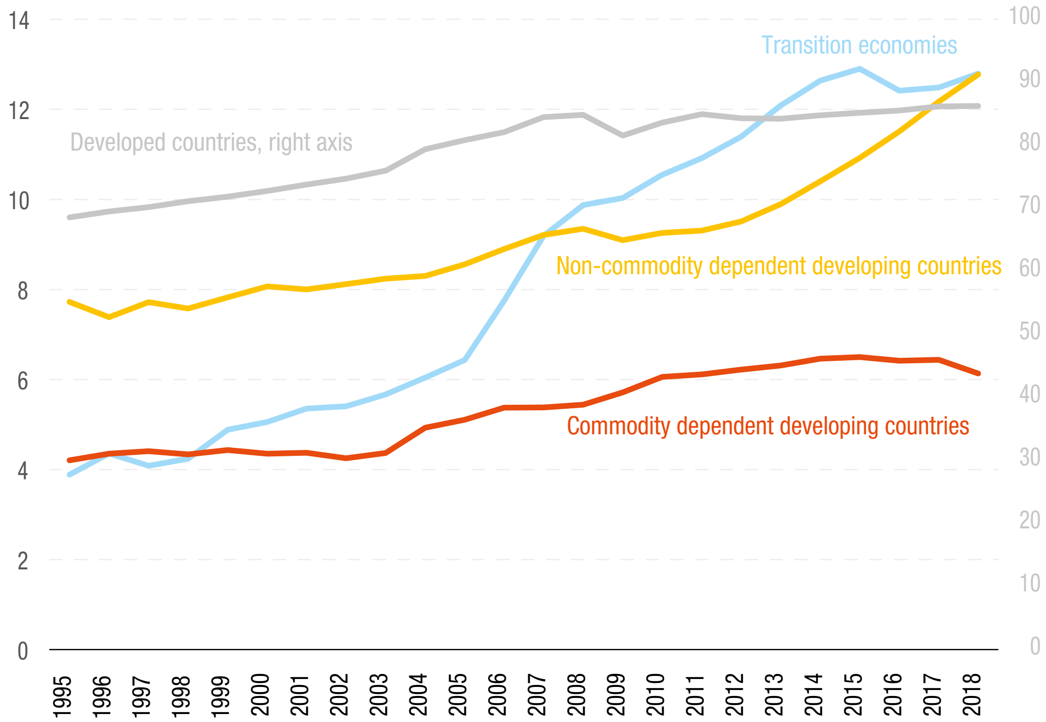
The chapter has five sections, as follows: in section 3.2, labour productivity trends are analysed through the lens of commodity dependence; in section 3.3, the patterns of structural change in commodity dependent developing countries since 1995 are highlighted; in section 3.4, sectoral productivity trends and drivers and their relationship with commodity dependence and technological development are examined; and in section 3.5, a summary and conclusions are provided.

3.2 Labour productivity trends

Labour productivity is defined as output per unit of labour. It is therefore calculated by dividing total output by the number of workers or the number of work hours in a given period. National GDP, value added generated by an economic sector or value added generated by an individual firm can each act as a proxy for output. Aggregate labour productivity is defined as the labour productivity of the economy as a whole, that is, GDP per worker. In this chapter, the term "labour productivity" refers to aggregate labour productivity unless specified otherwise and, for country groups, medians are used when the indicator reflects a specific level (for example, labour productivity in dollars) and averages are used when the indicator reflects a percentage (for example, growth rate of labour productivity).

In 1995–2018, the median labour productivity in commodity dependent developing countries was substantially below the median in non-commodity dependent developing countries and developed countries and, from 1999 onward, labour productivity in transition economies exceeded that in commodity dependent developing countries, with a rapidly widening gap (figure 3.1). The difference between the median labour productivity in commodity dependent developing countries and all other country groups was significantly greater in 2018 than in 1995, implying that while other groups significantly improved labour productivity, progress in commodity dependent developing countries was muted. Labour productivity in the latter was virtually stagnant from 1995 until the

Figure 3.1 **Median labour productivity**
(Thousands of constant 2010 dollars)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

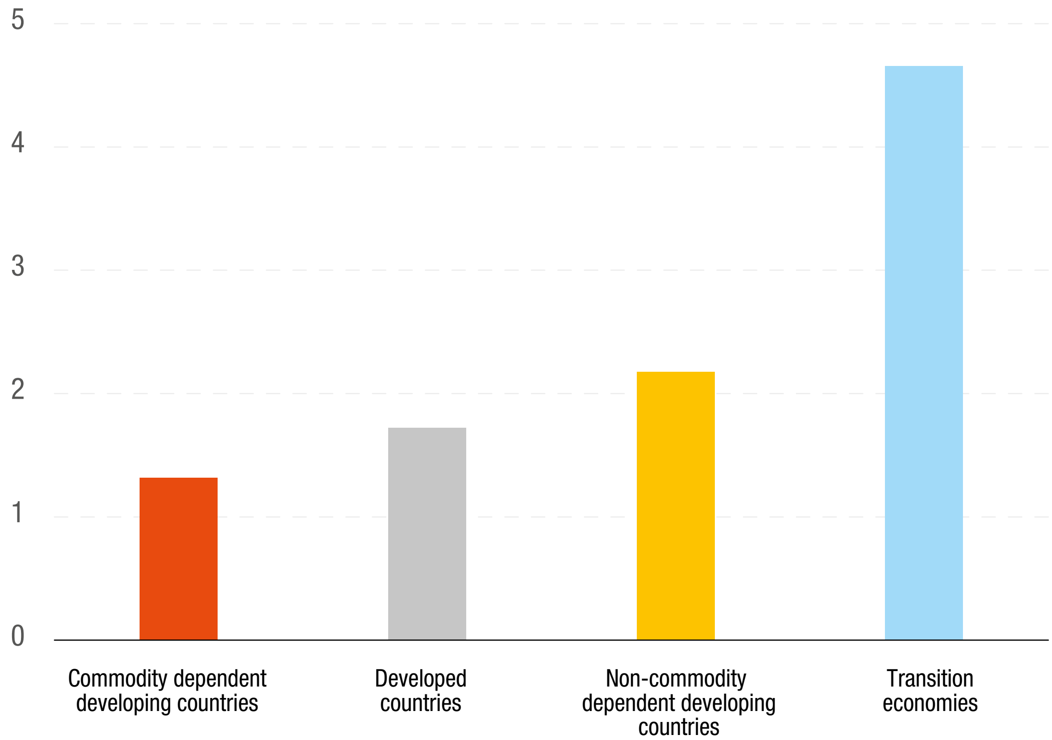
Notes: Transition economies, developing countries and developed countries are defined as in the UNCTADstat database. Commodity dependent developing countries are defined as developing countries with an average share of primary commodities in total merchandise exports greater than 60 per cent in 1995–2018. The data set covers 166 economies in 1995–2018 (see appendix, table A).

onset of the commodity price boom in 2003 and the compound annual growth rate of the median labour productivity in these countries in 1995–2002 was only 0.1 per cent. This rate increased to 4.3 per cent in the boom period in 2003–2011, after which growth levelled off, and the rate was negative in 2012–2018. During the boom period, labour productivity growth in commodity dependent developing countries was primarily fuelled by an accelerated flow of workers out of the agricultural sector towards non-farm employment in higher-productivity sectors and, to a lesser extent, by labour productivity growth within services sectors. The majority of workers exiting the agricultural sector moved to the construction sector and relatively low-productivity services sectors. In particular, the construction sector in commodity dependent developing countries benefited from increased spending on infrastructure and significant investments in mining undertaken during the boom period (World Bank, 2015).

In 1995–2018, the average annual growth rate of labour productivity in commodity dependent developing countries was 1.5 per cent, lower than in developed countries, at 1.7 per cent; non-commodity dependent developing countries, at 2.3 per cent; and transition economies, at 4.9 per cent (figure 3.2). Therefore, combined with a low initial level of labour productivity, slow productivity growth has been widening the productivity gap between commodity dependent developing countries and other country groups.

In addition to experiencing slower labour productivity growth, commodity dependent developing countries have also experienced negative productivity shocks at a greater frequency than other country groups. In 1995–2018, these countries experienced negative aggregate labour productivity growth on average once every three years, significantly more frequently than non-commodity

Figure 3.2 **Average annual growth rate of labour productivity, 1995–2018**
(Percentage)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

dependent developing countries, at 4.3 years; developed countries, at 5.8 years; and transition economies, at 7.2 years (figure 3.3, panel (a)). Labour productivity growth in commodity dependent developing countries was also more volatile than in non-commodity dependent developing countries and in developed countries, but less volatile than in transition economies (figure 3.3, panel (b)).

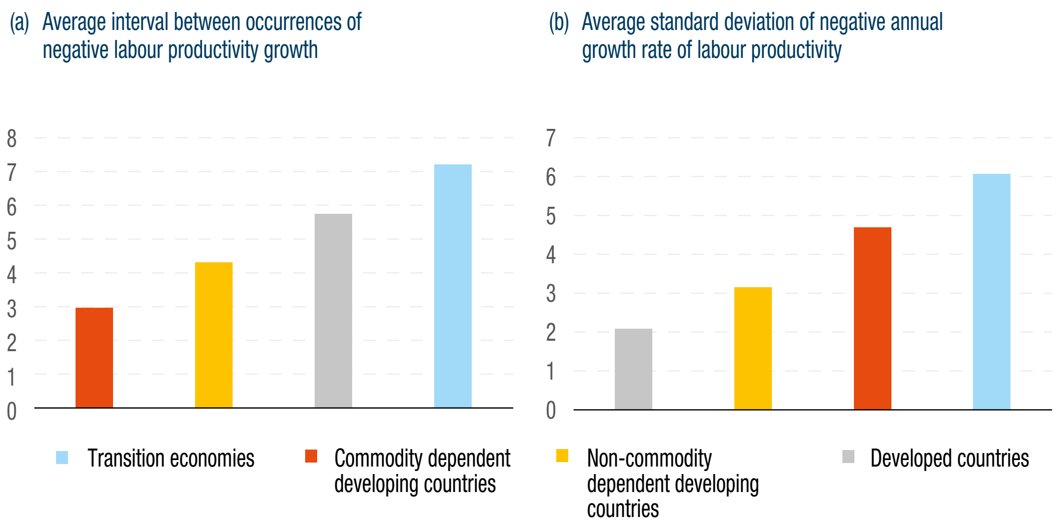
As shown in this section, in 1995–2018, in terms of aggregate labour productivity, commodity dependent developing countries lagged behind other country groups, including non-commodity dependent developing countries. Furthermore, commodity dependence was associated with comparatively low levels of labour productivity growth, a greater frequency of negative productivity shocks and an elevated volatility in productivity growth.

3.3 Structural change patterns

Aggregate productivity trends are determined by productivity trends within individual sectors and by changes in the structural composition of an economy. To explain the aggregate productivity trends in commodity dependent developing countries highlighted in section 3.2, it is therefore necessary to examine the structures of their economies. The structure of an economy can be described by the relative weights of its individual sectors, typically expressed as the share of value added or employment but which may also be expressed as the share of final consumption; the evolution of these shares over time is referred to as structural change. Developed countries underwent profound structural change along their development paths, which featured similar patterns of industrialization followed by an expansion of the weight of services in value added and employment (Herrendorf et al., 2013). Developing countries have also experienced structural change, but its depth and contribution to economic growth has varied substantially across countries since 1990 (McMillan et al., 2017).

Structural change characteristics in commodity dependent developing countries in 1995–2017 are highlighted in this section using a data set that disaggregates an economy into nine sectors (table 3.1). The empirical analyses in this section and in section 3.4 are based on a data set that incorporates data from the World Development Indicators database and the International

Figure 3.3 **Labour productivity, 1995–2018**
(Percentage)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

Table 3.1 Sectoral disaggregation of labour productivity

Sector	Components
Agriculture	Agriculture, forestry and fishing
Mining	Mining and quarrying
Manufacturing	Manufacturing
Utilities	Electricity, gas, steam and air conditioning supply
Construction	Construction
Trade services	Wholesale and retail trade; repair of motor vehicles and motorcycles; accommodation and food service activities
Transport services	Transportation and storage; information and communications
Financial and business services	Financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities
Other services	Public administration and defence; compulsory social security; education; human health and social work activities; arts, entertainment and recreation; other service activities; activities of households as employers; undifferentiated goods-producing and services-producing activities of households for own use; activities of extraterritorial organizations and bodies

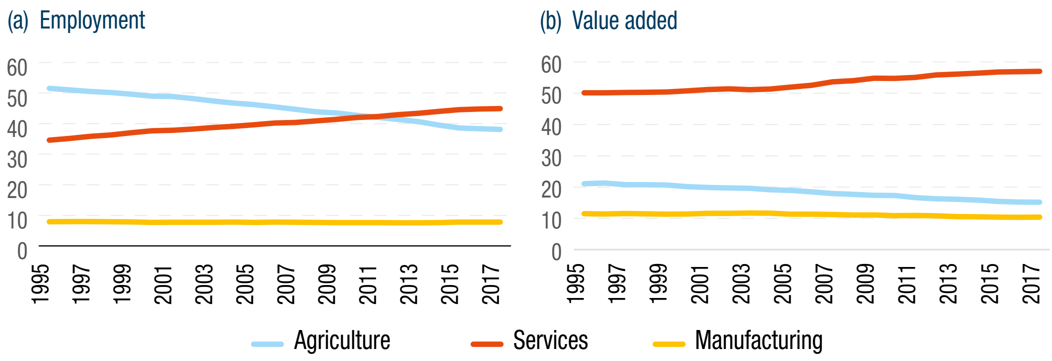
Source: UNCTAD, based on Dieppe and Matsuoka, 2020.

Telecommunication Union and trade data from the UNCTADstat database, as well as sectoral labour productivity data from the World Bank and a range of indicators from the Penn World Table (Dieppe and Matsuoka, 2020; Feenstra et al., 2015). This data set covers 94 countries in 1995–2017 that represent more than 90 per cent of global GDP and more than 85 per cent of the global population, according to data on GDP in 2019 (purchasing power parity) from the International Monetary Fund and data on the global population in 2019 from the United Nations world population prospects database (see appendix, table B).

In 1995–2017, structural change in commodity dependent developing countries was characterized by a steady flow of labour out of the agricultural sector and into services (figure 3.4, panel (a)). The average share of the agricultural sector in total employment decreased from 51.5 per cent in 1995 to 38.1 per cent in 2017. In the same period, the average share of services increased from 34.6 to 44.9 per cent. The average share of manufacturing remained almost constant, from 7.9 per cent in 1995 to 7.8 per cent in 2017. In commodity dependent developing countries, shares of value added showed similar trends as shares of employment (figure 3.4, panel (b)). In 1995–2017, the average share of agriculture in total value added decreased from 21.1 to 15.1 per cent. In the same period, the average share of services increased from 50.1 to 57.0 per cent and the average share of manufacturing decreased by 1.1 percentage points, from 11.5 to 10.4 per cent.

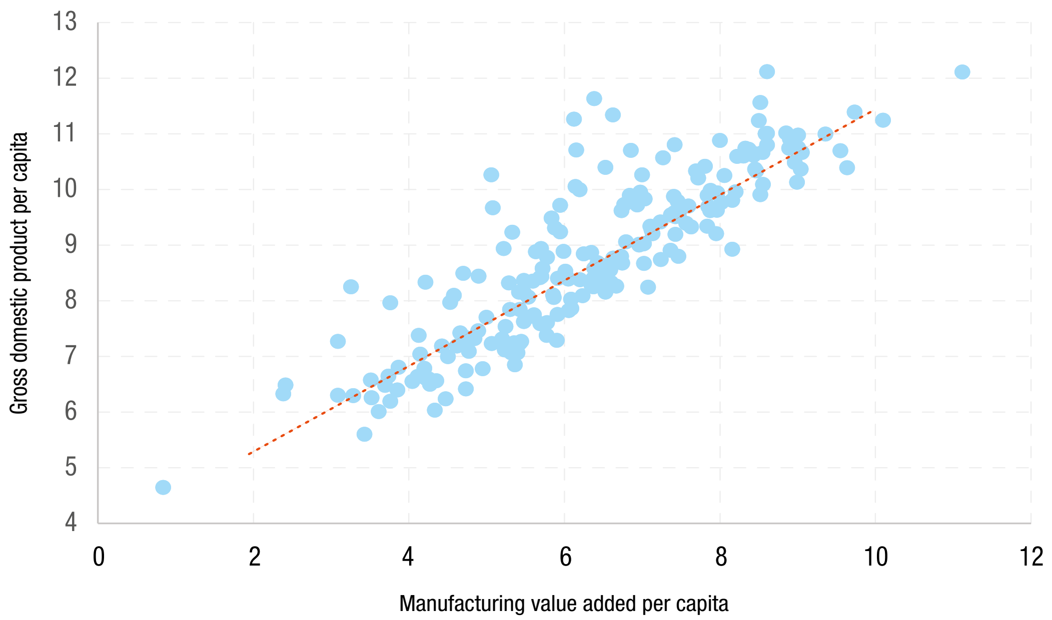
These trends show that structural change in commodity dependent developing countries did not follow a path of industrialization in 1995–2017. This suggests that these countries, as a group, are not moving towards target 9.2 under the Sustainable Development Goals to "promote inclusive and sustainable industrialization and, by 2030, significantly raise industry's share of employment and GDP, in line with national circumstances, and double its share in least developed countries". The two indicators, as noted in resolution 71/313 of the General Assembly, are manufacturing value added as a proportion of GDP and per capita; and manufacturing employment as a proportion of total employment. It is important to note that the level of manufacturing value added per capita is closely linked to average income and therefore to a range of other Goals, including Goal 1 on ending poverty and Goal 8 on promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (figure 3.5).

Figure 3.4 **Commodity dependent developing countries: Average sectoral shares**
(Percentage)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

Figure 3.5 **Manufacturing and output linkages, 2019**
(Constant 2015 dollars)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

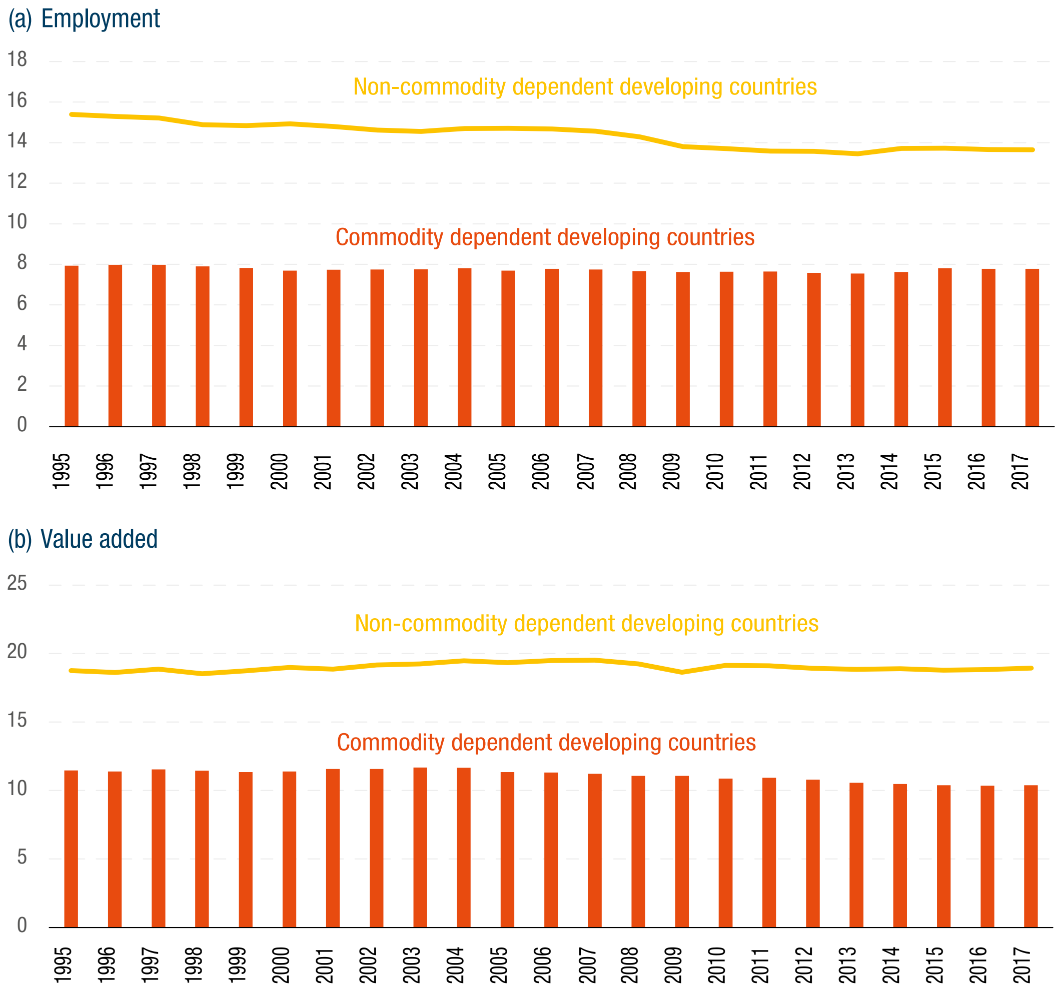
Notes: The data set includes all 208 economies in the database. The figure shows the natural logarithms of GDP per capita and value added per capita and a linear trendline.

The weight of manufacturing in employment and value added in commodity dependent developing countries has stagnated at levels far below those in non-commodity dependent developing countries (figure 3.6) and even further below the peak levels in developed countries (table 3.2).

Commodity dependent developing countries also lag substantially behind non-commodity dependent developing countries in terms of the share of global manufacturing employment, with a gap that widened from 27.6 percentage points in 1995 to 32.4 percentage points in 2017 (figure 3.7). Given the crucial role of the manufacturing sector in the development process (see Haraguchi et al., 2017, Rodrik, 2013, Rodrik, 2016, and Szirmai, 2012), this indicates an important policy challenge for commodity dependent developing countries.

It is important to note that the manufacturing sector continues to expand at the global level and can therefore still be a driver of growth in developing countries, including commodity dependent developing countries. Global manufacturing value added increased in terms of both level and per capita in 1990–2019, even when data for China is excluded (figure 3.8).

Figure 3.6 **Average share of manufacturing**
(Percentage)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

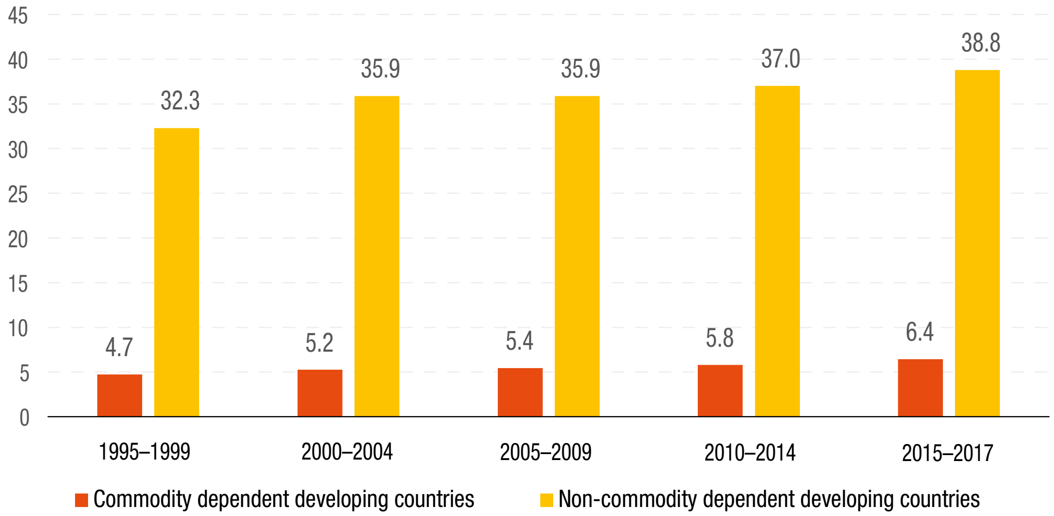
Table 3.2 Selected developed countries: Greatest share of manufacturing in total employment

	Share of manufacturing in total employment (percentage)	Year of peak level
Australia	24.7	1971
Canada	22.9	1970
France	26.0	1973
Germany	35.8	1970
Japan	26.2	1973
Republic of Korea	28.7	1989
United Kingdom	30.1	1971
United States	22.6	1970

Source: UNCTAD, based on data from the International Labour Organization, International Telecommunication Union and the UNCTADstat database.

Notes: Germany refers to the former Federal Republic of Germany. Manufacturing employment data is not available for the United Kingdom for 1970

Figure 3.7 **Share of global manufacturing employment**
(Percentage)

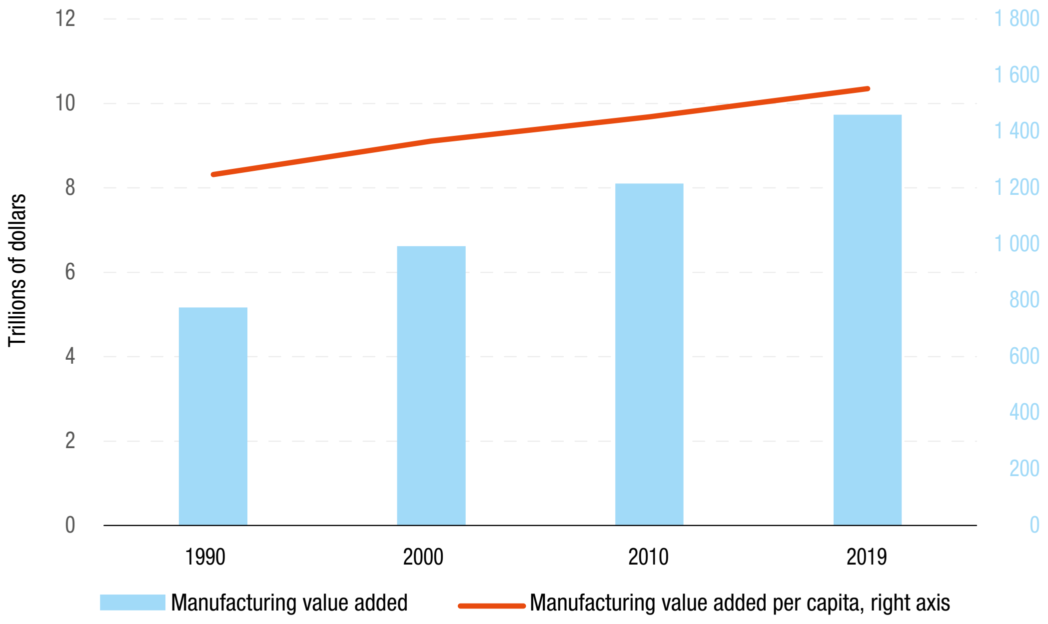


Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

Note: Data for non-commodity dependent developing countries excludes China, the country with the greatest number of manufacturing jobs, since the inclusion of this data would show an even wider gap and a greater increase in the gap in 1995–2017.

In commodity dependent developing countries, the majority of labour that has left the agricultural sector has moved to trade services (wholesale and retail trade; repair of motor vehicles and motorcycles; accommodation and food service activities) and to construction (figure 3.9). In 1995–2017, among all sectors, the trade services sector had the greatest increase in employment share. In 2017 in commodity dependent developing countries, among all services sectors, the trade services sector had the greatest average share of total employment, at 19.3 per cent, and of employment in services, at 43.0 per cent.

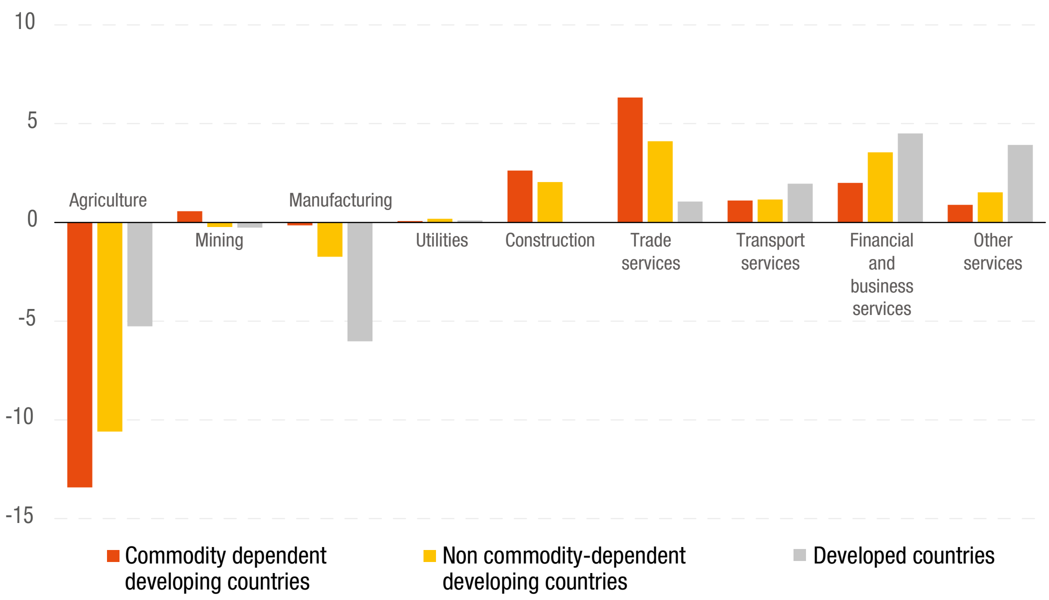
Figure 3.8 **Global manufacturing value added**
(Constant 2015 dollars)



Source: UNCTAD calculations, based on data from the United Nations Industrial Development Organization manufacturing value added 2020 database.

Note: Data for manufacturing value added excludes China, the country with the greatest manufacturing output.

Figure 3.9 **Change in average sectoral employment share, 1995–2017**
(Percentage points)



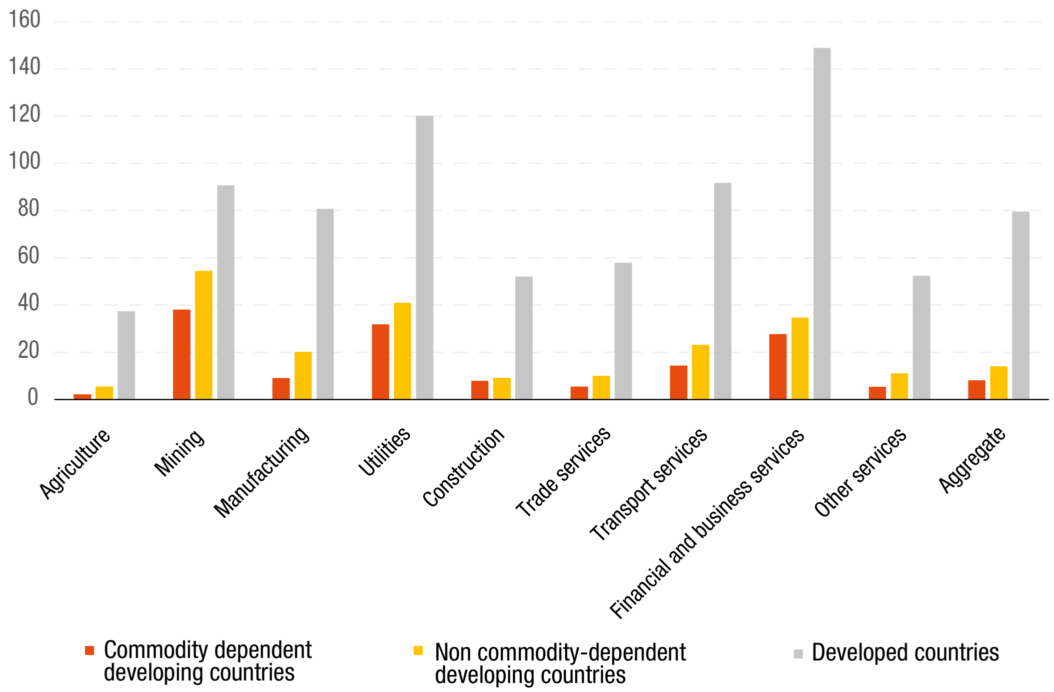
Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

A common feature of the construction and trade services sectors is their position at the lower end of the productivity spectrum not only in commodity dependent developing countries but also in developed countries (figure 3.10). Structural change in the former has disproportionately favoured sectors that appear to have less potential for future productivity growth compared with the manufacturing and other market services sectors. Furthermore, the difference in productivity levels between commodity dependent developing countries and developed countries is lower in trade services than in all other services sectors except other services (non-market services). This limits the potential for productivity gains through convergence effects, which help lower-productivity economies to catch up with higher-productivity economies and appear to be present in many sectors, including in services (International Monetary Fund, 2018). Furthermore, in commodity dependent developing countries, employment shares have shifted largely towards non-tradable sectors in which the potential for future expansion is limited to domestic demand.

There are two additional observations with regard to sectoral labour productivity levels in commodity dependent developing countries.

First, the sector with the highest median labour productivity level in commodity dependent developing countries is mining. However, the potential of this sector to contribute to aggregate labour productivity growth is limited since it generally does not employ many workers and often operates as an enclave with few linkages to other sectors. For example, in Zambia in 2017, the mining sector accounted for 80 per cent of exports but only 2.2 per cent of total employment. The employment share of mining in member States of the Organisation for Economic Co-operation and Development with large mining sectors, such as Australia and Chile, were in a similar range in 2017, at 1.8 and 2.4 per cent of total employment, respectively. In addition, sectoral differences

Figure 3.10 **Median labour productivity levels, 2017**
(Thousands of constant 2010 dollars)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

between median labour productivity levels in commodity dependent developing countries and developed countries is lowest in the mining sector. This could perhaps be explained by the global presence of large international mining companies that apply similar, capital-intensive technologies at mining sites in different countries.

Second, the sector with the second highest median labour productivity level in commodity dependent developing countries is utilities. This sector also does not have the capacity to absorb large numbers of workers. For example, in 2017, the average employment share of the utilities sector in developing countries and developed countries was 0.7 per cent and 1.4 per cent, respectively. These examples show that, while commodity dependent developing countries stand to gain from across-the-board productivity increases, not all sectors have the same potential to absorb large numbers of workers in higher productivity and better paid jobs and thereby generate broad-based development benefits.

As shown in this section, commodity dependent developing countries as a group have not followed a path of industrialization since 1995. Instead, the shares of manufacturing in employment and value added have peaked at significantly lower levels than in non-commodity dependent developing countries and developed countries. Structural change in commodity dependent developing countries has been characterized by a shift of employment shares away from the agricultural sector. Since labour productivity in agriculture remains low in these countries, any flow out of this sector results in productivity-enhancing structural change. However, employment shares have moved primarily towards non-tradable sectors at the lower end of the productivity spectrum, which raises questions about the long-term viability of the structural change path.

3.4 Sectoral productivity trends and drivers

The results of an empirical analysis of the links between labour productivity, commodity dependence and technological development are presented in this section. Based on the observation that aggregate productivity growth in commodity dependent developing countries is lower than that in non-commodity dependent developing countries, the focus is on the identification of the sources of productivity growth that are stunted in the former and the sectors that are most affected. This requires separating aggregate productivity growth into its two components of intrasectoral productivity growth and structural change, then examining intrasectoral productivity growth in each sector separately. There are different ways of disaggregating economy-wide productivity changes and computing average growth rates over time; the method followed here is that of Diao et al. (2017).

The growth rate of economy-wide labour productivity can be disaggregated into the two

$$\frac{\Delta Y_t}{Y_{t-1}} = \sum_i \frac{\theta_{i,t-1}}{Y_{t-1}} (y_{i,t} - y_{i,t-1}) + \sum_i \frac{y_{i,t}}{Y_{t-1}} (\theta_{i,t} - \theta_{i,t-1})$$

where Y and y_i represent economy-wide labour productivity and labour productivity in sector *i*, respectively; *t*, the period; and θ_i, the share of sector *i* in total employment.

The first expression on the right-hand side of the equation is the weighted sum of intrasectoral labour productivity changes in which the weights are the employment shares of the sectors. The second expression is the aggregate productivity change that is due to the sectoral reallocation of labour and is therefore the weighted sum of changes in employment shares in which the weights are the labour productivities of the sectors. The results of the disaggregation described in the equation are shown in table 3.3.

Table 3.3 Disaggregated labour productivity growth
(Percentage)

	Average aggregate growth rate of labour productivity, 1995–2017	Intrasectorial productivity growth	Structural change
Commodity dependent developing countries	1.8	0.8	1.0
Non-commodity dependent developing countries	2.3	1.7	0.6
Developed countries	1.6	1.3	0.3
Full sample	1.9	1.3	0.6

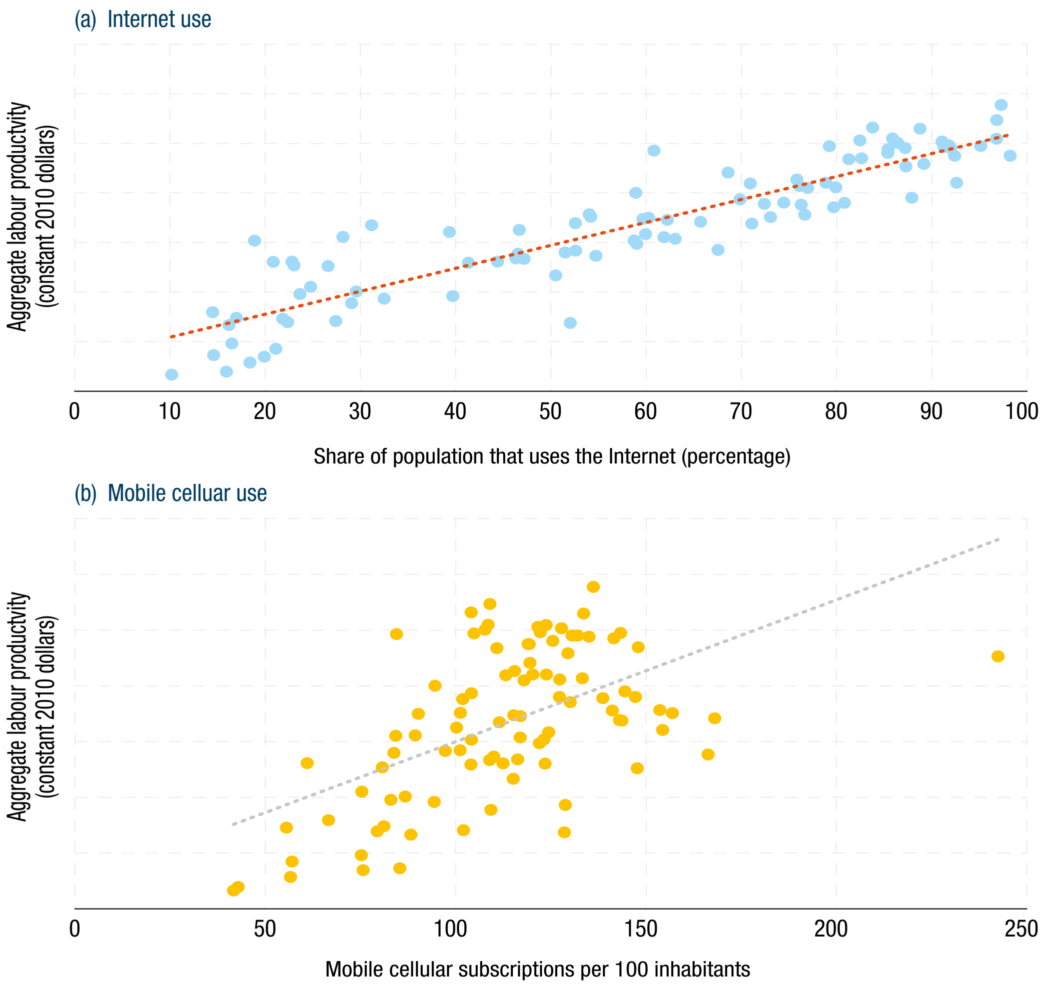
Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

Notes: Labour productivity growth rates are based on real value added in constant 2010 prices. The figures in column 1 differ from the figures in section 3.2 since the latter are based on a data set covering more countries and an additional year.

The results show that aggregate labour productivity growth in commodity dependent developing countries was slower than in non-commodity dependent developing countries, which concurs with the findings analysed in section 3.2. Structural change contributed more to overall productivity growth in commodity dependent developing countries than in non-commodity dependent developing countries and developed countries. This is primarily because in the former, a greater share of labour shifted away from the agricultural sector, which is typically the least productive sector. It is important to note that agriculture in these countries accounted for substantially greater average employment shares than in other country groups at the start of and throughout the period 1995–2017. For example, in 1995, the average share of employment in the agricultural sector was 51.5 per cent in commodity dependent developing countries and 31.8 per cent in non-commodity depending developing countries. Average intrasectoral productivity growth rates in non-commodity dependent developing countries were more than twice as great as those in commodity dependent developing countries and intrasectoral productivity growth in the latter was outpaced by that in developed countries. Furthermore, labour productivity in non-commodity dependent developing countries grew faster than the global average, while the opposite was observed in commodity dependent developing countries.

The results serve as a starting point for further analysis (see Csordás, 2021). Based on the observation that commodity dependent developing countries feature lower levels of intrasectoral productivity growth, a series of regressions may be carried out in which the average growth rates of labour productivity within individual sectors in 1995–2017 are the variables to be explained. This allows for an investigation of whether the link between commodity dependence and a lower level of intrasectoral labour productivity growth is uniform or heterogenous across sectors. The key explanatory variable is the average annual share of primary commodities in total merchandise exports as a measure of commodity dependence. Since there is a strong positive correlation between indicators of technological development and aggregate labour productivity, the average share of the population that uses the Internet and, alternatively, the number of mobile cellular subscriptions per 100 inhabitants, are included in the regressions as proxies for such indicators (figure 3.11). The control variables include the average human capital index, the average annual share of gross capital formation in GDP, the average annual population growth and the initial level (that is, in 1995) of sectoral labour productivity.

Figure 3.11 **Average aggregate labour productivity and indicators of technological development, 2015–2017**



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, the International Telecommunication Union and the UNCTADstat database.

Note: The y axes show the natural logarithm of aggregate labour productivity.

Technological development is expected to be positively associated with productivity growth. Likewise, a higher level of human capital and greater shares of gross capital formation in GDP, which is a measure of physical investment, are expected to be associated with higher levels of labour productivity growth. Population growth may be negatively related to labour productivity growth since the latter is a per capita measure. Finally, if there is conditional convergence at the sectoral level, countries with a lower initial level of labour productivity are expected to have greater labour productivity growth rates. The descriptive statistics for the main variables included in the regression are shown in table 3.4.

The results show that commodity dependence is primarily linked with lower levels of labour productivity growth in the manufacturing sector. With regard to the manufacturing sector in different country groups, the average share of primary commodities in exports and the average growth rate of labour productivity is presented in figure 3.12, showing a negative association between commodity dependence and productivity growth in manufacturing.

Table 3.4 Main variables

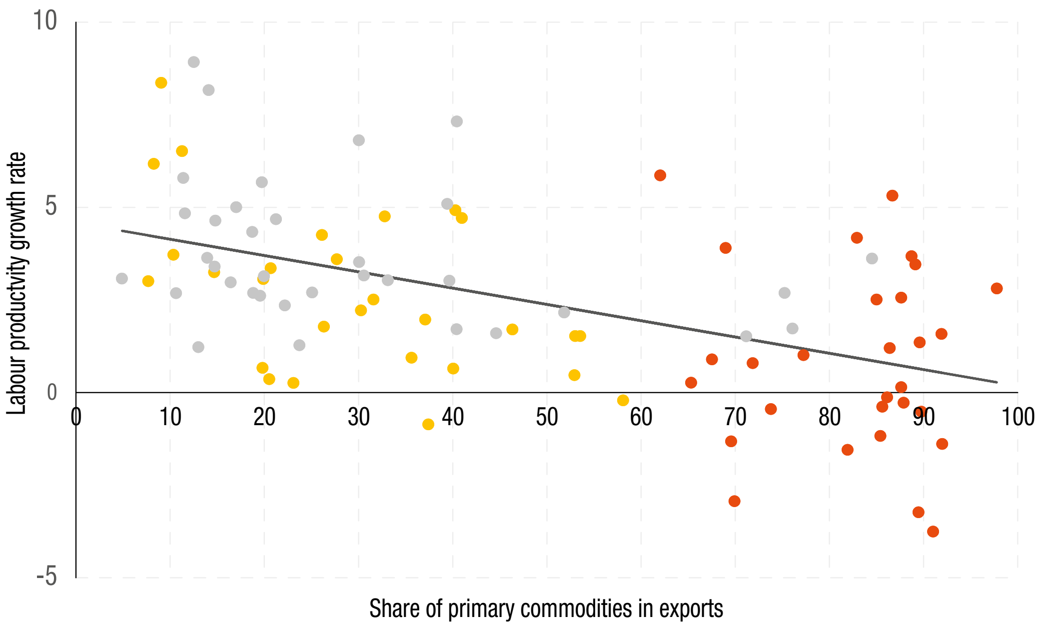
Indicator	Description	Mean	Standard deviation	Number of observations	Data source
Commodity dependence	Share of primary commodities, precious stones and non-monetary gold in total merchandise exports (percentage)	46.40	29.7	2 162	UNCTADstat database
Technological development 1	Share of population using the Internet (percentage)	30.63	30.15	2 110	World Development Indicators database
Technological development 2	Number of mobile cellular subscriptions per 100 inhabitants	64.08	50.29	2 130	World Development Indicators database
Human capital	Human capital index based on years of schooling and returns to education	2.62	0.66	2 116	Penn World Table, version 9.1
Investment	Average annual share of gross capital formation in GDP (percentage)	24.16	6.37	2 047	World Development Indicators database
Population growth	Average annual growth rate	1.22	1.39	2 139	World Development Indicators database

Source: UNCTAD.
Note: Primary commodities, precious stones and non-monetary gold are those referred to by United Nations standard international trade classification 0 + 1 + 2 + 3 + 4 + 68 + 667 + 971.

The measures of human capital, technological development and investment show a statistically significant positive association with labour productivity growth in the manufacturing sector and the estimated coefficient of the initial level of labour productivity is negative and statistically significant. With regard to the other sectors, there is a robust, statistically highly significant negative association between the initial level of labour productivity and labour productivity growth in all sectors except agriculture, which suggests that there was broad-based conditional convergence, although at different rates, in 1995–2017. This finding complements the results of a study by the International Monetary Fund (2018) that found evidence of an unconditional convergence of productivity levels in most sectors but not in agriculture.

The link between human capital, technological development and investment, on the one hand, and labour productivity growth, on the other hand, is not homogeneous across sectors. This suggests that, while broad-based investments in education, technology and infrastructure are likely to yield aggregate productivity gains, their impact may be maximized if sector-specific challenges and opportunities are taken into account. Such targeted measures could, for example, consist of developing the specific skills required for employment in emerging manufacturing and services sectors.

Figure 3.12 **Manufacturing sector, 1995–2017**
(Percentage)



Source: UNCTAD calculations, based on data from Dieppe and Matsuoka, 2020, and the UNCTADstat database.

Note: The negative association is statistically significant at the 99 per cent level across a range of model specifications.

As shown in this section, commodity dependence can be an impediment in developing countries aiming to industrialize on the way to achieving the Sustainable Development Goals. A positive message for commodity dependent developing countries is that there is ample scope for labour productivity growth in both of its components. The significant distance of the productivity levels in virtually all sectors in these countries to the global productivity frontier represents significant potential for aggregate productivity growth through intrasectoral productivity gains. Similarly, the significant productivity differences across sectors in these countries highlight the potential of structural change to contribute to aggregate productivity growth.

3.5 Conclusion

The link between commodity dependence, labour productivity trends and structural change was examined in this chapter, showing that commodity dependence is associated with low levels of labour productivity, slow productivity growth and a high frequency of negative productivity shocks.

Commodity dependent developing countries have not followed a path of industrialization since 1995 and their levels of industrialization appear to have peaked at much lower shares of manufacturing in employment and value added than in non-commodity dependent developing countries and developed countries. Structural change in the former has been characterized by a shift of employment shares from agriculture towards construction and non-tradable services sectors. The greatest increase in absolute and relative employment was concentrated in low-productivity services such as retail and wholesale trade. Growth in these sectors is largely limited to the confines of the domestic economy and does not benefit from trade expansion. In addition, productivity growth through potential convergence in these sectors is limited since they are on the lower-productivity end and distant from the global productivity frontier. This raises questions about the sustainability of the current development path in these countries.

A positive view of the large gap between productivity levels in commodity dependent developing countries and the global frontier is that it represents substantial potential for intrasectoral productivity growth. In addition, while the highest-productivity sectors in these countries, namely, mining and utilities, have limited potential to absorb labour, there are also substantial productivity differences between agriculture and manufacturing and between different services sectors, which represent substantial potential for aggregate productivity growth through structural change. Technological upgrading can play an important role in this process.

The empirical analysis suggests that commodity dependence is associated with lower levels of intrasectoral productivity growth in the manufacturing sector. This constitutes a policy challenge in commodity dependent developing countries since the manufacturing sector plays an important role in the development process. For example, the manufacturing sector traditionally employs a significantly greater share of low-skilled workers than services (Hallward-Driemeier and Nayyar, 2018). Furthermore, manufacturing creates tradable goods, so that the growth of manufacturing is not limited to the domestic market, which is relatively small in many commodity dependent developing countries. An increase in manufacturing exports reduces dependence on commodities, moving a country beyond the negative effects of commodity dependence discussed in chapter 1.

The manufacturing sector also tends to generate stronger backward and forward linkages, so that manufacturing growth can generate multiplier and spillover effects that benefit other sectors of the economy and aggregate growth. Sustainable industrialization, as aimed for under Goal 9, should therefore remain high on the agenda in many commodity dependent developing countries. However, given the ongoing expansion of services sectors in these countries, it is also important to devise strategies that enhance services-led growth through, for example, its contribution to employment generation, technological development and economy-wide productivity gains.

The importance of diversifying production and export patterns in commodity dependent developing countries and reducing commodity dependence is highlighted in this chapter. Strengthening broad-based drivers of labour productivity, including education, technology and infrastructure, are necessary in order to raise productivity levels across the board. However, horizontal policies need to be complemented by targeted measures that address sector-specific obstacles to productivity growth (see chapter 5). For example, skills development programmes need to ensure that the flow of labour into higher-productivity sectors is not limited by a lack of workers with the appropriate skill set. Technological upgrading and innovation that spurs productivity growth within individual sectors should be enabled and promoted through the development of adequate infrastructure, including digital infrastructure. The following chapters highlight how technology can help to reduce commodity dependence, spur innovation and drive productivity growth, along with a range of policy measures that can support structural change and productivity growth and thereby help commodity dependent developing countries embark on a more resilient and sustainable development path.

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Appendix

A. Economies included in the data set used in section 3.2

Commodity dependent developing countries	Non-commodity dependent developing economies	Developed countries	Transition economies
Afghanistan	Bahamas	Australia	Albania
Algeria	Bangladesh	Austria	Armenia
Angola	Bhutan	Belgium	Azerbaijan
Argentina	Brazil	Bulgaria	Belarus
Bahrain	Cabo Verde	Canada	Bosnia and Herzegovina
Belize	Cambodia	Croatia	Georgia
Benin	China	Cyprus	Kazakhstan
Bolivia (Plurinational State of)	Hong Kong SAR	Czechia	Kyrgyzstan
Botswana	Costa Rica	Denmark	Montenegro
Burkina Faso	Dominican Republic	Estonia	Republic of Moldova
Burundi	Egypt	Finland	Russian Federation
Cameroon	El Salvador	France	Serbia
Central African Republic	Eswatini	Germany	Tajikistan
Chad	Guatemala	Greece	Turkmenistan
Chile	Haiti	Hungary	Ukraine
Colombia	Honduras	Iceland	Uzbekistan
Comoros	India	Ireland	
Democratic Republic of the Congo	Indonesia	Italy	
Congo	Israel	Japan	
Côte d'Ivoire	Jordan	Latvia	
Ecuador	Republic of Korea	Lithuania	
Equatorial Guinea	Lebanon	Luxembourg	
Ethiopia	Lesotho	Malta	
Fiji	Liberia	Netherlands	
Gabon	Madagascar	New Zealand	
Gambia	Malaysia	Norway	
Ghana	Mauritius	Poland	
Guinea	Mexico	Portugal	
Guinea-Bissau	Morocco	Romania	
Guyana	Nepal	Slovakia	
Iran (Islamic Republic of)	Pakistan	Slovenia	
Iraq	Panama	Spain	
Jamaica	Philippines	Sweden	
Kenya	Samoa	Switzerland	
Kuwait	Singapore	United Kingdom	

Commodity dependent developing countries	Non-commodity dependent developing economies	Developed countries	Transition economies
Lao People's Democratic Republic	South Africa	United States	
Malawi	Sri Lanka		
Maldives	Saint Vincent and the Grenadines		
Mali	Thailand		
Mauritania	Tunisia		
Mongolia	Turkey		
Mozambique	Viet Nam		
Myanmar			
Namibia			
Nicaragua			
Niger			
Nigeria			
Oman			
Papua New Guinea			
Paraguay			
Peru			
Qatar			
Rwanda			
Saudi Arabia			
Senegal			
Seychelles			
Sierra Leone			
Solomon Islands			
Saint Lucia			
Sudan			
Suriname			
Sao Tome and Principe			
United Republic of Tanzania			
Timor-Leste			
Togo			
Tonga			
Uganda			
United Arab Emirates			
Uruguay			
Vanuatu			
Zambia			
Zimbabwe			

Abbreviation: SAR, Special Administrative Region.

B. Economies included in the data set used in sections 3.3 and 3.4

Commodity dependent developing countries	Non-commodity dependent developing economies	Developed countries	Transition economies
Argentina	Bangladesh	Australia	Russian Federation
Belize	Brazil	Austria	Serbia
Bolivia (Plurinational State of)	China	Belgium	
Botswana	Hong Kong SAR	Bulgaria	
Burkina Faso	Taiwan Province of China	Canada	
Cameroon	Costa Rica	Croatia	
Chile	Dominican Republic	Cyprus	
Colombia	Egypt	Czechia	
Ecuador	Eswatini	Denmark	
Ethiopia	Honduras	Estonia	
Fiji	India	Finland	
Ghana	Indonesia	France	
Iran (Islamic Republic of)	Jordan	Germany	
Jamaica	Lesotho	Greece	
Kenya	Malaysia	Hungary	
Lao People's Democratic Republic	Mauritius	Iceland	
Malawi	Mexico	Ireland	
Mongolia	Morocco	Italy	
Mozambique	Pakistan	Japan	
Namibia	Philippines	Latvia	
Nigeria	Republic of Korea	Lithuania	
Paraguay	Singapore	Luxembourg	
Qatar	South Africa	Netherlands	
Rwanda	Sri Lanka	New Zealand	
Saint Lucia	Saint Vincent and the Grenadines	Norway	
Senegal	Thailand	Poland	
Uganda	Turkey	Portugal	
United Republic of Tanzania	Viet Nam	Romania	
Zambia		Slovakia	
		Slovenia	
		Spain	
		Sweden	
		Switzerland	
		United Kingdom	
		United States	

Abbreviation: SAR, Special Administrative Region.

CHAPTER

4

Structural Transformation through Technological Change and Innovation

4.1 Introduction

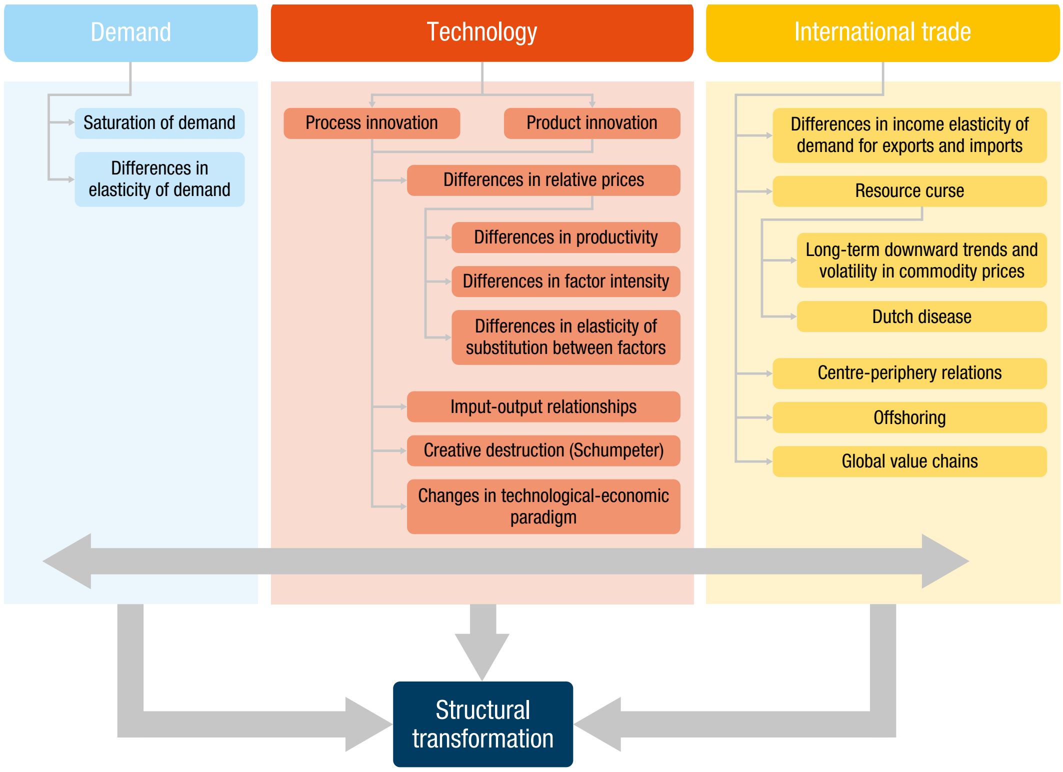
Commodity dependence is persistent, difficult to emerge from and associated with lower levels of productivity in the manufacturing sector, as shown in the previous chapters. Therefore, any policy intervention to improve technological capacities in commodity dependent developing countries, to reduce commodity dependence, needs to focus on increasing labour productivity in the manufacturing sector. Productivity in these countries may also be low in agriculture and, comparatively, in services. Technological upgrading in these sectors may therefore also be important.

The ways in which technological change and innovation for economic diversification have an impact on structural transformation in commodity dependent developing countries are discussed in this chapter. The technological transformation of an economy happens through innovation, namely, production that is new in the country (product innovation) or production that modifies existing methods to increase productivity and reduce costs (process innovation).[21] Both forms of innovation trigger shifts in income, consumption, employment and output, which result in changes in the structure of the economy, that is, the relative shares of output and employment in different sectors. Technological change also affects the economic structure through input–output relationships between sectors, such as a change in final product prices due to a change in the prices of intermediate products. The process of creating new products that replace old ones, in the Schumpeterian process of creative destruction, and the long-term changes in the economy and society due to the emergence of new technological–economic paradigms, also have an impact on the structure of the economy. However, technological change is not the only driver of structural transformation; changes in domestic and global demand and in international trade patterns also affect the structure of the economy (figure 4.1). A recent survey of the literature identifies the various channels through which changes in technology, demand and trade patterns impact structural transformation (Cantore and Alcorta, 2021). Changes in demand affect the dynamics of structural transformation through differences in the elasticity of demand (for example, demand for staple foods is less elastic with regard to increases in income than demand for consumer electronics) and the saturation of demand (for example, there are limits to the amount of consumption of staple foods). Changes in international trade prices and patterns affect the structure of the economy through differences in the income elasticity of demand for exports and imports. Another critical driver, in particular in commodity dependent developing countries, is the "resource curse" due to long-term downward trends and volatility in commodity prices, as well as the effects of Dutch disease. Another driver is the differences between developed and developing countries in technological diffusion, product specialization and the impact on terms of trade, constraining economic growth and affecting the likelihood of diversification out of commodity sectors. Such differences have been studied in the Latin American structuralist literature that considers the impacts of technological gaps and trade relations between developed countries at the centre of the global economy and developing countries at the periphery (see, for example, Prebisch, 1950). Globalization and the effects of offshoring and global value chains also affect changes in the structure of the economy.

Such changes in technology, demand and trade patterns are intertwined in complex ways. Nevertheless, technological change can be considered the prime mover of structural economic dynamics (Pasinetti, 1993). It affects demand through changes in income, input–output relationships and the substitution or complementarity of products and it has an impact on international trade through effects on the relative prices of products in global markets. Escaping the commodity dependence trap implies that commodity dependent developing countries will experience these changes.

21 With regard to agricultural products, process innovation also relates to compliance with measures, including sanitary and phytosanitary standards and technical barriers to trade, implemented either domestically or in export destination markets.

Figure 4.1 **Drivers of structural transformation**



Source: UNCTAD, based on Cantore and Alcorta, 2021.

Technological transformation leads to structural transformation when innovation changes the structure of an economy by moving employment and output from low-productivity sectors to higher-productivity sectors. Higher-productivity sectors are generally associated with higher levels of technology. Both process and product innovation can result in structural transformation, yet in commodity dependent developing countries, process innovation and the resulting increase in productivity tend to result in lower prices for agricultural produce or lower levels of employment in the fuels and mining sectors. However, product innovation leads to economic diversification and the creation of new sectors with new opportunities for employment and further gains in productivity through subsequent learning by doing and process innovation.

This chapter is focused on the impact of technological change on structural transformation through product innovation and economic diversification. Stylized facts are presented in section 4.2 related to technological change, diversification and structural transformation, based on recent literature providing economic complexity perspectives on structural transformation, which show that product innovation towards more complex products, and the resulting economic diversification, is essential for structural transformation.[22] In section 4.3, the position of commodity dependent developing countries is discussed in terms of the technological landscape and gaps in comparison with more technologically advanced economies. In section 4.4, a summary and conclusions are provided.

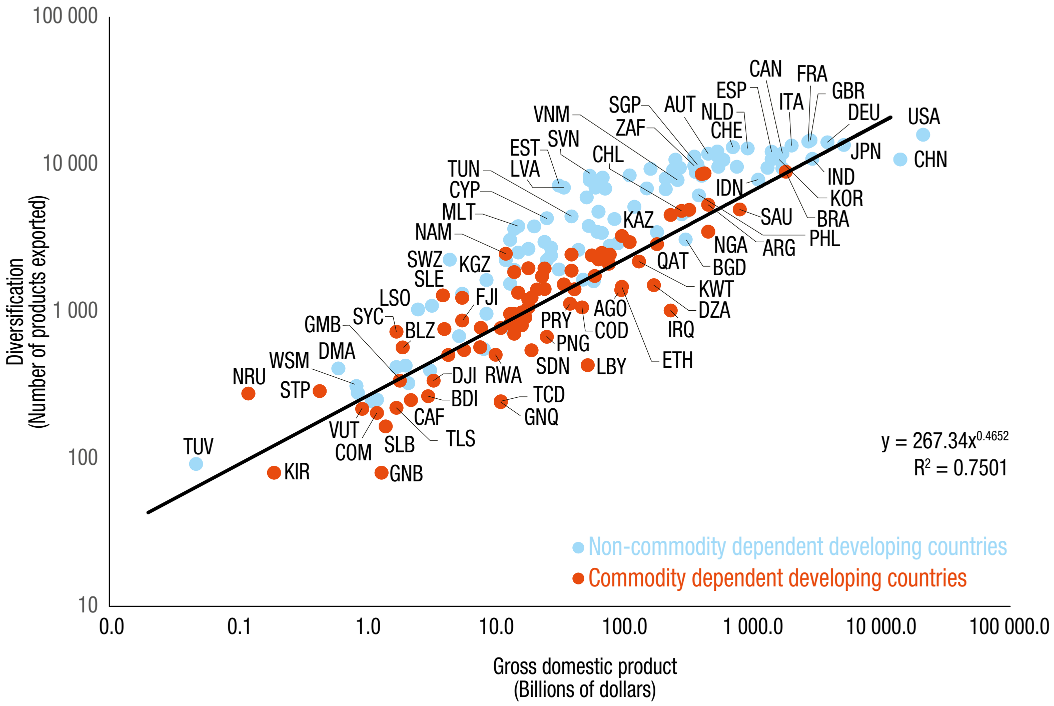
22 For a review of the literature, see Freire, 2021.

4.2 Stylized facts

Product innovation, adding more productive sectors, is critical for economic diversification. With more jobs and production in higher-productivity sectors, the size of an economy expands. Diversification is therefore associated with higher levels of total GDP (figure 4.2).[23] However, most commodity dependent developing countries are less diversified than non-commodity dependent developing countries with similar levels of GDP, meaning that the former generate a higher level of output from fewer sectors, which may help explain why they may remain in a state of commodity dependence for a long time.

Each product requires specific technologies in order to be produced and these technologies are not limited to those in a firm or farm but encompass the entire chain needed to create and bring the product to the market. They include capital-embodied technologies, such as machines, vehicles, buildings and infrastructure, and labour-embodied technologies, such as business models, operational procedures and know-how. Therefore, the more diversified an economy, the higher its level of technological development; and the higher the level of the technological

Figure 4.2 **Diversification and output, 2019**



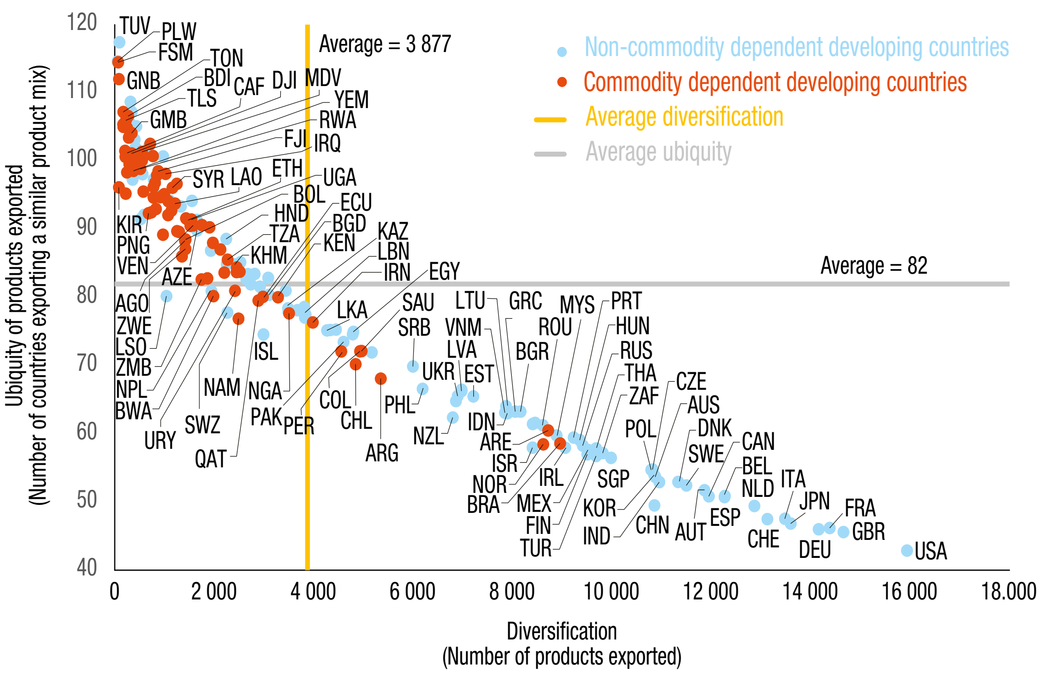
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The number of products is based on United Nations standard international trade classification (5-digit level), revision 3, disaggregated by unit value as proposed in Freire (2017). Names of economies are abbreviated using International Organization for Standardization alpha-3 codes.

23 See, for example, Economic and Social Commission for Asia and the Pacific, 2011, and Freire, 2017. Studies focused on the association between diversification and income per capita find that diversification is associated with economic development along most of the development trajectory of a country; the relationship is non-monotonic (Cadot et al., 2010; Imbs and Wacziarg, 2003). The less-studied relationship between diversification and total GDP is highlighted in this chapter (Freire, 2019; Lei and Zhang, 2014).

development of products, the fewer the countries that can produce and market them. Higher levels of diversification are therefore also associated with less competition in export markets. As shown in figure 4.3, in 2019, the average indicator of diversification was 3,877 products and the average ubiquity of exports, or number of countries competing by exporting a similar basket of products, was 82. Most of the more diversified countries facing less competition than the global average are non-commodity dependent developing countries. The exceptions are Argentina, Brazil, Chile, Colombia, the Islamic Republic of Iran, Peru, Saudi Arabia and the United Arab Emirates. Most commodity dependent developing countries have diversification levels below the global average and face competition from over 82 countries that export similar products.

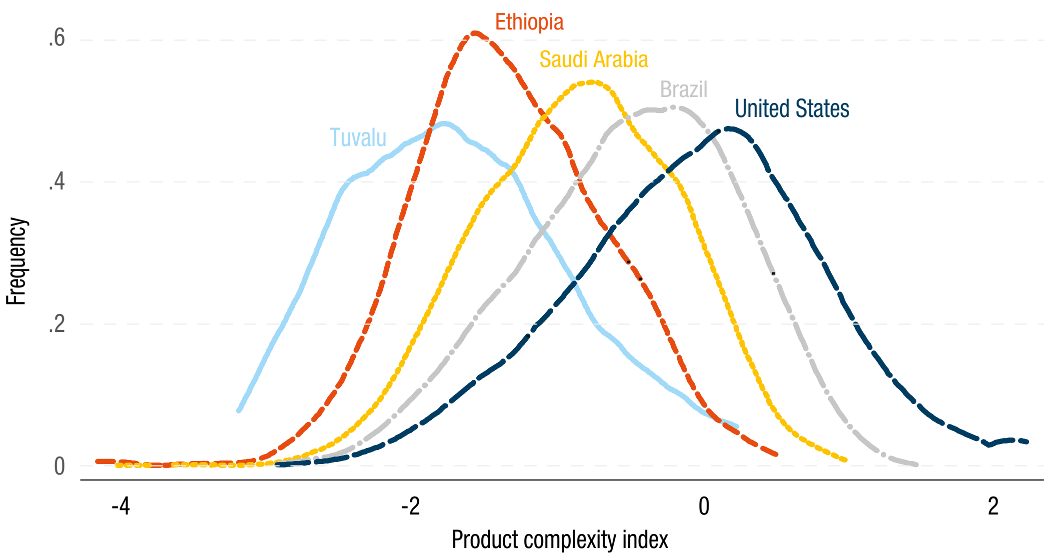
Information about the national level of diversification and ubiquity of exports is used to compute economic complexity indices that act as proxies for the levels of technology and productive capacities in an economy (Hidalgo and Hausmann, 2009; Tacchella et al., 2012). Indices are also used to estimate the level of technology involved in the production of each product. More complex products are considered to require higher levels of technology. Countries produce products of a range of complexity. Usually, the distribution of the product complexity of exports has a normal distribution shape, as shown in figure 4.4, which illustrates how the distribution of the product complexities of countries overlap, even among countries with different levels of technological and productive capacity. Development is associated with diversification towards products with above-average complexity (Freire, 2017). This may be seen, for example, with regard to Viet Nam (figure 4.5).

Figure 4.3 **Diversification and exports, 2019**



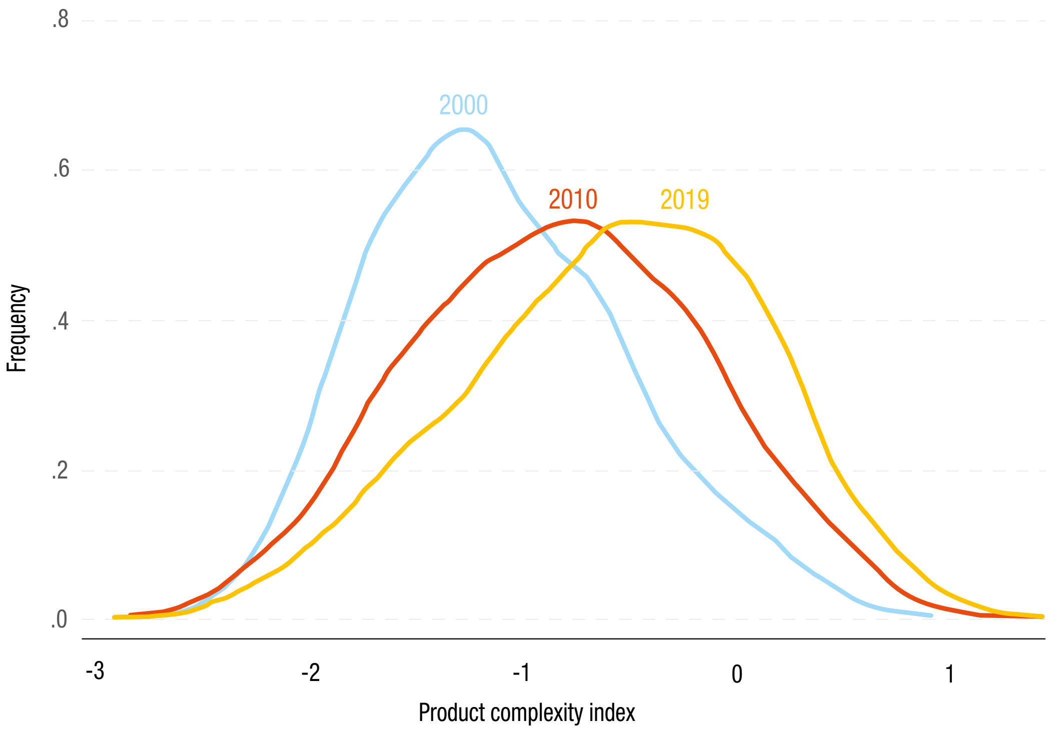
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The number of products is based on United Nations standard international trade classification (5-digit level), revision 3, disaggregated by unit value as proposed in Freire (2017). Names of economies are abbreviated using International Organization for Standardization alpha-3 codes.

Figure 4.4 **Complexity of product mix of exports, 2019**



Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Frequency in the y axis represents the share of the number of product categories with a given complexity (x axis) in total exports. For the index, 0 = global average and 1 = standard deviation.

Figure 4.5 **Viet Nam: Increasing complexity of product mix of exports**

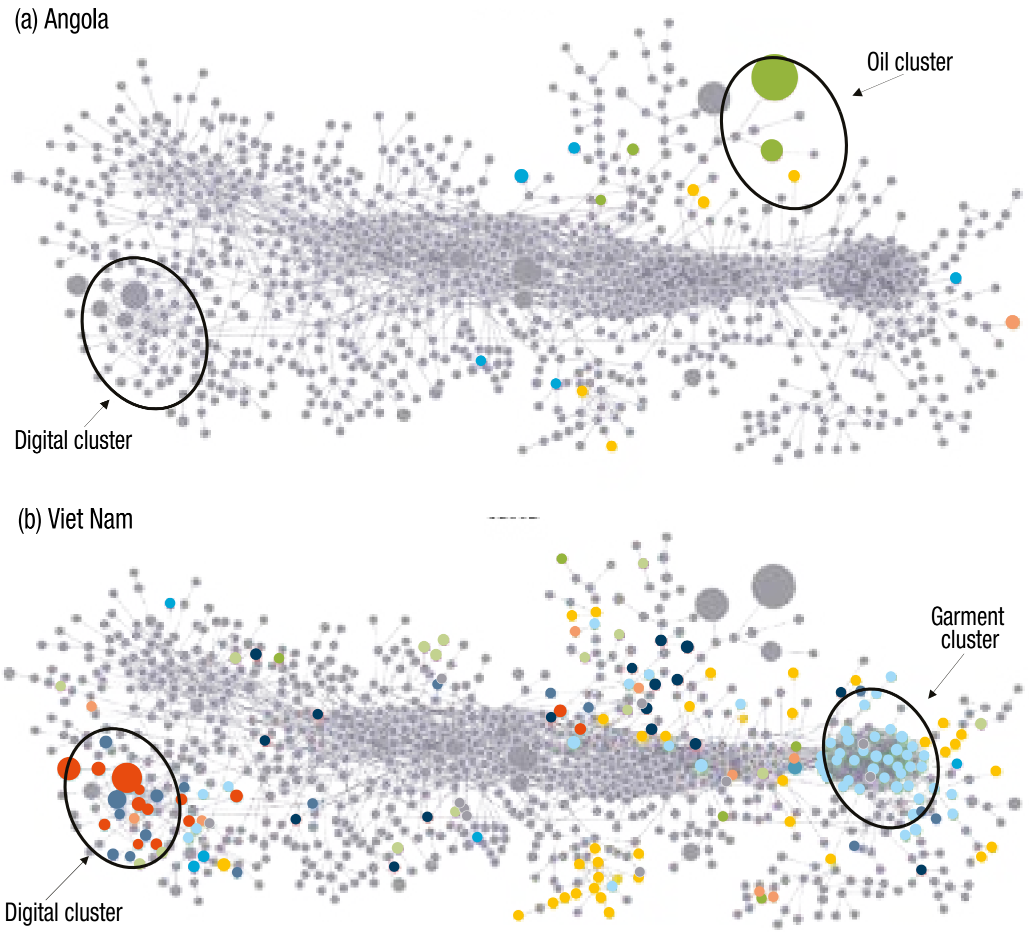


Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Frequency in the y axis represents the share of the number of product categories with a given complexity (x axis) in total exports. For the index, 0 = global average and 1 = standard deviation.

If innovation is critical for structural transformation, how can this process be fostered? It is important to note that innovation is a combination of existing technologies in new configurations or economic activities. Therefore, innovation is path dependent; it depends on the set of technologies already accumulated in an economy. Research on economic complexity has produced maps that illustrate such path dependency (Hidalgo et al., 2007). The product spaces of Angola and Viet Nam are shown in figure 4.6, whereby each node represents a product and they are connected based on how likely products are to be exported jointly. Some products connect to many other products. For example, the production of machinery and electronics requires technologies that may be the building blocks of production in many different sectors. Therefore, diversification toward these products can facilitate further diversification in the future. Other products may be seen as dead ends since, once a country reaches their level of production, it is difficult to use the capabilities they have to move to another product. Most such products are commodities; the production of primary products usually involves technologies that offer fewer possibilities for further combinations and, thereby, diversification. As shown in the figure (panel (a)), the example of Angola illustrates the situation in commodity dependent developing countries, with the distance evident between the products that are exported by Angola at a comparative advantage over other countries, namely, oil products, and the products that are not exported by Angola. The figure indicates that technological and productive capacities are not easily transferable to production in the digital cluster without a more direct promotion of this cluster. Larger jumps in innovation, whereby some of the technologies needed are not available in an economy and must be learned or transferred from abroad, require more support from Governments. Viet Nam is an example of a country that has successfully diversified its economy (figure 4.6, panel (b)). In the 1990s, Viet Nam was at the same level of development as the least developed countries. Viet Nam has succeeded in increasing its technological and productive capacity to further industrialize its economy and expand production from agriculture and low value added manufacturing such as of garments to production in the digital cluster. In 2005–2018, according to data from the UNCTADstat database, the share of high-technology exports increased from 6 to 35 per cent and the share of exports of primary resources decreased from 52 to 22 per cent. The push for industrialization began in the 1990s, with an industrial and trade policy that merged import substitution measures and export subsidies to promote an export-driven growth strategy, supported by strong foreign direct investment. Other policies have also contributed to productive development, including with regard to the establishment of export processing and industrial zones, the development of urban infrastructure and the enhancement of education (United Nations Human Settlements Programme, 2015).

Innovation requires the exchange of knowledge among the main actors of national innovation systems, namely, Governments, firms, research centres, universities, consumers and financial institutions. Firms and their entrepreneurs have the critical role of taking the risk to innovate by bringing a new good or service to the market. Innovators need financing to obtain the resources to innovate. The decision to innovate therefore depends on many factors, not only the availability of and access to technology. Global demand for new or improved products affects incentives for innovation. Although short-lived in comparison with periods of low prices, high commodity prices also create incentives in commodity dependent developing countries to produce more of the same and therefore remain commodity dependent, thereby reducing the incentive to innovate and diversify the economy. They also contribute to deindustrialization due to the tendency for currency overvaluation. In periods of low commodity prices, the challenges to diversification relate to declining resources, particularly hard currency for importing capital goods. Fiscal constraints faced by Governments may prevent them from providing the required complementary infrastructure and quality education to increase the capacity of the economy for technological learning and innovation.

Figure 4.6 **Product space**



Source: UNCTAD calculations, based on data from the Harvard University Atlas of Economic Complexity.
Note: Each node represents a product; if a node is connected to another, it means the country also exports the connected product.

4.3 Technological landscape and gaps

The technological landscape and gaps characterizing most commodity dependent developing countries with regard to the three major commodity groups of agricultural products, fuel-related products and minerals, ores and metals are presented in this section. The discussion is focused not only on commodity sectors but also on the whole economy, including other sectors such as manufacturing and services, to provide a full picture of the technological situation in commodity dependent developing countries and how they compare with other countries.

What is the level of technological development in commodity dependent developing countries? There are several ways to give a partial answer to this question, based, for example, on the level of labour productivity (output per worker); the export capacity for high-technology goods and digitally deliverable services; and human capacity and infrastructure to be able to use technology. Assessed against such measures, commodity dependent developing countries have on average lower level of technological capacity than non-commodity dependent developing countries, transition economies and developed countries (table 4.1).

Table 4.1 **Selected indicators of technological development**
(Median)

	Commodity dependent developing countries	Non-commodity dependent developing countries	Transition economies	Developed countries
Labour productivity, 2020 (2011 dollars, purchasing power parity)	13 965	32 116	35 299	86 068
Merchandise exports as share of global merchandise exports, 2019 (percentage)	0.11	0.60	0.21	1.39
High-technology manufactures exports as share of total merchandise trade, 2019 (percentage)	0.02	0.03	0.04	0.59
Digitally deliverable services exports as share of total service trade, 2019 (percentage)	17	18	15	40
ICT services exports as share of service exports, balance of payments, 2017 (percentage)	3	5	8	8
Number of researchers in research and development per million people, 2018	396	1 856	1 120	6 970
Number of Internet users as share of population, 2017 (percentage)	27	56	65	87
Mean download speed, 2020 (megabits per second)	1	4	7	31

Source: UNCTAD calculations, based on data from Fastmetrics, the International Labour Organization, the International Telecommunication Union, the UNCTADstat database, the United Nations Educational, Scientific and Cultural Organization and the World Integrated Trade Solution database.

In this section, the concept of economic complexity is used as a proxy for the level of technological development in a country, to assess the status and evolution of technological development in commodity dependent developing countries. The technological development index values of the latter are shown in table 4.2 (see the appendix for the index values of 196 economies). The leading commodity dependent developing countries are Brazil (32.7), the United Arab Emirates (29.7) and Argentina (14.9) and those with the lowest values are South Sudan, Kiribati, Guinea-Bissau and the Federated States of Micronesia.

The level of technological development in commodity dependent developing countries is low compared with in the United States, as is also true for most other countries. A comparison of the level of technological capacity in commodity dependent developing countries with that in other country groups indicates that there is a wide range of index values in each group (figure 4.7). The average is not a good summary measure because there are outliers with higher values that push up the measure. The median in commodity dependent developing countries (1.55) is lower than that in other groups, followed by transition economies (4.80), non-commodity dependent developing countries (5.17) and developed countries (34.36). A similar pattern is seen in the maximum values of each group: commodity dependent developing countries (32.69); transition economies (34.75); non-commodity dependent developing countries (53.92); and developed countries (100). It is notable that in each group, the economies at the bottom have similar lower values of technological

Table 4.2 **Commodity dependent developing countries: Technological development index, 2019**

Brazil	32.7
United Arab Emirates	29.7
Argentina	14.9
Chile	12.6
Colombia	12.3
Saudi Arabia	12.2
Peru	11.2
Iran (Islamic Republic of)	9.1
Nigeria	7.4
Kenya	6.6
Ecuador	6.0
Qatar	5.8
Namibia	5.2
Uruguay	4.9
Oman	4.6
Ghana	4.6
Bahrain	4.5
Kuwait	4.0
United Republic of Tanzania	4.0
Botswana	3.9
Myanmar	3.6
Madagascar	3.4
Senegal	3.3
Zambia	3.2
Cameroon	3.0
Côte d’Ivoire	2.8
Venezuela (Bolivarian Republic of)	2.5
Algeria	2.4
Zimbabwe	2.4
Bolivia (Plurinational State of)	2.4
Uganda	2.4
Angola	2.3
Trinidad and Tobago	2.3
Ethiopia	2.2
Mozambique	2.2
Sierra Leone	2.1
Afghanistan	1.9
Lao People’s Democratic Republic	1.8
Togo	1.8
Paraguay	1.8
Syrian Arab Republic	1.7

Table 4.2 **Commodity dependent developing countries: Technological development index, 2019** *(continued)*

Mali	1.6
Mongolia	1.5
Democratic Republic of the Congo	1.5
Jamaica	1.4
Brunei Darussalam	1.4
Iraq	1.4
Gabon	1.3
Niger	1.2
Fiji	1.2
Guinea	1.1
Burkina Faso	1.1
Seychelles	1.1
Malawi	1.1
Congo	1.1
Papua New Guinea	1.0
Suriname	1.0
Benin	0.9
Belize	0.8
Mauritania	0.7
Sudan	0.7
Maldives	0.7
Guyana	0.6
Rwanda	0.6
Libya	0.6
Yemen	0.5
Djibouti	0.4
Gambia	0.4
Sao Tome and Principe	0.3
Nauru	0.3
Central African Republic	0.3
Equatorial Guinea	0.3
Burundi	0.3
Vanuatu	0.3
Chad	0.3
Somalia	0.3
Comoros	0.2
Timor-Leste	0.2
Eritrea	0.2
Solomon Islands	0.2
Tonga	0.2
South Sudan	0.1

Table 4.2 **Commodity dependent developing countries: Technological development index, 2019** *(continued)*

Kiribati	0.1
Guinea-Bissau	0.1
Micronesia (Federated States of)	0.0

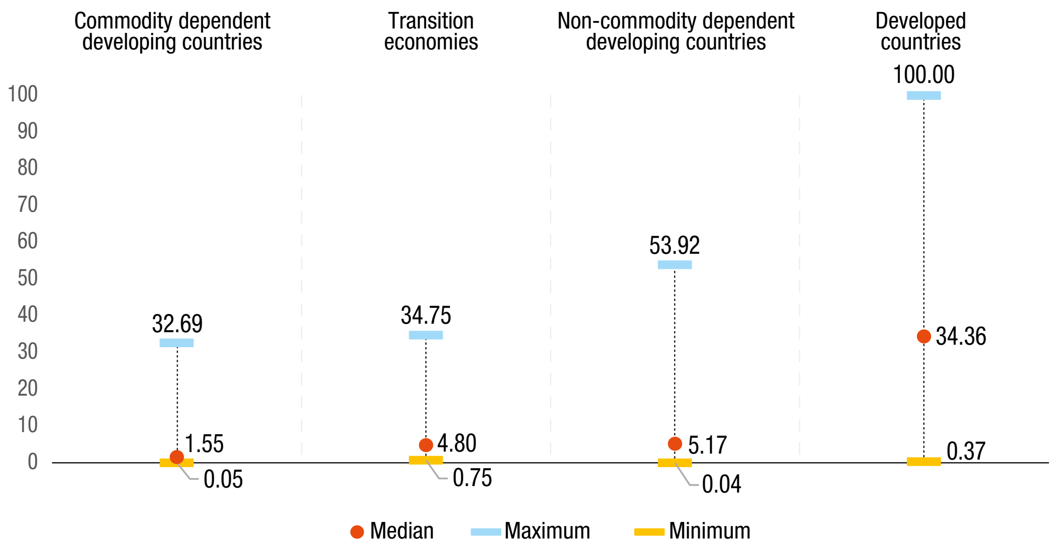
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

development, even among developed countries, mainly represented by economies with small populations that have reached a high level of GDP per capita due to high value services such as finance and high-end tourism.

Among commodity dependent developing countries, the median among the countries that are more reliant on agricultural product exports usually has a lower level of technological development than the median among countries dependent on mining and on fuel-related products (figure 4.8). This reflects the fact that the fuels and mining sectors are more capital-intensive than agriculture, although they usually operate as enclaves dominated by multinational enterprises. However, the range of values of the level of technological development in those countries dependent on agricultural products and on fuel-related products is greater than that in countries dependent on mining, which may be due to the smaller set of the latter countries (10) compared with the other subgroups. Therefore, in general, there does not seem to be any systematic advantage or disadvantage in any type of commodity dependence. Most commodity dependent developing countries have similarly low levels of technological development.

There is also little difference between the medians in the groups of low income (1.11), lower middle-income (1.80) and upper middle-income (1.42) commodity dependent developing countries

Figure 4.7 **Technological development index, 2019**

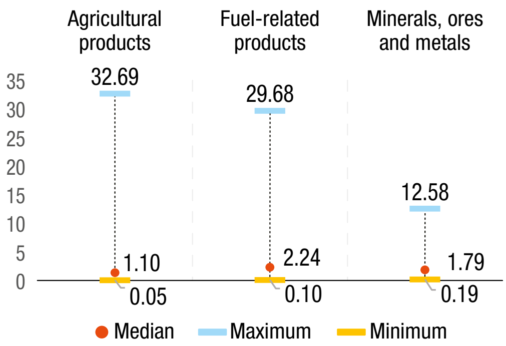


Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

(figure 4.9). Those that are high-income countries generally have higher levels of technology, but the median among the countries still has a low index value (4.54). Brazil (32.69) and some other upper middle-income countries have higher index values. Therefore, there is not a strong association between income per capita and the level of technological development of a country. As noted, the stronger association is between total GDP and diversification and, therefore, the level of technological development. Economies with smaller populations can reach greater GDP per capita at lower levels of technological development in production (Freire, 2017).

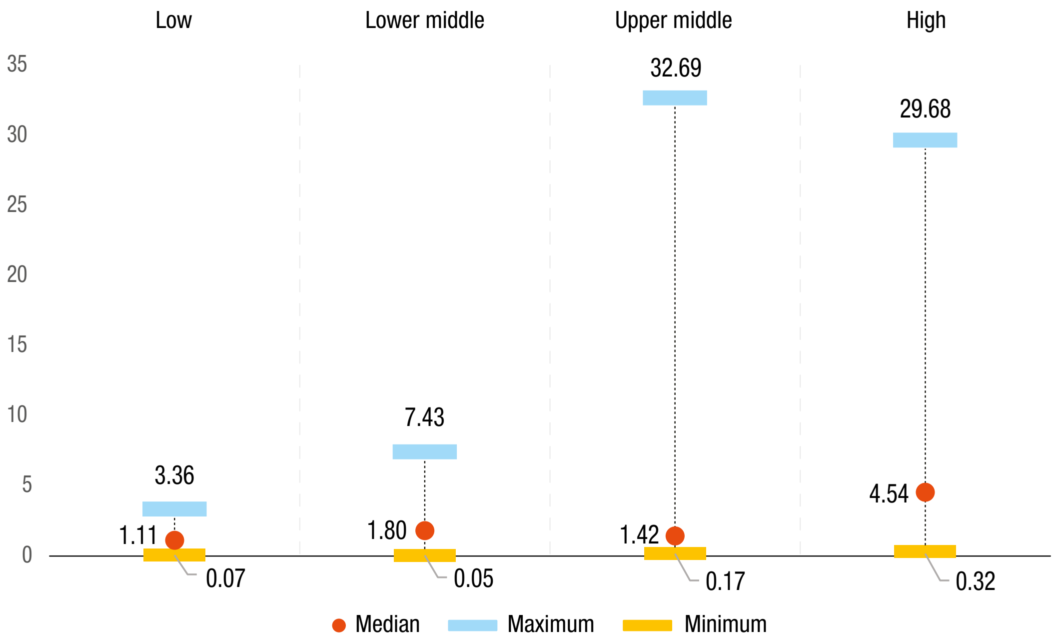
In the past 25 years, commodity dependent developing countries have made minimal gains in technological development when measured against the technological frontier as represented by the United States (figure 4.10). It is important to note that the basis of comparison has also changed over time. Therefore, any gain represents a reduction in the technological gap even if there are technological improvements at the frontier. The challenge is with regard to the slow pace of such improvements. In 1995, the median among commodity dependent developing countries

Figure 4.8 Commodity dependent developing countries: Technological development index by type of commodity dependence



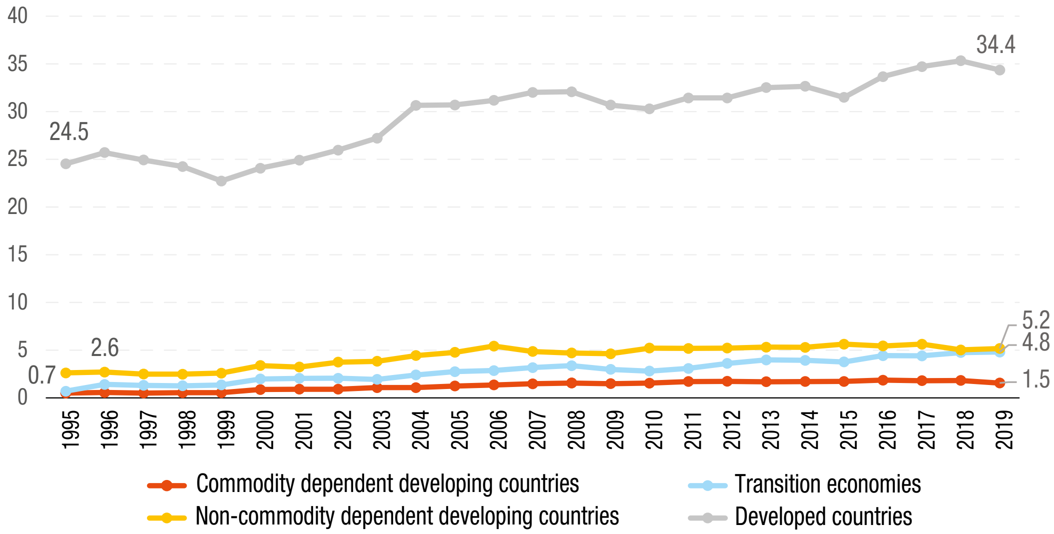
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

Figure 4.9 Commodity dependent developing countries: Technological development index by level of income



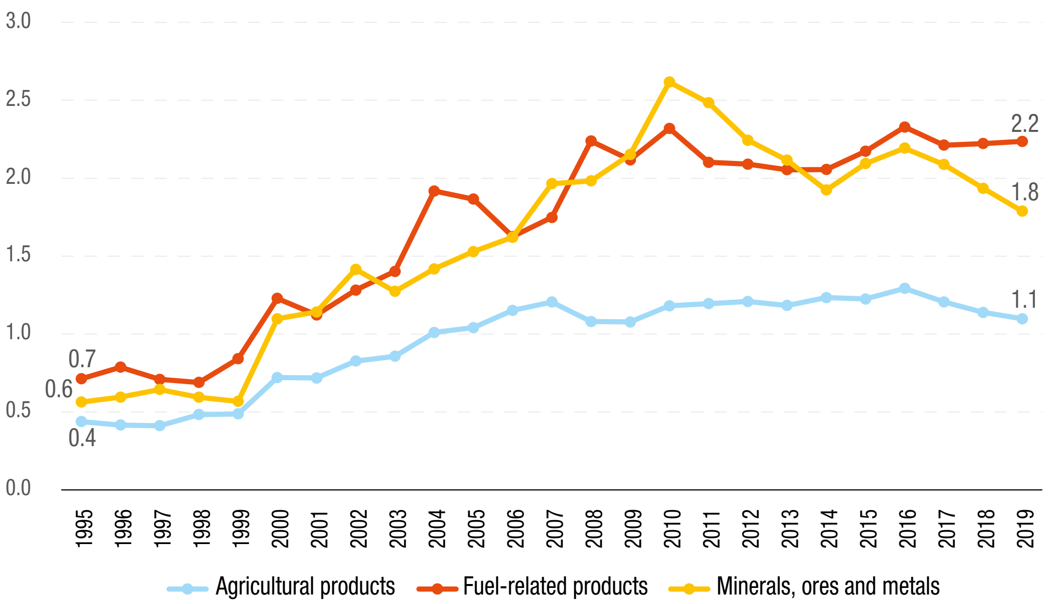
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

Figure 4.10 **Technological development index, 2019**



Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Adjustments have not been made with regard to changes in the composition of country groups in this period. The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

Figure 4.11 **Commodity dependent developing countries: Technological development index (median by type of commodity)**



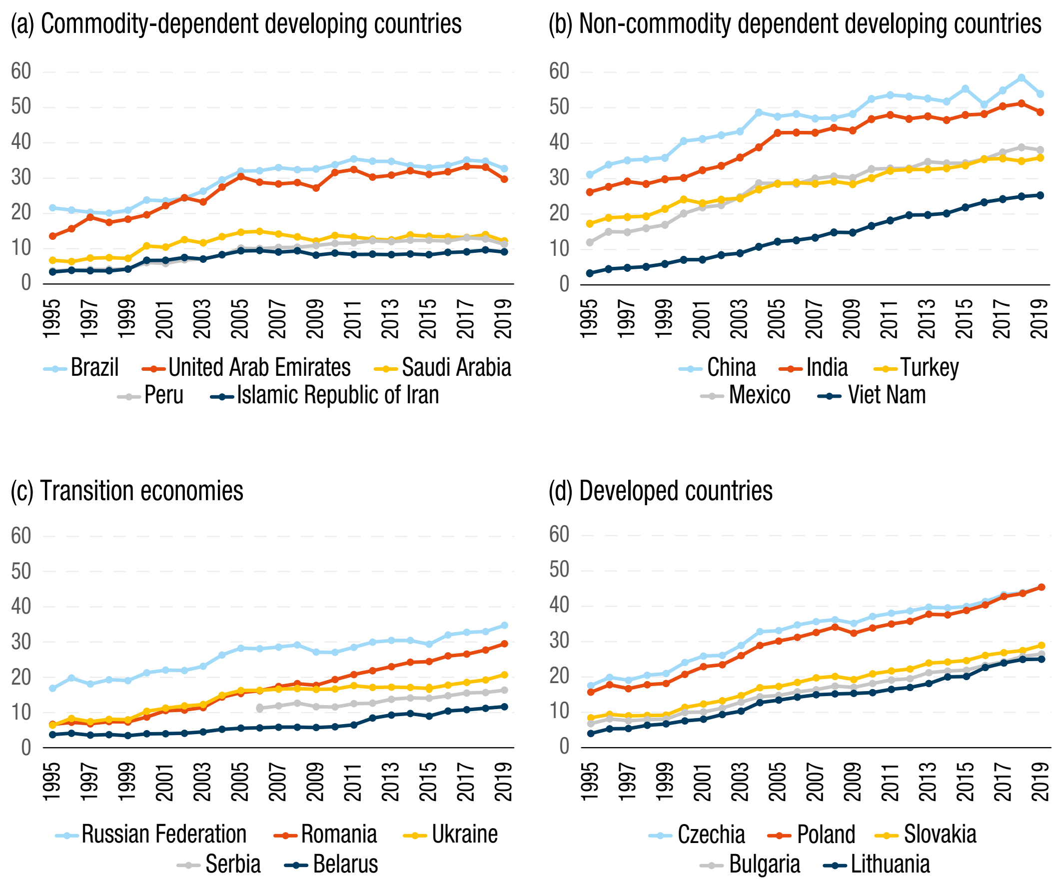
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

had a level of technological development at 0.7 and, in 2019, at 1.5. Transition economies made faster gains in this period, with the median in 1995 at the same level of technological development as the median among commodity dependent developing countries and, in 2019, at 4.8, much closer to the level of technological development of the median among non-commodity dependent developing countries (5.2). Developed countries made more significant gains, with a median value at 24.5 in 1995 that increased to 34.4 in 2019. In 1995–2019, technological development increased by a factor of three in the median among all commodity dependent developing countries.

The median among commodity dependent developing countries dependent on agricultural products had a level of technological development at 0.4 in 1995 and at 1.1 in 2019 (figure 4.11). In the same period, the median among commodity dependent developing countries dependent on mining increased from 0.6 to 1.8 and on fuel-related products increased from 0.7 to 2.2. The three subgroups experienced faster increases in levels of technological development in the first half of the 2000s, the period of the commodity price boom. Since the global financial crisis of 2008/09, technological development has remained mostly stable but decreased in commodity dependent developing countries dependent on mining from the highest level of 2.6 in 2010.

Many countries have been able to make greater gains in technological development since 1995 (figure 4.12). Among commodity dependent developing countries, Brazil, the Islamic Republic of Iran, Peru, Saudi Arabia and the United Arab Emirates made more significant progress. These countries experienced a faster increase in technological development during the pre-crisis period of the commodity boom in 2003–2007. Among transition economies, the Russian Federation

Figure 4.12 **Technological development index: Countries with greatest gains**



Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

and Ukraine followed a similar pattern. Progress was faster among fast-growing non-commodity dependent developing countries (China, India, Mexico, Turkey and Viet Nam) and developed countries (Bulgaria, Czechia, Lithuania, Poland and Slovakia). Lithuania and Viet Nam made significant progress from initial low levels of technological development.

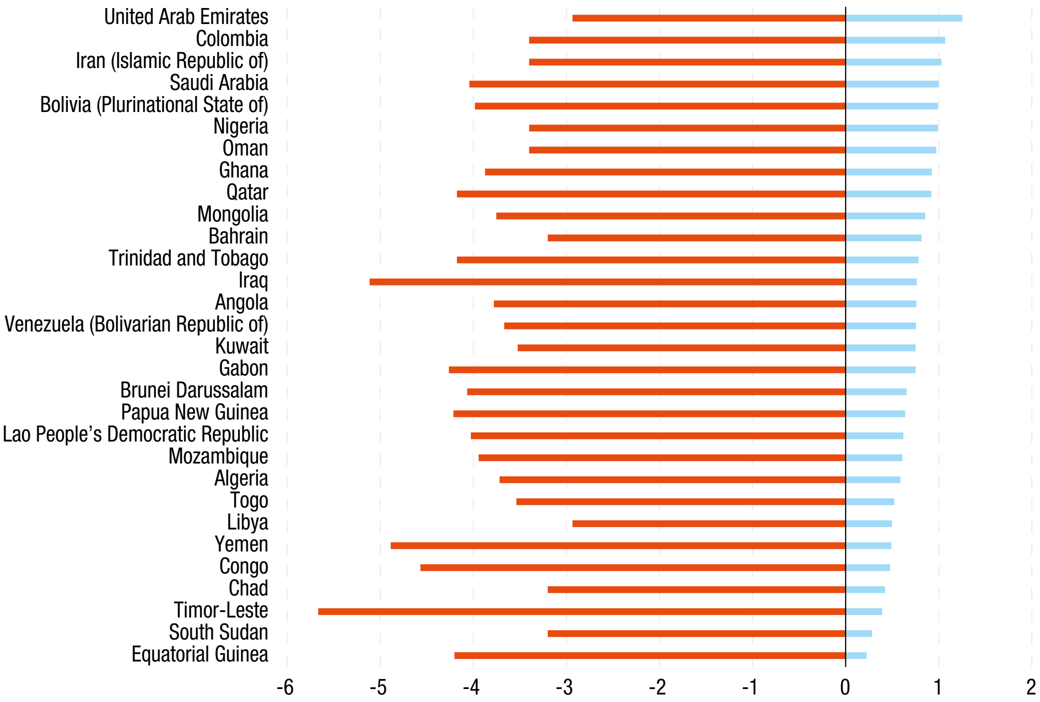
The range of technological capacity in commodity dependent developing countries may be assessed with regard to the distribution of the product complexity of exports (figure 4.13). Irrespective of specialization, most commodity dependent developing countries export products in the range of the global average of product complexity to minus three standard deviations of the global average (0 to -3). Many countries also export products that require even lower levels of technological capacity (-4 to -3) and a few, mainly commodity dependent developing countries dependent on agricultural products, export products that require the lowest level of technological capacity (less than -4). Higher levels of technology allow countries to produce and export products at levels above the global average complexity.

Figure 4.13 Commodity dependent developing countries: Complexity of product mix of exports by sector, 2019

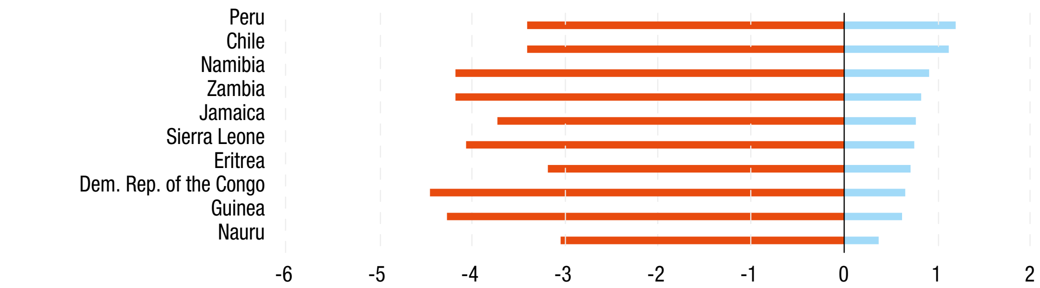
(a) Agricultural products

Figure 4.13 Commodity dependent developing countries: Complexity of product mix of exports by sector, 2019 *(continued)*

(b) Fuel-related products



(c) Mining

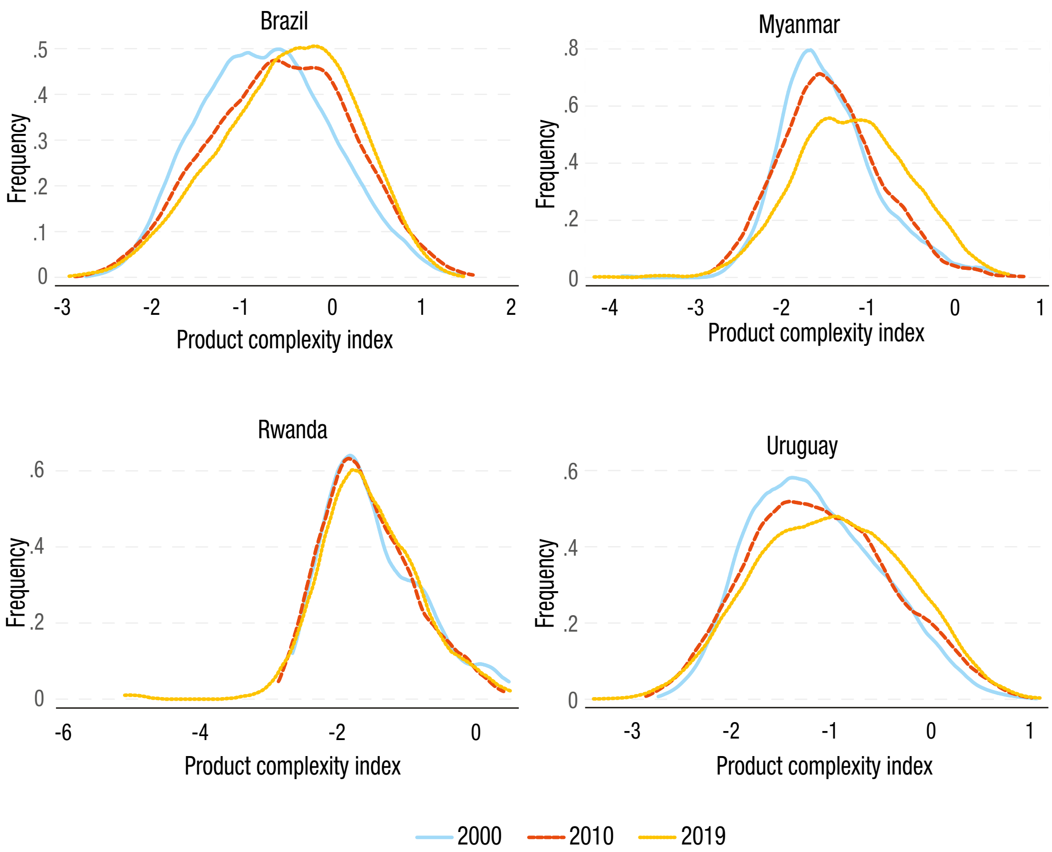


Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: For the product complexity index, 0 = global average, 1 = standard deviation.

The evolution of the product complexity distribution in selected commodity dependent developing countries that have agricultural products, fuel-related products or minerals, ores and metals as the main commodity exports, respectively, is shown in figures 4.14, 4.15 and 4.16. As shown in figure 4.14, there has been a shift towards greater technological capacity in the production base, in particular in Brazil and Myanmar. Countries that have moved towards greater product complexity also lessened the frequency or concentration of products with average complexity and increased diversification. By contrast, in Rwanda, there has been little change in the complexity of exports.[24]

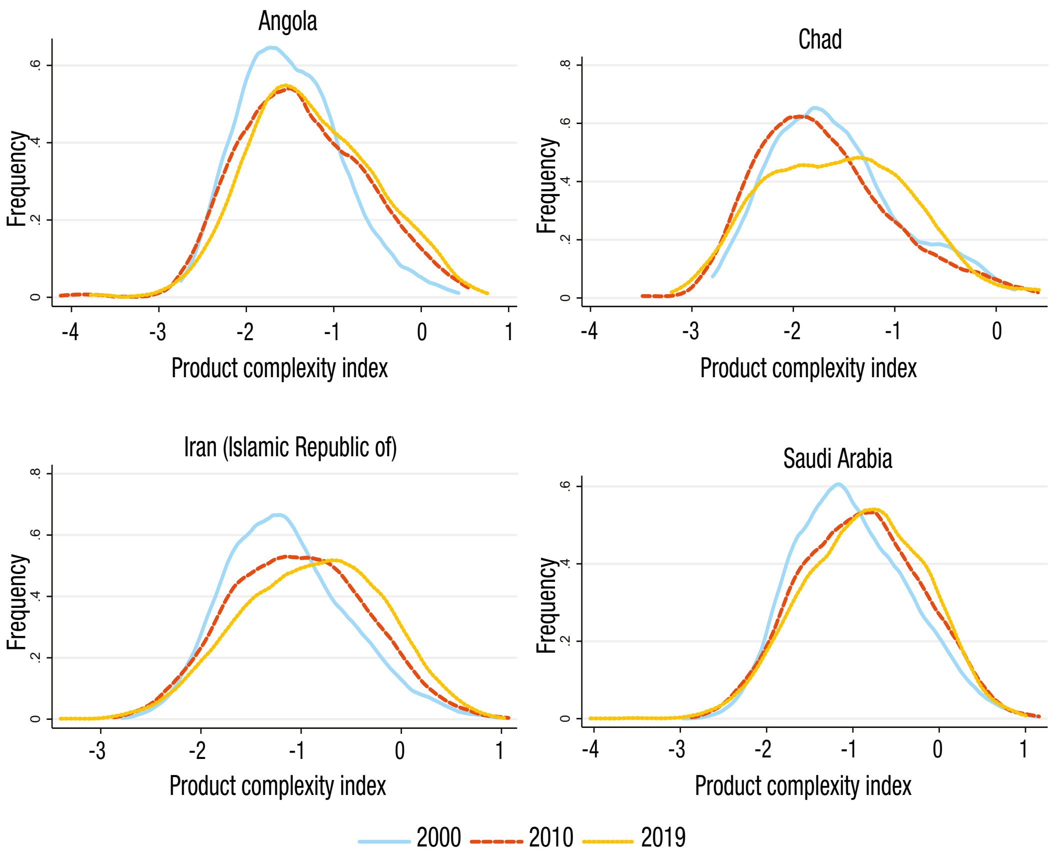
24 This also serves to highlight a limitation of this analysis in that it does not capture technological capacities related to services. For example, in Rwanda, the latter have increased significantly in recent years in digitally deliverable services.

Figure 4.14 **Evolution of distribution of product complexity, agricultural products as main commodity exports**



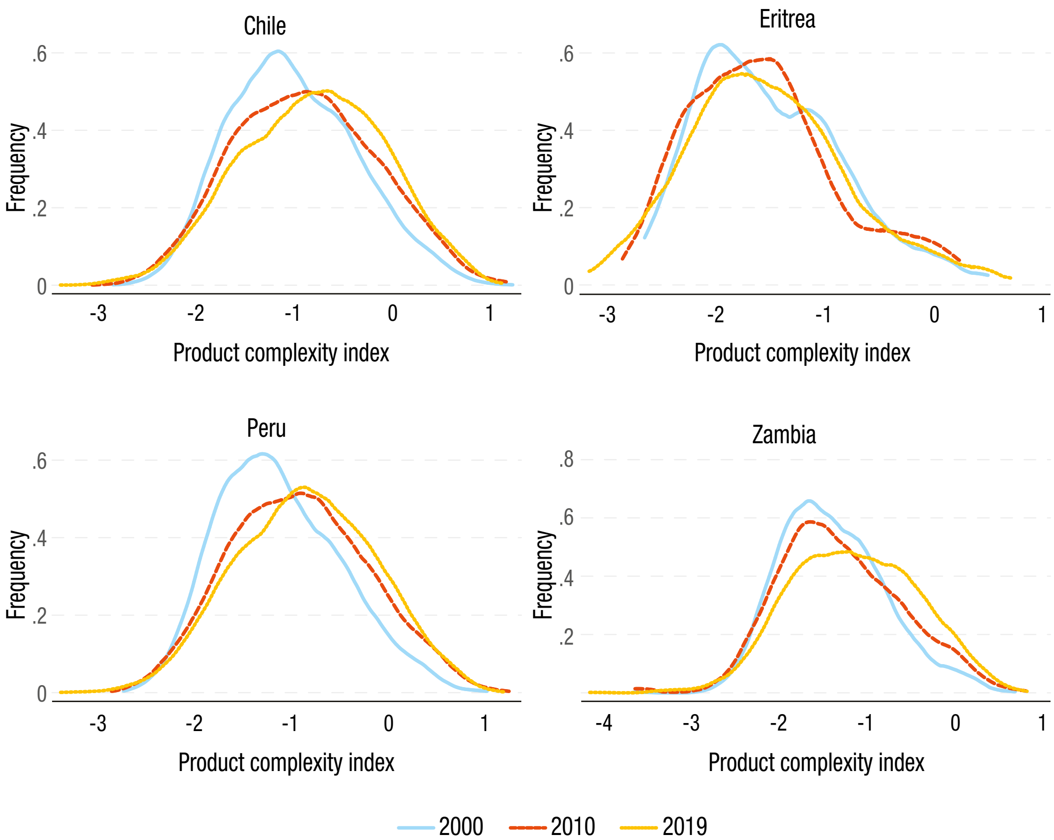
Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Frequency in the y axis represents the share of the number of product categories with a given complexity (x axis) in total exports. For the index, 0 = global average and 1 = standard deviation.

Figure 4.15 **Evolution of distribution of product complexity, fuel-related products as main commodity exports**



Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Frequency in the y axis represents the share of the number of product categories with a given complexity (x axis) in total exports. For the index, 0 = global average and 1 = standard deviation.

Figure 4.16 **Evolution of distribution of product complexity, minerals, ores and metals as main commodity exports**



Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Note: Frequency in the y axis represents the share of the number of product categories with a given complexity (x axis) in total exports. For the index, 0 = global average and 1 = standard deviation.

4.4 Conclusion

The relationship between technological change, innovation, economic diversification and structural transformation was addressed in this chapter. Based on analyses of their economic complexity, most commodity dependent developing countries have low levels of technological capacity and, in the past 25 years, have made minimal gains in closing technological gaps. Technological change and innovation lead to structural transformation when they result in economic diversification towards more complex products. Diversification is path-dependent; the products already produced in a country therefore have an impact on the likelihood of diversification into new products. Larger jumps in product complexity require more substantial support from Governments, to build absorptive capacities and create the conditions for introducing a more complex production structure in a country.

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Appendix

Technological development index, 2019

Rank		Value
1	United States	100.0
2	United Kingdom	83.3
3	Germany	80.3
4	France	79.6
5	Japan	73.1
6	Italy	71.8
7	Switzerland	68.8
8	Netherlands	63.9
9	Spain	58.6
10	Belgium	58.2
11	Canada	55.1
12	Austria	54.5
13	China	53.9
14	Sweden	51.6
15	Denmark	50.0
16	India	48.8
17	Republic of Korea	46.5
18	Australia	45.6
19	Czechia	45.4
20	Poland	45.4
21	Singapore	38.9
22	Hong Kong (China)	38.4
23	Turkey	38.1
24	South Africa	37.2
25	Finland	36.7
26	Thailand	36.4
27	Mexico	35.9
28	Russian Federation	34.8
29	Hungary	34.4
30	Ireland	33.6
31	Portugal	33.2
32	Brazil	32.7
33	Malaysia	31.6
34	Norway	31.5
35	Israel	30.8
36	United Arab Emirates	29.7
37	Romania	29.5
38	Slovakia	28.9

Rank		Value
39	Slovenia	28.9
40	Bulgaria	26.5
41	Greece	26.1
42	Indonesia	25.6
43	Viet Nam	25.3
44	Lithuania	25.0
45	Estonia	22.0
46	New Zealand	21.5
47	Luxembourg	21.4
48	Latvia	20.9
49	Croatia	20.7
50	Ukraine	20.7
51	Philippines	17.7
52	Serbia	16.3
53	Argentina	14.9
54	Morocco	12.9
55	Chile	12.6
56	Colombia	12.3
57	Saudi Arabia	12.2
58	Belarus	11.7
59	Peru	11.2
60	Egypt	11.1
61	Pakistan	11.1
62	Tunisia	10.3
63	Cyprus	10.2
64	Sri Lanka	9.8
65	Iran (Islamic Republic of)	9.1
66	Malta	8.6
67	Bosnia and Herzegovina	8.4
68	Lebanon	8.2
69	Mauritius	7.9
70	Costa Rica	7.6
71	Kazakhstan	7.6
72	Nigeria	7.4
73	Panama	7.0
74	Iceland	6.7
75	Kenya	6.6
76	Bangladesh	6.3
77	North Macedonia	6.1
78	Ecuador	6.0
79	Qatar	5.8
80	Dominican Republic	5.7
81	El Salvador	5.4

Rank		Value
82	Guatemala	5.4
83	Namibia	5.2
84	Georgia	5.0
85	Jordan	5.0
86	Uruguay	4.9
87	Eswatini	4.6
88	Albania	4.6
89	Oman	4.6
90	Ghana	4.6
91	Bahrain	4.5
92	Cambodia	4.4
93	Republic of Moldova	4.1
94	Kuwait	4.0
95	United Republic of Tanzania	4.0
96	Botswana	3.9
97	Honduras	3.8
98	Nepal	3.8
99	Myanmar	3.6
100	Macao (China)	3.4
101	Armenia	3.4
102	Madagascar	3.4
103	Senegal	3.3
104	Zambia	3.2
105	Cameroon	3.0
106	Côte d’Ivoire	2.8
107	Kyrgyzstan	2.7
108	Azerbaijan	2.7
109	Uzbekistan	2.6
110	Venezuela (Bolivarian Republic of)	2.5
111	Algeria	2.4
112	Zimbabwe	2.4
113	Bolivia (Plurinational State of)	2.4
114	Uganda	2.4
115	Nicaragua	2.3
116	Angola	2.3
117	Trinidad and Tobago	2.3
118	Ethiopia	2.2
119	Mozambique	2.2
120	Sierra Leone	2.1
121	Montenegro	2.0
122	Afghanistan	1.9
123	Lesotho	1.9
124	Lao People’s Democratic Republic	1.8

Rank		Value
125	Togo	1.8
126	Paraguay	1.8
127	San Marino	1.7
128	Syrian Arab Republic	1.7
129	Andorra	1.6
130	Mali	1.6
131	Mongolia	1.5
132	Democratic Republic of the Congo	1.5
133	Jamaica	1.4
134	Brunei Darussalam	1.4
135	Iraq	1.4
136	Gabon	1.3
137	Democratic People's Republic of Korea	1.3
138	Haiti	1.2
139	Niger	1.2
140	Fiji	1.2
141	Guinea	1.1
142	Burkina Faso	1.1
143	Seychelles	1.1
144	Malawi	1.1
145	Bahamas	1.1
146	Congo	1.1
147	Papua New Guinea	1.0
148	Suriname	1.0
149	Turkmenistan	0.9
150	Benin	0.9
151	Barbados	0.9
152	Belize	0.8
153	Cuba	0.8
154	Tajikistan	0.8
155	Mauritania	0.7
156	Sudan	0.7
157	Maldives	0.7
158	Guyana	0.6
159	Rwanda	0.6
160	Libya	0.6
161	Antigua and Barbuda	0.5
162	Cabo Verde	0.5
163	Dominica	0.5
164	Liberia	0.5
165	Bhutan	0.5
166	Yemen	0.5
167	Djibouti	0.4

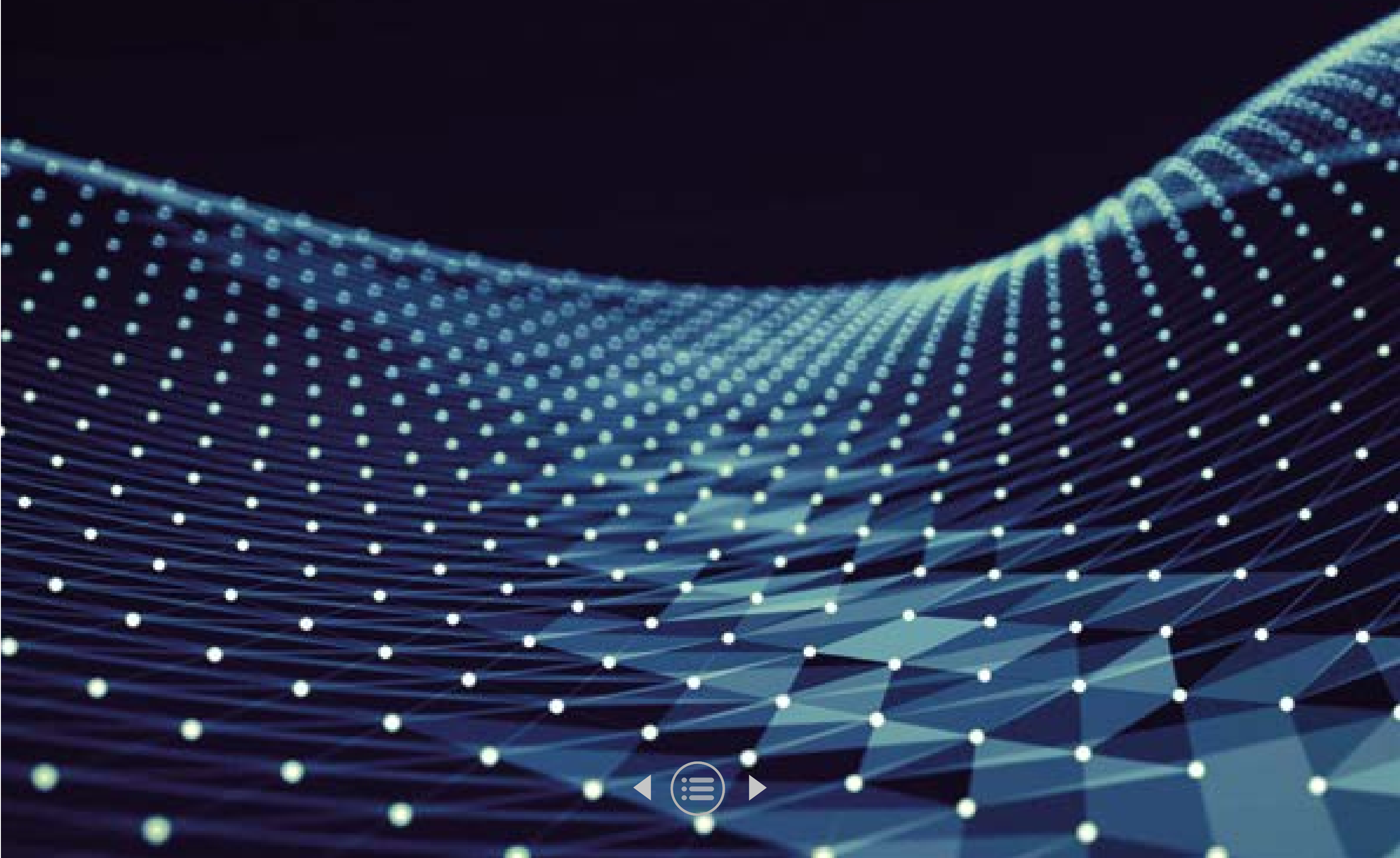
Rank		Value
168	Gambia	0.4
169	Saint Lucia	0.4
170	Bermuda	0.4
171	Occupied Palestinian Territory	0.4
172	Sao Tome and Principe	0.3
173	Marshall Islands	0.3
174	Saint Vincent and the Grenadines	0.3
175	Nauru	0.3
176	Samoa	0.3
177	Central African Republic	0.3
178	Equatorial Guinea	0.3
179	Saint Kitts and Nevis	0.3
180	Burundi	0.3
181	Grenada	0.3
182	Vanuatu	0.3
183	Chad	0.3
184	Somalia	0.3
185	Comoros	0.2
186	Timor-Leste	0.2
187	Eritrea	0.2
188	Solomon Islands	0.2
189	Tonga	0.2
190	Niue	0.1
191	South Sudan	0.1
192	Kiribati	0.1
193	Tuvalu	0.1
194	Guinea-Bissau	0.1
195	Micronesia (Federated States of)	0.0
196	Palau	0.0

Source: UNCTAD calculations, based on Freire, 2019, and data from the United Nations Comtrade database.
Notes: Commodity dependent developing countries are indicated in blue. The index is measured from 0 to 100; 100 indicates the economic complexity of the United States.

CHAPTER

5

Enabling Technological Transformation



5.1 Introduction

The persistence of commodity dependence, as shown in chapter 2, has contributed to the recent revival of discussions about industrial policy[25] or at least the debate about its rationale in both academia and policy circles. However, the context prevailing in the 1960s and 1970s, considered as the golden age of a more interventionist approach in economic management, has changed dramatically. Features such as commodity price volatility, limited value addition in commodities production, and pervasive low productivity as identified in chapter 2, have persisted with fluctuating intensity over more than half a century. Additional elements have also emerged and become constraints in most commodity dependent developing countries.[26] Predominant ones are climate change (UNCTAD, 2019a) and associated stranded asset risks, dominant position of corporations in global value chains, and the automation of low skilled tasks and more generally, as discussed in chapter 3, increased exposure to labour saving technological innovations in both tradable and non-tradable sectors.

Results presented in previous chapters point to the important role that technological transformation[27] could play in helping define a successful diversification strategy in commodity dependent economies and particularly developing ones. Empirical analysis in chapter 1 suggests that commodity dependence is negatively associated with a large set of broad indicators of technological advancement and penetration. There is further indication in chapter 2 that commodity dependence could be responsible for lower labour productivity in manufacturing and in some services sectors, either services that are tradable or have a strong social component such as health and education. The level of complexity of exported goods in commodity dependent economies remains relatively low, as shown in chapter 3. As also shown, a comprehensive effort towards technological transformation would be a necessary condition to promote sustained structural transformation and eventually diversification.

In this chapter, answering two main questions is attempted. What are the enablers of technological transformation in the context of a commodity dependent economy? What would a successful implementation strategy consist of?

While extensive analytical work can help identify proper enablers of technological transformation, the second question does not have a unique and unequivocal answer. Insights from previous chapters revealed that defining a strategy aimed at promoting structural change and, eventually, diversification of both production and exports in commodity dependent developing countries must take account of country specific characteristics and contingencies, as well as external conditions.

The rest of the chapter is organized as follows. Some core enablers of technical transformation along different diversification paths are discussed in section 2. A set of past and current experiences to identify core components of successful implementation are presented in section 3. In section 4, some concluding remarks are presented.

5.2 Enabling technological transformation

Technological transformation has proven a necessary component of a successful economic development strategy built around the enhancement and expansion of productive capacities.

25 See Inter-American Development Bank, 2014, and UNCTAD, 2016, for a recent review of various approaches and critical assessment. See UNCTAD, 2018, for a discussion about national investment policies.

26 See Chang, 2011, and Chang and Andreoni, 2020, for a general discussion.

27 The term technological transformation is used instead of innovation in order to avoid any possible confusion but the two should be considered as interchangeable.

Such expansion aims at promoting economic diversification and requires, in most circumstances, a full-fledged structural change strategy.[28] As pointed out in Ocampo (2020) structural change should be conceptualized as a meso-economic process that encompasses production composition effects, intrasectoral and intersectoral linkages, market structures, the functioning of factor markets and the underlying institutions. The literature has so far identified the inappropriate treatment of production-related market failures and so-called government failures as possible major sources of failing policy reforms.[29] While the government failures could impose binding constraints on any sort of policy reform, the inappropriate treatment of production-related market failures may be constraining only for certain types of policy reforms.

Well-known and highly debated government failures include poor governance, poor macroeconomic management, a poor institutional framework and poor or inappropriate public investment and spending. Government failures may further include a dysfunctional fiscal system, a weak welfare State and the absence of policy dialogue at the national and sectoral levels. Market failures are potentially strong impediments to an evolving production structure able to generate dynamism through innovations in the Schumpeterian sense and complementarities linking firms and production activities, eventually leading to economic growth development. Inadequate provision of infrastructure, such as roads and ports, restricted or exclusive provision of education services, lack of information on either supply or demand, or both, and an excess concentration of firms in some specific market may also generate or be associated with a market failure.

Even though diversification is usually based on a country's economic structure, its driving forces reflect experiences observed at a much higher level of granularity. Firms or clusters of firms and their dynamics are always at the core of successful stories and may help explain failures to a large extent. They should be involved in the elaboration of any policy strategy towards diversification. An additional element to be considered concerns the demand conditions prevailing in both domestic and international markets. Demand conditions prevailing in international markets include market access conditions, an important element even if policy reform does not include explicit export orientation. As discussed in the next section, diversification may not necessarily entail the promotion and expansion of totally new sectors of activity but could rather target higher levels of value addition in relation to an abundant commodity. Commodity beneficiation may involve some reliance on foreign knowledge and ultimately investment, but at the same time may enlarge the scope of implementable technological transformation.

In the context of some structural change strategy, policies aiming at promoting technological transformation may be of a general nature to reduce the gap with the international technological frontier and hence detached from any sectoral policy. Policies may also have a specific scope, pointing to the development of specific sectors. While the former approach may be directed towards a longer-term set of objectives to promote broad-based structural transformation, the latter approach would be adopted to reach short- to medium-term sectoral development objectives. Countries and in particular commodity dependent ones, as discussed in chapter 3, may pursue both types of objectives to prevent inertia and traps in productive capacity as identified in chapter 2. Of note, however, is that even horizontal types of policy interventions may de facto lead to some sector bias.[30] The set of policy interventions required to support technological transformation will then be defined by the mix of short- versus longer-term objectives with regard

28 See UNCTAD, 2020, for a discussion applied to the least developed countries; African Development Bank, Organisation for Economic Co-operation and Development, United Nations Development Programme and United Nations Economic Commission for Africa, 2009, for a discussion specific to the African context; and Cherif and Hasanov, 2019, for an extensive discussion about the Asian miracle experiences.

29 Rodrik, 2004, provides an extensive discussion of such failures with a number of concrete examples.

30 See Lederman and Maloney, 2012, for a discussion and practical illustrations.

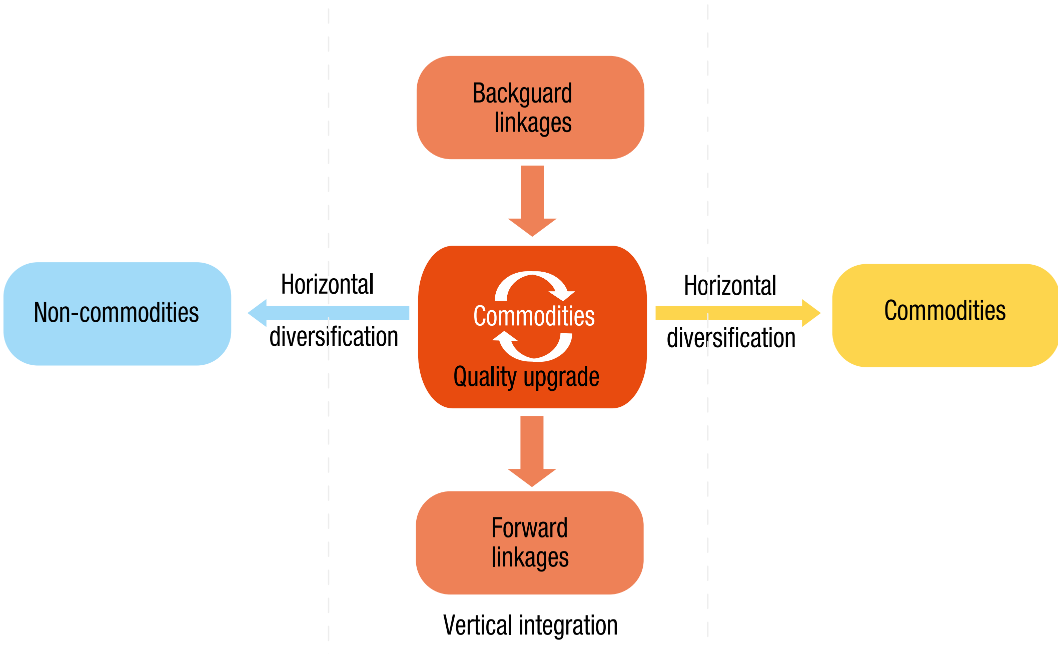
to productive capacity enhancement and, ultimately, the diversification path chosen by countries. In other words, the set of enablers would vary across the various options in terms of productive capacity enhancement and expansion.

Diversification paths

Governments in commodity dependent economies willing to promote diversification in domestic production face several decisional layers. They should first identify the diversification strategy to be implemented. Diversification away from commodities production could follow different paths, as shown in figure 5.1. The often-recommended path is a shift towards manufactures, usually characterized by higher productivity (e.g. Rodrik, 2004). Such a shift may operate either by means of the promotion of sectors and products unrelated to the set of commodities produced or through the exploitation of forward linkages within a process of vertical integration. Vertical integration can also operate by exploiting linkages to backward products or services.[31] Diversification could also be obtained by promoting the production of other commodities. Another important source of diversification is a quality upgrade of the set of commodities currently produced, as discussed in chapter 3.

Technological requirements to enact some productive transformation will be different according to the type of diversification path contemplated by policymakers. Moreover, the capacity of Governments to undertake effectively in some structural transformation strategy is expected to depend on the type of commodity dependence that characterizes their current production structure. Consequently, different types of commodity dependence may call for different types of enablers within a similar diversification strategy.[32]

Figure 5.1 Diversification paths in a nutshell



Source: UNCTAD.

31 Forward and backward linkages referred to here are in line with Hirschman's view (1958) about economic development.
32 See, for instance, Chang, 2011, and Ocampo, 2020, for a general discussion.

5.3 Enablers of technological transformation and diversification paths

Two types of commodity dependence may be worth distinguishing: dependence on point-source natural resources (minerals and energy commodities) and dependence on soft commodities. The usefulness of such a categorization is twofold. First, while both categories are natural resources, point-source natural resources are essentially extractive while soft commodities are not, strictly speaking, even though they rely on the inner abundance of arable land. This difference cannot be ignored when considering the overall productive structure of an economy and the rationale for choosing a diversification path. Second, abundance in point-source natural resources is usually associated with higher rents. Whether these rents are distributed fairly among the various actors involved in the exploitation of those point-source natural resources is part of the dependency issue and will be briefly discussed below. Enablers should then be considered alongside these differences. Some may appear necessary independently of the dependence profile of an economy and the diversification objectives of the Government. Some others may be crucial to certain specific conditions, as illustrated below and summarized in table 5.1.

5.3.1 Horizontal enablers

Independently of the of the type of commodity dependence and the diversification path chosen, some enablers to technology transformation are always necessary even though they are seldom sufficient.

A first crucial enabler to technological transformation is access to technology and possibly its transfer. Together with invention, technological transfer is a major driver of technological transformation. The lack of it remains a major issue in many developing countries, explaining to a large extent their relative remoteness with respect to the technological frontier.[33] Technology transfer would be effective only if producers active domestically are able to adapt existing technologies to local conditions. In that respect, innovation is also at work but relates to the production process more than to technology itself.

Foreign direct investment has proven to play a central role in the transfer of technology and technical know-how, particularly in the context of production fragmentation and outsourcing observed during the last 20 to 30 years. To become fully effective, technology transfer should

Table 5.1 Horizontal versus vertical enablers

Horizontal	Vertical	
Hard and soft commodity dependence	Hard commodity dependence	Soft commodity dependence
• Access to technology Infrastructure • Entrepreneurial capacity in technological adoption • Worker's capacity in technological adoption • Appropriability of innovation • Access to financial resources • Trade integration	• Fiscal capacity • Responsible and inclusive investment (domestic and foreign)	• Access to productive capital • Access to information on technological innovations and know-how

Source: UNCTAD.

33 See Cirera and Maloney, 2017, for an extensive critical review of the issue and some new stylized facts.

lead to local innovation at least in the medium run. This requires national innovation systems to be either created or reinforced. An effective institutional framework able to coordinate the various actors engaged in innovation and learning – research and development centres, universities and technology schools, extension services and the innovating firms themselves – would be necessary. In addition, investments may have to be redirected over the long term towards new capabilities and an ambitious educational strategy in support of these processes.

Another enabler closely linked to the previous one relates to the capacity of skilled entrepreneurs and workers to adopt new production processes effectively and efficiently. Technological progress through either adoption of existing technology often at a mature stage, or innovation, or a mix of the two, stands as a major contributor to structural change. Seeing firms as major actors in successful policy implementation would help refine institutional reforms by removing in the first place any excessive administrative procedures. It would also be necessary to facilitate the identification of needs in skills and in any lacking or missing element that could encourage technology transfer, adoption and in some cases innovation. Direct public support may be relevant if the gap in technology and technological know-how that firms are facing is not too wide. An innovative process requires active management from innovating firms. Such a process requires investment in learning and physical capital, as well as in intangibles, including technological learning. When firms' productive capacities stand far away from the technological frontier, public policies should aim at promoting innovation at a much larger scale and define policy objectives over a relatively long period of time.

Technical know-how is acquired through a maturing process that is closely linked to the production experience. Such experience entails uncertainty that could make firms fail if they do not benefit from some secure source of income. The role of production experience has also been identified as crucial in "evolutionary" theories of technical change (e.g. Lee, 2019, and Lall, 2003). Practical experience facilitates transferability when technology is borrowed from abroad and applied to domestic conditions and specificities. However, it can also play a central role in an innovation process. Success in creating technology relies heavily on the accumulated technological knowledge and production experience of firms (i.e. of managers and production workers) involved in the process, which in new technological fields could include new entrants.

A relatively skilled labour force characterized by widespread managerial skills and technical competences has proven to be crucial in defining the capacity of an economy to engage in sustained technological upgrading.[34] Even though short- to medium-term objectives are not necessarily consistent with investment in human capital accumulation, such as health and education, part of the resources involved should be devoted to the latter in order to establish the grounds for the success of future projects independently of the political forces at work.

An additional enabler is full appropriability of technological innovation. As the latter can suffer from standard appropriation externalities, and hence intellectual property, regulation has been a long-accepted remedial policy. More generally, the existence of institutions aimed at increasing information and coordination among agents is essential to any development process. Institutions that reduce inefficiencies associated with contract incompleteness may include the rule of law, social norms and regulatory frameworks (North, 1990). Different mixes of public and private institutions can also be contemplated and should be in line with each country's tradition. Moreover, different mixes of international, national and local institutions can also help resolve market failures due to asymmetries of information. All these institutions determine the capacity of Governments to implement policy reforms directed towards structural change. The existence of an effective

34 See Maloney and Nayyar, 2018, for an extensive discussion.

innovation system can also reduce the incidence of appropriation externalities.[35] An innovation system usually involves public institutes that disseminate best practice information, such as research institutes and university departments specializing in basic research. The existence of coordination failures among such non-market institutions in national innovation systems is a recurrent issue, and failures surrounding the acquisition of firm capabilities could be a direct consequence. Reducing as much as possible such coordination failures could clearly promote and accelerate technological upgrading and adoption on a large scale.

In addition to human capital accumulation, some physical capital accumulation is likely to be needed to accompany technological upgrading and transformation. Access to credit, particularly in developing countries, is a major determinant of capital accumulation and eventually technology adoption. The existence of a possibly close relationship between capital accumulation and productivity growth is also usually recognized. However, the strength of that relationship is likely to vary depending on other features of the economy and overall policy framework (e.g. Cherif, Hasanov and Zhu, 2016). Credit markets may not generate optimal volumes of transactions in the face of information asymmetries or inadequate collateral in the absence of properly defined and legally binding property rights (e.g. Besley, 1994). Such an absence may lead, for instance, to situations where borrowers are unable to recover the funds they lent. Again, reducing as much as possible the prevalence of market failures would be required to facilitate the adoption and development of new technologies.

A core enabler of technological transformation is infrastructure. As shown in the first chapter of this report, the use of internet can be associated with a lower probability of being a commodity dependent economy. Access to internet is one of the most critical components for unlocking the possibilities offered by digital technologies. There are disparities in access between rural and urban areas especially in the least developed countries. The introduction of digital technologies in rural areas can be a challenge. There is often a lack of infrastructure, including basic information technology (IT) infrastructure. The costs associated with IT infrastructure require public funding and strong political commitment. Infrastructure development can also be directed to the promotion or reinforcement of geographical clusters of firms expected to foster technological transformation (e.g. Duranton and Puga, 2004). To make the establishment of firms' clusters effective, infrastructure facilities (e.g. uninterrupted electricity supply) are crucial.

Trade integration can also significantly enable technological upgrading and may be associated with any diversification path in any type of commodity dependence economy. All forms of trade liberalization can increase productivity by inducing a better allocation of production factors.[36] Trade integration can also lead to the adoption of more advanced technologies by the most productive firms. If the benefit of technological adoption is proportional to revenues and its cost is fixed, then trade integration would promote the former by increasing revenues of exporting firms and especially of the most productive. Based on Argentinian firm-level data, Bustos (2011) finds that after the establishment of MERCOSUR, firms in industries benefiting from higher reductions in Brazilian tariffs increase investment in technology faster. The effect of tariffs is highest in the upper-middle range of the firm-size distribution, that is, the most productive ones. Using manufacturing establishment data for Chile, Colombia, India and the United States, Hallak and Sivadasan (2013) further show that, conditional on size, exporters sell higher quality products, charge higher prices, pay higher input prices and higher wages, and use capital more intensively. This adds to the evidence that trade integration may lead to some form of technological upgrading also possibly embedded in product quality improvements.

35 See African Development Bank et al., 2009, for an extensive discussion and provision of several case illustrations in the African context.

36 Recent trade literature has shown that trade integration reallocates market shares towards the most productive firms, thus increasing aggregate productivity. See Bernard, Jensen, Redding and Schott, 2012, for a review.

5.3.2 Vertical enablers

Other enablers should be considered when aiming at fostering technological transformation. However, their relative influence is expected to vary depending on the type of commodity dependence a country is facing and/or the diversification path followed.

In principle, countries relatively amply endowed with point-source natural resources should be able to mobilize public funding more easily thanks to the rents they derive from extractive activities. However, a fiscal resource curse may result from these windfalls, severely constraining fiscal capacity.[37] Standard arguments suggest that increasing natural resource rents may be harmful to taxation, as Governments may find it convenient to substitute tax revenues with resource revenues. Governments that benefit from natural resource revenues may see a reduced incentive to invest in fiscal capacity. Availability of natural resource endowments is seen as an easy-to-obtain source of revenues in comparison with other traditional sources of tax revenues, such as value added tax and income taxes.[38] Some empirical investigations[39] show that rents coming from point-source natural resources have a negative effect on fiscal capacity. However, empirical results also suggest that countries with political institutions that place institutionalized constraints on executive power tend to be immune to the fiscal resource curse.

Low agricultural productivity remains a key development challenge in commodity dependent developing countries. Most firms in developing countries employ only a few workers, if any (Hsieh and Olken, 2014). A key concern is that the small size of firms may prevent them from adopting technology in the quest for diversifying production, either through horizontal diversification within the agricultural sector or through product quality improvements. The adoption of new technologies is often embodied in large machines, and most firms might not have the scale to make the investment profitable. The promotion of effective technology adoption should thus be based on market and institutional features that would allow some pooling of financial resources. Supporting collective structures to provide small firms with the necessary equipment to adopt more advanced farming technologies and techniques could prove effective in relaxing existing production scale constraints. Firms may be offered the opportunity to rent machines instead of buying them. They may also benefit from some advisory services to upgrade technical know-how. Such services could be provided by public or publicly funded entities. Rental activities may also be marketed and eventually opened to competition if the size of the market permits. In a recent study, Bassi, Muoio, Porzio, Sen and Tugume (2020) show that small firms in urban Uganda engage in active rental markets and that this allows them to access modern machines with a capacity too great for any single firm to fully make use of. Renting not only limits concerns related to the small scale of firms, but also provides a valuable policy tool to foster technology adoption and productivity in settings plagued by market imperfections.

In addition, farmer-to-farmer information diffusion has also proven to be a cost-effective approach for improving practices and profits for smallholder dairy farmers in East Africa (Behaghel, Gignoux and Macours, 2020). A necessary, if not sufficient, condition for new technologies or practices to be adopted is that farmers need to know about them in the first place. Any means of promoting the diffusion of information on innovations that can help increase agricultural productivity may help technology diffusion and adoption.

Technology adoption and eventually diversification may also be facilitated by participation in global value chains. However, the latter relationship is anything but automatic, as suggested by existing empirical results. Recent research (Álfaro-Ureña, Manelici and Vasquez, 2020) suggests that

37 Besley and Persson, 2011, define fiscal capacity as the ability of a fiscal system to raise revenues from a broad tax base.

38 See Chang and Lebdioui, 2020, for a general discussion.

39 See Masi, Savoia and Sen, 2020, for a recent contribution.

becoming part of the global value chains of multinational corporations could transform developing economies through improved performance of domestic firms. Multinational corporation buyers not only provide increased demand for their goods, but also provide learning opportunities associated with technological upgrade. However, several empirical studies also found that only middle- and high-income countries benefit, on aggregate, from participating in global value chains. Conversely, those benefits are minimal for small countries or less advanced economies (Fagerberg, Lundvall and Shrolec, 2018; Kummritz, 2014). This is explained to a large extent by the governance modalities of value chains and the degree of control and power asymmetries along a value chain (Greenville, Kawasaki and Beaujeu, 2017). As described in Montalbano and Nenci (2020), lead firms may exert their market power by specifying the rules of production. If local suppliers are characterized by weak capabilities and operate within weak national innovation systems, production modalities may be dictated by the leading actor of the global value chain. Such a locked-in situation would also be observed if production technology is strongly specific to the transaction between the input provider and the buyer (Kuijpers and Swinned, 2016). Moreover, local firms are more likely to be exposed to competition from other input providers. Therefore, improving the access of local producers to foreign buyers would be effective in improving production conditions and capacity only within a regulatory and institutional framework able to avoid dominant positions along the production chain.

In the same connection, foreign direct investment has proven to play a central role in the transfer of technology and technical know-how. So far, foreign direct investment has been mostly directed towards economies with abundant point-source natural resources. This does not preclude any commodity dependent country from attracting more foreign direct investment to fulfil technological transformation ambitions, although it may require more institutional efforts for exporters of soft commodities in comparison with hard and energy commodities.[40] However, foreign direct investment may impose some constraints or limitations on the diversification path chosen. Indeed, most of the literature in developing country contexts finds no evidence of horizontal spillovers and emphasizes vertical spillovers through backward linkages from foreign firms to domestic suppliers as the main source of productivity effects (e.g. Blalock and Gertler, 2008; Kugler, 2006). The available evidence also suggests that the type of the foreign investor, whether a joint venture or a wholly foreign-owned firm, matters for the extent of spillovers (Smarzynska Javorcik, 2004). There is also strong evidence to suggest that a dominance of foreign firms upstream has a negative impact on the productivity of downstream domestic firms. Direct forward linkages from foreign-invested input suppliers to domestic customers have also been found to be positively related to productivity.

Moreover, having a direct link with an upstream foreign direct investment firm (where the link is associated with a technology transfer) mitigates part of the negative externality from the dominance of wholly foreign owned firms in upstream sectors (Newmann, Rand, Talbot and Tarp, 2015). To become fully effective, technology transfer should lead to local innovation, at least in the medium term. This requires national innovation systems to be either created or reinforced. In addition, investments may have to be redirected, over the long term, towards new capabilities and an ambitious educational strategy that supports these processes (Lee, 2019).

5.4 Implementing technological transformation

This section presents some examples of technological transformation and adoption that occurred in different groups of commodity dependent countries along different diversification paths.

40 Trade agreements may be part of these efforts. As shown in UNCTAD, 2014, trade agreements can generate incentives for multinational corporations to start some activities in a host's domestic market as they would be able to take advantage of some preferential market access granted by the partners of trade agreements.

5.4.1 Illustration: Hard commodity export dependent countries

As already mentioned, energy-dependent countries may benefit from large rents generated by the exploitation of their natural resources. If properly managed those rents may serve diversification purposes by allowing the funding of large infrastructural investments.

Forward linkages

As discussed in UNCTAD 2019b, several fuel-export dependent countries have been able to expand their export baskets by exploiting immediate forward linkages. Some countries were able to increase the amount of processed products that are energy intensive (e.g. refined fuels, such as gasoline or kerosene, and assorted petrochemicals, including alcohols, fertilizers and plastics) to their basket of exports. For some energy-intensive products (e.g. aluminium), most non-energy inputs had to be imported (e.g. alumina or bauxite) and, as such, contributed to a lesser extent to domestic value addition.

During the last two decades, Oman has been able to multiply its export share of chemicals by 10, starting from a mere 1 per cent of total merchandise exports back in the second half the 1990s. This process has been driven by an increase in the exports of fertilizers and different hydrocarbon derivatives, such as alcohols and phenols. In Trinidad and Tobago, the share of chemicals (including different products such as fertilizers) in exports rose almost twofold since the late 1990s. In both Oman and Trinidad and Tobago, the strongest enabler has been heavy investment in production plants. Three plants were opened between 2002 and 2009 in Trinidad and Tobago, which led to an increase of 1.9 million tons in the installed productive capacity of ammonia. Two plants, opened in 2004 and 2005, respectively, increased annual methanol production by 3.6 million tons. In both countries, even though most recent investments have been injected by foreign companies, the Government remains active and has been at the core of initiating these activities.

Oman also offers another example of successful government intervention in the promotion of value addition in the energy sector. In its strategic growth plans, three major projects have been implemented to drive the Oman Oil Refineries and Petroleum Industries Company (75 per cent owned by the Ministry of Finance and 25 per cent by the Oman Oil Company) transformation from a national oil refinery to an international integrated refining and petrochemicals company. Heavy public investments have been made to support such a transformation: $1.5 billion in 2006, $1.6 billion in 2010, $2.7 billion in 2016 and $3.6 billion in 2018.[41] As a result, refining capacity has been significantly expanded by the opening in 2006 of the Sohar 1 refinery and in 2017 of the Sohar 2 refinery. The increase in the production of chemical products, such as paraxylene and benzene, proceeded along with the opening of an aromatics plant in 2010. Production of polypropylene has also been promoted with a multibillion-dollar contract granted to Lyondell Basell recently completed. Such implementation may eventually lead to some technological transfer in the medium term. Diversification and technological progress are expected to be fostered by the merger in 2019 of nine business units, led by the Oman Oil Company and the Oman Oil Refineries and Petroleum Industries Company, to create an integrated energy company that operates across the entire value chain of the hydrocarbon sector.

Backward linkages

Other strategies have been successfully implemented by exploiting backward linkages to the commodities sector. Some of them led to the development of both service and industry activities with a high tradability potential. Norway has set up a very innovative oil and gas industry with

41 The Sohar Refinery Improvement Project in 2016, the Muscat Sohar Product Pipeline in 2017 and the Liwa Plastics Project in 2018. For more details, see https://www.oq.com/.

substantial linkages, creating a Norwegian model of petroleum exploration as well as accelerating a manufacturing industry that supports the sector (e.g. Fagerberg et al., 2009). The Norwegian State understood that, despite the absence of government failures, the existence of market failures could prevent domestic firms from engaging in the oil and gas industry. The State then adopted a strongly interventionist approach (Leskinen, Klouman Bekken, Razafinjatovo and García, 2012), with its main objective being the creation and growth of a local cluster of firms. The Norwegian State was eventually able to foster technological transfer and promote innovation. For instance, the licensing process required foreign operators to define plans to develop the competencies of local suppliers (Heum, 2008). In addition, starting in the late 1970s, the Government required that at least 50 per cent of the research and development funds needed to develop a field had to be spent in Norwegian entities (Leskinen et al., 2012). The emergence of a high-technology and successful oil service cluster that had not existed before (e.g. Sasson and Blomgren, 2011; Cherif and Hasanov, 2019) helps to explain how Norway has become one of the richest countries in the world, despite the strong dependence on oil exports and the perverse effects this originally had on other tradable sectors.

Intersectoral horizontal diversification

Horizontal diversification towards sectors that are not directly linked to the prevalent commodity sector may imply pushing an economy beyond its current comparative advantage. In the case of fuel-export dependent economies, this may be facilitated by using resources, both pecuniary and in kind, accumulated through the exploitation of energy commodity. Indonesia succeeded in reducing dependence on oil through countercyclical spending and investment into agriculture. A de facto countercyclical budget resulted in a surplus, which enabled the Government to react proactively to the end of the oil price boom in 1981. Structural change was promoted by using the country's oil resources to increase agricultural productivity. Applied research to promote productivity played a major role. The availability of new rice varieties was instrumental in boosting productivity in the agricultural sector, a major driver of domestic demand (Gelb and Grasmann, 2010). Applying broad-based development policies, the Government made possible the distribution of new disease-resistant and high-yield rice varieties. Oil resources were also used to develop deposits of natural gas not only for export, but also as an input into fertilizer production. The use of domestically produced fertilizers, sold to domestic farmers at a subsidized price, helped increase agricultural yields significantly (Ibid., 2010). Consequently, the country is not considered an energy-dependent country anymore and this has been the case for almost a decade. Energy products and agricultural products both represent about one quarter of the total exports of Indonesia.

Indonesia has also been able to expand exports of processed and semi-processed goods during the last two decades. As shown in UNCTAD 2019b, robust growth has been observed in exports of vegetable oils (led by palm oil) and, to a much lesser degree, natural rubber. The shares of crude and refined vegetable oils in total merchandise exports were multiplied by four in the last decade, those of natural rubber by about two and those of processed oils and fats by five, though from very low initial values. From the beginning of the 2000s, the country's non-commodity exports increased by a factor of 1.4 and accounted for more than one third of the increase in total merchandise exports. Important products exported have been footwear, motor vehicles and wood products, including paper, furniture and other worked wood products. The export growth of motor vehicles reflected significant increases in domestic production. Passenger vehicle production has increased almost fourfold since the early 2000s.

Malaysia is another well-known example of successful diversification away from commodities, though from reliance on the accumulation of resources, thanks to commodity sectors. Several phases can be identified in the structural transformation process where technology transformation has played a key role. The country used to be an agrarian economy up to the 1960s. Commodities, namely tin, rubber and later palm oil, dominated the exports of Malaysia in the 1950s and 1960s. Oil and gas grew in importance, especially from the later part of the 1970s. Investment in research and development, funded through revenues from commodities, first contributed to a rise in productivity of rubber and agricultural diversification (e.g. Lebdioui, 2020). The Rubber Research Institute of Malaysia, which was established in 1926, played a central role in productivity improvements of the country's rubber industry.[42] Thanks to applied research findings, passed on to rubber estates due to strong incentive schemes and subsidies, acreages were replanted with higher-yielding planting materials. A direct consequence was an increase in the share of tapped acreage under high-yielding planting material, which moved from about 30 per cent in 1955 to about 91 per cent by 1970. Higher productivity came with a higher quality of the natural rubber produced which, in turn, has allowed producers to make new rubber products, such as tires and gloves, fostering vertical diversification in the rubber industry. Malaysia has become one of the largest producers of natural rubber gloves and has been further diversifying into higher-end products of medical gloves for the medical and health sectors (e.g. Yusof and Bhattasali, 2008).

Commodity revenues were also used to diversify away from rubber production into palm oil in response to competition from synthetic rubber and pessimism over the long-term price trends for rubber. Revenues levied by means of a specific tax (known as "cess") were used to intensify applied research on palm oil cultivation and to develop land development schemes for the cultivation of palm oil. The Palm Oil Research Institute Malaysia, the counterpart to the Rubber Research Institute of Malaysia, monitored the production of necessary research and development inputs to ease diversification into palm oil. Investments in research and development not only increased the yield of palm oil production, but also allowed the development of some resource-based products, including petrochemicals. Unfortunately, palm tree plantations have expanded at the cost of often unmonitored deforestation, with devastating effects for both the environment and the displaced population.[43] However, recent research[44] shows that palm oil production can be made more sustainable through intensification, no-deforestation and no-peat strategies, as well as through land swapping. The future of palm oil clearly lies in sustainable production along the supply chain.[45] In that respect, 60 per cent of the country's total oil palm area has already received Malaysian Sustainable Palm Oil certification, which requires producers to meet certain environmental and labour rights standards.

Keeping these negative spillover effects in mind and arguing in favour of proactive policy to eliminate them, proactive policies in the rubber and palm oil sectors can be associated with a steep increase in exports in those sectors between 1960 and 1990 (Rahman, 1998). Malaysia has also put significant political and financial efforts into diversification of the economy away from natural resources. An export-led industrialization orientation from the 1970s raised the share of manufactured exports in total exports to more than two thirds in the 2000s. Exports of electronics and electrical products account for a sizable share of total manufactured exports.

Even though the industrial sector had been increasingly prioritized by successive Governments of Malaysia, the agricultural and rural sector remained the focus of development policies in the fight against poverty but also with the commercialization and ultimately the export of products as the

42 For a discussion, see http://www.lgm.gov.my/general/rrim70yrs.aspx.

43 See for instance European Union, European Parliament, 2017.

44 See for instance Purnomo, Okarda, Dermawan, Pebrial Ilham, Pacheco, Nurfatrianie and Suhendang, 2020.

45 The Government of Malaysia decided in March 2019 to cap oil palm plantation expansion to 6.5 million hectares by 2023 (see for instance New Straits Times, Malaysia to cap 6.5m ha of oil palm plantations by 2023, 3 March, available at https://www.nst.com.my/business/2019/03/466143/malaysia-cap-65m-ha-oil-palm-plantations-2023). That was up from 5.85 million hectares reached in 2018. The Government further committed to restrict the development of peatland and to ban the conversion of permanent forest reserves for palm oil. Malaysia was expected to have all its palm plantations certified sustainable by the end of 2020, with the Government helping small farmers to do so.

primary objective (Gelb and Grasmann, 2010). The oil sector has not only played a role in funding (up to one third of government expenditures), it has also been part of the Government's diversification strategy, with technology transformation at the core. The State-owned oil company Petronas played a central role in exploitation and negotiating technology transfers from multinational firms. It thereby built-up expertise and know-how in the wake of the Norwegian experience described previously and now competes successfully in the international market. Additional elements that contributed positively to the structural transformation and diversification of the economy of Malaysia include macroeconomic stability, high rates of saving and investment, and economic openness. Moreover, Malaysia invested heavily in energy and infrastructure and built an extensive network of highways, which link the country to neighbouring countries, as well as an advanced telecommunication systems.

The experience of Botswana is also instructive, as it points to the necessity of defining coordinated actions to be able to observe long-lasting structural changes. In that respect, Governments of Botswana have been able to use diamond revenues to set up plans and programmes aimed at diversifying the domestic economy. However, coordination issues among the entities involved may help to explain the still high reliance on commodity revenues. Botswana currently has a population of about 2.4 million people, while historically the country was a rural economy with limited economic potential. But the discovery of the Orapa diamond mine in 1967 helped turn the country into a model of development and democracy in Africa (e.g. Acemoglu, Johnson and Robinson, 2001). Since its independence in 1966 and until the late 1990s, Botswana was one of the fastest growing economies in the world, with an average annual GDP growth of nearly 10 per cent. The country has managed to avoid the effects of the "resource curse" that has plagued many other African States. The diamond industry of Botswana currently contributes more than one third of tax revenue and about one quarter of GDP, making mining the country's most important economic activity (Botswana, Bank of Botswana, 2020). Prudent and long-term governance choices owing to the country's long-standing political stability and democratic culture have been important factors in this success story.

The close relationship between the Government and the private sector for diamond mining has also significantly contributed to the success of Botswana. The partnership between the Government and the international diamond conglomerate, De Beers, is an important illustration of a successful private–public partnership. The Government of Botswana has a 15 per cent stake in De Beers. In addition, the mining company Debswana and the Diamond Trading Company Botswana, the world's largest and most sophisticated rough diamond sorting and valuing operation, is a 50–50 joint venture partnership between the Government of Botswana and De Beers. Thanks to this unique arrangement, it has been estimated that 80 cents of every dollar of income generated by De Beers goes to the Government. However, notwithstanding a significant set of policies and strategies and incentive schemes implemented by the Government to promote economic diversification since the Industrial Development Act of 1968 and subsequent national development plans, the economy remains heavily dependent on diamond mining, with a narrow and shallow private sector.[46] Most of these policies and programmes have probably been piecemeal, fragmented and uncoordinated, explaining their relatively low performance in terms of structural change. The proliferation of institutions that were intended to drive diversification has also been a core part of the problem. There has been serious duplication of efforts and uncoordinated operations among these institutions, sometimes resulting in rivalries, thus undermining the very objectives for which they were established.[47]

The country's Vision 2016 programme emphasized back in 1996 that the economic challenges of Botswana had generally been the result of failure to implement existing policies, rather than

46 See Sekwati, 2010, for a brief review of industrial strategies implemented the last three decades of the past century.

47 See Kaboyakgosi and Keneilwe, 2013, for an extensive discussion.

a reflection of the merit of those policies and, therefore, recommended stringent monitoring and evaluation throughout the public sector. With the current high fluctuation of commodity prices and projected decreasing diamond extraction, diversification remains essential to the country if it is to achieve its development objectives. The launch of the Botswana Vision 2036 programme coincided with the fiftieth anniversary of the country's independence and the launch of the eleventh national development plan, which covers a six-year period from April 2017 to March 2023. Botswana Vision 2036 includes transforming Botswana into a high-income country, where continued growth would be supported by a more inclusive, diversified and export-led economy, and building a sustainable environment through the optimal use of natural resources. Apart from building its financial, agricultural and service industries, Botswana is keenly looking to grow its ICT sector. Despite being landlocked, the Government of Botswana has an ambitious plan, which it expects will define the long-term economic aspirations of Botswana, to position the country as an economic hub in Southern Africa.

5.4.2 Illustrations: Soft commodity export dependent countries

With relatively high price volatility prevailing in international markets, countries exporting mostly agricultural commodities have been eager to find efficient ways to diversify production not only away from the agricultural sector, but also within the sector itself. Horizontal diversification away from agricultural production is likely to require investments that agrarian countries may not be able to afford. This may help explain the limited number of successful stories, the most remarkable of which remain the experiences of the Asian miracles. Moreover, even though diversification within the agricultural sector may represent an easier strategy to adopt, it is highly improbable that this could foster overall diversification. Intrasectoral diversification may be motivated by strong food security considerations that become binding in cases of strong reliance on imports to cover the basic needs of a population.

Backward linkages

Backward production linkages refer to linkages from the farm to the part of the non-farm sector that provides inputs for agricultural production, for example, agrochemicals; the production of agrochemicals relies essentially on fuel-based commodities. Promoting such linkages may prove difficult when they rely on commodities that a country does not produce. However, backward linkages may also involve technological know-how or technology-based processes. Today's farming is significantly impacted by smart technologies which may represent sustained and sustainable sources of productivity growth. Smart agriculture does not refer only to autonomous equipment, such as tractors or weeding robots, but also to the application of Internet of things-solutions as in the use of sensors to collect environmental and machine metrics. Smart agriculture is seen as a direct application of the fourth technological revolution (Industry 4.0) paradigm to agriculture. Through smart agriculture, farmers would be able to make informed decisions almost in real time and over the whole production cycle. This could generate sustained productivity gains and enhanced production quality.

No large-scale case illustration of smart agriculture exists so far, but several small-scale experiences have been assessed. Assessments have also occurred at the level of individual plants, as factories that grow plants are one of the smart farming applications. A company located in Nakhon Nayok, Thailand, and founded in 2016 provides an example of a plant factory.[48] The company's corporate vision has been to adopt modern digital technology to provide fresh organic vegetables and fruits to the Thai market. A plant factory with artificial intelligence light is an indoor farming system connected with a smart control system. The structures of this plant factory separate the plants

48 See Santiteerakul, Sopadang, Tippayawong and Tamvimol, 2020, for a complete assessment.

from the external environment so that the plants are protected from uncertain conditions. These systems permit high-quality and high-yield production year-round under a controlled environment. Internet of things-based technologies allow farmers to plan production by using mobile devices for the monitoring and controlling their farming systems. As compared with conventional organic agriculture, the company has proven to perform better in most dimensions, reducing the level of utilization of all the resources involved. For instance, among the benefits of this technology are an 80 per cent reduction in fertilization costs because of lower fertilizer consumption, a 99 per cent reduction in water consumption and a 99 per cent reduction in land use compared to conventional agriculture, due to higher productivity per production area. Product weight per unit is larger, by 33 to 75 per cent, and the quality grade of the product is higher. These results translate into a 30 per cent reduction in unit cost, a 50 per cent reduction of infrastructure cost and a 30 to 50 per cent reduction in plant defects. Moreover, the plant factory keeps the cultivated area clean and free from pests. By fostering the development of these technologies domestically and helping farmers to adopt them, countries may increase the chances of achieving food security.

The adoption of Internet of things-solutions for agriculture is constantly growing.[49] The global smart agriculture market size is expected to reach $10 billion by 2023 (compared to slightly over $5 billion in 2016).[50] A successful policy strategy could be based on four core policy action modules.

The first module would consist of making information about Internet of things-solutions available and accessible to farmers. A necessary, if not sufficient, condition for new technologies or practices to be adopted is that farmers first need to know about their existence. Any means of promoting the diffusion of information about innovations that can help increase agricultural productivity may help technology diffusion and adoption. In developing countries, there is a large variety of agricultural mobile applications, offered by either public organizations or local enterprises supported by mobile network operators. In India, a government portal offers a variety of mobile applications for agriculture, horticulture, animal husbandry and other agricultural fields.[51] In Kenya, SMS and a voice mobile application are used to provide information as part of a subscription service.[52] The objective is to increase the productivity of farms through access to expertise, information and knowledge. In the same vein, another SMS service application[53] allows small-scale farmers to ask questions by means of SMS to other registered users in Côte d'Ivoire, Kenya, Uganda and the United Republic of Tanzania.

A partnership with smart agricultural consulting firms can be set up and funded by a Government or international partners so that information can be provided free of charge to farmers. For example, the German Agency for International Cooperation commissioned the development and diffusion of an application for smallholder potato farmers in India.[54] In cases where smart farming requires some capital equipment, such as tractors, another option is made available in the context of technical diffusion and relates to the pooling of investment resources, as discussed earlier.

The second policy action module relates to reform of the regulatory framework to promote quality certification and recognition, both domestically and internationally. Compliance with regulations, such as sanitary and phytosanitary measures and technical barriers to trade that prevail in a specific market, is a sine qua non to access a given market. However, meeting all requirements related to such regulations would entail some specific investment and adaptation of production processes. If this translates into prohibitive additional production costs, often sunk, small-scale

49 See FAO, 2019, for a comprehensive review of existing opportunities and market development.

50 See Navarro, Costa and Pereira, 2020.

51 See https://mkisan.gov.in/.

52 See www.icow.co.ke/.

53 See https://wefarm.co/.

54 For additional information, see https://www.smartfarmingtech.com/.

producers may be unable to explore new market opportunities.[55] Moreover, certification is often provided by specialized laboratories that may not be active within a specific country which would further increase the cost of exporting.

Governments may be willing to reform domestic regulations to reduce regulatory gaps with more advanced economies. This would not only lead domestic producers to upgrade their production capacity (subsidy schemes may alleviate any cost impact on smaller-scale farmers) but also promote food security domestically, contributing to the achievement of Sustainable Development Goal 2. One recent example is the agricultural development programme of Senegal. The promotion of fruit and vegetable export chains was integrated into the programme, with the objective of also impacting the safety of products sold on the domestic market. The increase in the supply of export products, such as melon, watermelon and green beans, in the local market counter seasonally illustrates the possible existence of positive spillover effects.[56]

The third policy action module, in conjunction with the previous one, would establish financing schemes to allow any farmer to participate in diffusion efforts through capacity-building activities for their peers.

The fourth policy action module should aim at promoting the adaptation of technologies to local conditions and providing incentives to innovate in Internet of things-solutions. Such a module would be implementable with the use of all data collected through the solutions adopted originally. There is a clear potential for learning by producing, fostered by a systematic analysis of the information collected. Domestic research institutions should be involved or even created to cope with the challenge of data collection and exploitation. In the project involving an application for smallholder potato farmers in India mentioned previously, all agronomic content and recommendations are first tested and approved through participatory technology development with farmers adapting as much as possible to local specific conditions.

Forward linkages

Forward production linkages refer to the part of the non-farm sector that uses agricultural output as an input. The distribution and processing of agricultural output are fundamental components of forward production linkages. Examples of marginal processing within the input producing country abound. Cotton in Africa[57] and coffee in Latin America[58] are often cited. However, technology adoption in vertically integrated production chains may be facilitated by participation in global value chains even though this could entail undesirable situations.

Small-scale projects may also represent informative examples. This is the case for instance in the resurgence of raisin production in Afghanistan, through the private sector and facilitated by international development funds. The development of a fruit processing company, which was created in 2014 with the aim of bringing the latest raisin wash technology to the country's raisin sector, has benefited from the support of working capital financing of the International Finance Corporation and advisory services, with a total investment of up to $3 million. The company further benefits from the guarantee offered by the Multilateral Investment Guarantee Agency that covers up to $7.8 million of equity investments and loan guarantees.[59] The interventions of the International Finance Corporation and the Multilateral Investment Guarantee Agency have been made commercially viable, despite the high risks involved in the investments, by innovatively using blended finance

55 See Fugazza, Olarreagga and Ugarte, 2017, for some evidence based on the experience of Peruvian firms.
56 Complete information on the programme is available at www.ipar.sn/IMG/pdf/pracas_version_finale_officiele.pdf.
57 See UNCTAD, 2019c.
58 See International Coffee Organization, 2019.
59 See OECD and United Nations Capital Development Fund, 2019, for a review of the project.

solutions. These investments are part of the broader National Horticultural and Livestock Project. The objective of the project is to introduce new agricultural practices and help farmers enhance their productivity levels and comply with international standards. Many raisin drying houses are being constructed – these are owned by farmers who will eventually be integrated into the supply chain of the company. The involvement of the International Finance Corporation went beyond providing affordable financing by sharing industry comprehensive guidance to the client, ranging from advising on plant and storage capacity designs and recruiting a financial and operational management team, to brokering negotiations with potential buyers in potential export markets. The company investments are expected to double the country's raisin processing capacity and increase quality by implementing modern processing technology and food safety practices. Such technological transformation should help local raisin farmers gain access to global export markets and eventually support sustainable livelihoods for close to 3,000 rural smallholder farmers. Selling prices for raisin farmers in the region are also expected to rise by 15–20 per cent compared to current market prices.[60] This would be the combined effect of a quality premium and uninterrupted sales on international markets and elimination of intermediaries in procurement, apart from the lead firm itself.

Participation in global value chains does not necessarily have to take place on large geographical scales and may be concentrated at a regional level. Cotton could again provide interesting examples, especially in Southern Africa. The case of hemp production and processing in Malawi and South Africa (Lowitt, 2020) can be considered. While Malawi, which has recently legalized industrial hemp production, has a clear comparative advantage in production, South Africa has excess and unused capacity in almost all downstream processing activities. There is an intensive research and development and technology development programme under way in South Africa in a multitude of industrial and consumer products based on industrial hemp inputs. In addition to productive capacity, the South African industrial hemp market is growing. The value chain complementarity between Malawi and South Africa is strong. The fact that both Malawi and South Africa are members of the Southern African Development Community should facilitate the establishment of an intraregional production and supply chain. As such the creation of an interregional industrial hemp value chain between Malawi and South Africa is feasible and could potentially be both lucrative and sustainable.

The most viable and strongest demand-led niche markets for industrial hemp are, for the time being, production of hemp oils to be used in cosmetics and personal care products, production of hemp seeds for human consumption as a "super food" and production of cannabidiol oil for therapeutic use. Even if demand were not to expand further, current conditions are sufficient to guarantee profitability for producers in both countries.

Horizontal intersectoral diversification

The most remarkable success stories in terms of horizontal diversification, technological upgrade and eventual catching up with advanced economies often refer to the experiences of the Asian miracles (i.e. Hong Kong and Taiwan Province of China (China), Republic of Korea and Singapore). Industrial policy played a preeminent role in the development experiences of these economies. The strategy of their industrial policy/public interventions was based on three pillars that shaped what has been defined as a true industrial policy (Cherif and Hasanov, 2019). The first pillar was public intervention to create new capabilities in sophisticated industries. The policies pursued aimed at steering the factors of production into technologically sophisticated tradable industries beyond the current capabilities to swiftly catch up with the technological frontier. The second pillar was a sustained promotion of exports. Any new industrial product was expected to be exported

60 For the project description and product projections, see https://www.miga.org/project/rikweda-fruit-process-company-0.

within a short time spell, with the use of market signals from the export market as feedback for accountability and rapid adaptation by both a Government and the firms. The third pillar was strong competition on both domestic and international markets and strict accountability. While public support was provided, competition among domestic firms was also highly encouraged in both domestic and international markets. This made performance a de facto condition to benefit from subsidies.

The outcomes of such a strategy were striking. The Republic of Korea, for instance, was exporting mainly non-fuel crude materials until the first half of the 1960s. Non-manufactures represented about 90 per cent of its basket of exported products until the surge of the manufacturing sector which made up about 70 per cent of exports at the end of the 1960s. The economy went from no experience in running an integrated steel mill to building one of the biggest mills in the world. Hyundai was originally a construction company and, despite having no experience in modern shipbuilding, it built the largest shipyard in the world (and simultaneously its first ship). The company also moved to the automobile industry with no prior experience. The company built a factory right away, with annual capacity exceeding the total annual car sales of the whole country. It was also able to build networks of dealerships in the United States, the largest and most competitive market in the world at that time.

The experiences of the Asian miracles have never been replicated at a comparable scale and are often considered as particular. What made the development strategy of these Asian economies successful is not only the non-orthodox combination of public interventions and policies but also a favourable international economic and political context.[61] Good fortune may have also played some role, even though good fortune may be considered as endogenous to good policy.[62] Other country or region-specific features, such as culture and social organization, probably constitute additional core elements for explaining such extraordinary catch-up and convergence. Currently, even if an economy were to start from similar initial conditions and implement the same set of policies and regulations, it is unlikely that the results would be the same, as external conditions have changed dramatically. The international fragmentation of production and the evolution of the international trading system have resulted in rapidly evolving comparative advantage patterns.[63] As a consequence, the set of strategic options Governments may consider have significantly narrowed and may necessitate complex fine tuning and adaptive responses. Some authors argue that, rather than pointing to classical horizontal diversification, resource dependent countries should focus on the promotion of backward and forward linkages to the commodity sector.[64]

5.5 Conclusion

As discussed in this chapter, technology and technical know-how represent major factors of successful implementation of most diversification strategies. Technological improvements operate either by means of some transfer operations, as a direct consequence of innovation or a mix of the two. Technological transfer has proved to be most effective when producers active domestically are able to adapt existing technologies to local conditions. In that respect, innovation is also at work but relates to the production process more than to technology itself. Foreign direct investment has proven to play a central role in the transfer of technology and technical know-how, particularly due to production fragmentation and outsourcing observed over the last 20 to 30 years. To become fully effective, technology transfer should lead to local innovation at least in the medium

61 See Cherif and Hasanov, 2019, for a comprehensive discussion.

62 See for instance Leung, Tan and Yang, 2004, for a critical assessment.

63 See Hanson, Lind and Muendler, 2018, and Krishna and Levchenko, 2013, for some empirical evidence and theoretical insights.

64 See for instance Morris and Fessehaie, 2014, and Morris, Kaplinsky and Kaplan, 2012, for a discussion about African countries.

run. This requires national innovation systems to be strengthened and made more effective in fostering innovation that promotes national development and the achievement of the Sustainable Development Goals.

An effective institutional framework able to coordinate the various actors engaged in innovation and learning – research and development centres, universities and technology schools, extension services and the innovating firms themselves – would also be necessary. In addition, investments may have to be redirected over the long term towards new capabilities and an ambitious educational strategy in support of these processes. Other common features among the policies implemented in the various country cases reviewed in this chapter include risk-taking when relying on revenues from natural resources, characterized by high price volatility on international markets, and encouraging competition in domestic and international markets. It is important to be aware that success is not immediate. To be successful, the countries discussed in this chapter in most cases pursued diversification policies over decades. Moreover, for diversification to succeed, concerted efforts are required to channel resources towards well identified and achievable objectives, especially financial resources, and to build effective institutions.

Complementarities could be strong enough to call for an O-ring (Kremer, 1993) type of policy approach requiring all policy interventions to be executed proficiently and coherently. This would imply that without a successful implementation of at least a subset of policy actions and reforms, the overall policy objective would not be reached. The literature has so far identified, as possible, major sources of failing policy reforms, non-appropriate treatment of production-related market failures and so-called government failures (e.g. Rodrik, 2004). As pointed out in Ocampo (2020), structural change should be conceptualized as a meso-economic process that encompasses production composition effects, intrasectoral and intersectoral linkages, market structures, the functioning of factor markets and the underlying institutions.

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CHAPTER

6

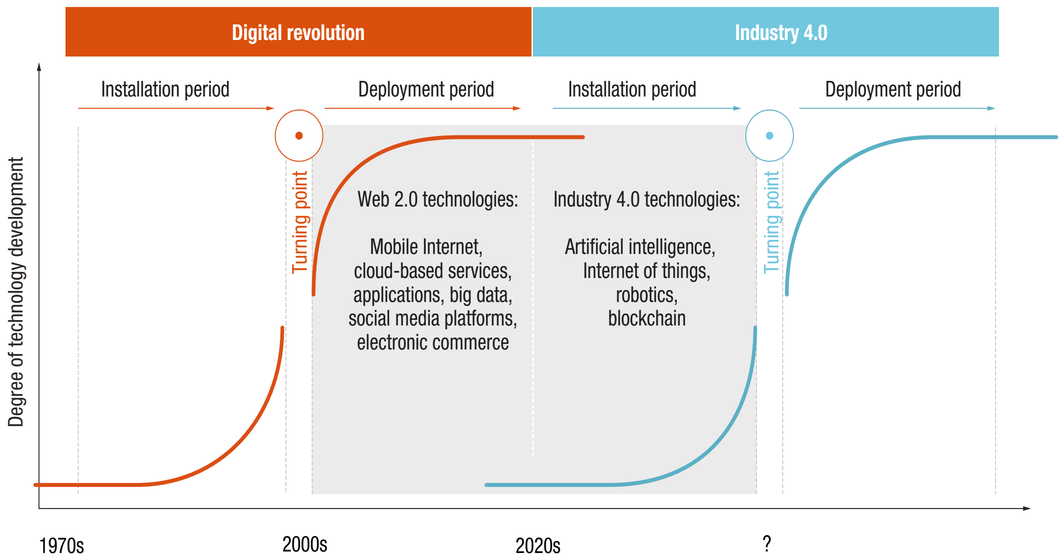
Opportunities from Technological Revolutions

6.1 Introduction

What are the roles of new technologies in structural transformation in commodity dependent developing countries? New technologies offer the possibility of new combinations, or innovations, and are essential for the technological upgrading of traditional production sectors in these countries, as well as diversification into other sectors. This chapter is focused on new technologies that trigger new technological–economic paradigms, that is, the clusters of technologies, products, industries, infrastructures and institutions that characterize a technological revolution (Perez, 2002; UNCTAD, 2021).

The role of finance is critical in this process as it provides the resources needed for innovation. The interplay of productive and financial capital is part of the life cycle of a technological revolution, with an installation period followed by a deployment period. The duration of the life cycles of previous technological revolutions has been 20–50 years and financial booms and busts have marked the transitions from installation to deployment periods, as discussed in section 6.2. Technological–economic revolutions require specific infrastructure, such as reliable electricity and ICT; and institutions, such as laws and regulations, some of which should be provided by the Government. In the past, such revolutions began in one or a few countries at the technological frontier. New technologies percolated through the economy by being combined with traditional technologies in a gradual process from core sectors of the economy in which the new technologies emerged towards other sectors and from countries at the centre of the technological revolution towards other countries. It may be argued that the mature phase of the deployment period of the current digital revolution is ongoing, characterized by use of the Internet, mobile connectivity and web 2.0 technologies (figure 6.1; UNCTAD, 2021). This technological–economic paradigm has, among other changes, resulted in an increasing share of global value chains in global production and decreasing costs of communications and transactions, as well as the emergence of electronic commerce. The digital revolution has already reached a mature phase in developed countries, having affected economies and societies, yet it is still in the installation period in many developing countries, including many commodity dependent developing countries, and has not yet reached the most traditional

Figure 6.1 **Technological revolutions: Two latest waves**



Source: UNCTAD, based on Perez, 2002.

sectors. Some studies suggest that a new technological–economic paradigm, Industry 4.0 has begun, characterized by frontier technologies such as artificial intelligence, robotics, blockchain technology and gene editing, as well as the use of renewable energy technologies (Schwab, 2017). The latter are important in addressing the effects of climate change (UNCTAD, 2021).

Technological revolutions and their impacts in commodity dependent developing countries are discussed in section 6.3. As these technological waves are in the initial stages in most of these countries, in particular the least developed countries, many of the possibilities of these technologies, for use in applications that could contribute to increasing productivity in resource-based sectors and in moving countries away from commodity dependence, are discussed. However, technological feasibility is not a guarantee that new technologies will be economically applicable in the context of low-income commodity dependent developing countries with a large labour surplus. Major factors that limit the deployment of frontier technologies include the fact that the skills of the labour force and the required ICT infrastructure have not yet been built and that the necessary institutional changes have not yet been implemented, as well as a lack of investment due to the scarcity of financial resources (UNCTAD, 2021). The current (digital) and emerging (Industry 4.0) technological revolutions will change commodity sectors and related global value chains and will have significant impacts in commodity dependent developing countries. These countries may not yet be ready to deploy Industry 4.0 technologies, but there are other ways of taking advantage of such technologies, as addressed in section 6.4. There are challenges involved, yet harnessing such technologies could help these countries to diversify and structurally transform their economies. In this regard, a three-pronged strategy for structural transformation in commodity dependent developing countries is presented in section 6.5, based on continued efforts to diversify economies toward more complex products that are close to each other in the product spaces of countries; the promotion of digitalization to catch up with the digital revolution; and the preparation of people, firms and farms for the frontier technologies of Industry 4.0. Conclusions are provided in section 6.6.

6.2 Technological revolutions

There is a big push in developing countries to enhance digitalization, electronic commerce and digital integration in global value chains and these are all signs of the further deployment of the digital revolution. In addition, these trends have been accentuated by the pandemic, which has highlighted the importance of the digital economy and digital services as a lifeline to keeping society and the economy afloat in times of crisis. However, for many people in low-income and lower-income developing countries, concerns about artificial intelligence and robotics are considered less relevant given the need to catch up with the previous technological revolutions involving industrialization, electricity and mass production. The framework of technological–economic paradigms includes five technological waves since the industrial revolution; many consider that Industry 4.0 is the latest (table 6.1; Perez, 2002; Schwab, 2017).

Where do commodity dependent developing countries stand with regard to previous and current technological revolutions? Some of the elements of previous paradigms are still being implemented in different economic activities in commodity dependent developing countries. In many of them, mechanization (first technological revolution) has not reached most farms, large shares of the population lack access to electricity (third), many production sectors have not been able to take advantage of economies of scale and become internationally competitive (fourth) and the digital revolution (fifth) has been limited to the use of mobile telephones and digital platforms. These waves of technological change start in one or two of the most technologically advanced countries, then spread worldwide, first to other developed economies, then to more complex sectors in emerging economies and later to economies that are at the periphery (Perez, 2002). It takes time to deploy technology, for two main reasons. First, such deployment happens from one sector to another as

Table 6.1 **Technological revolutions: Overview**

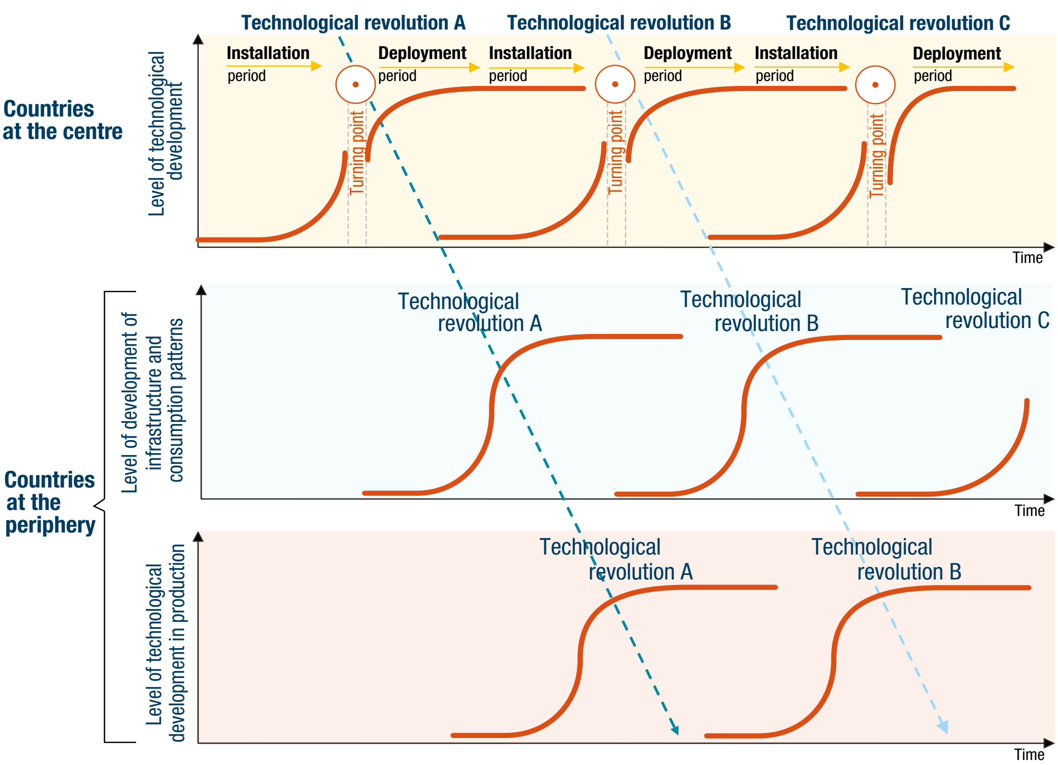
Revolution	New technologies or new and redefined industries	Paradigm	Key commodities
First: Industrial revolution, 1771	Mechanized cotton Wrought iron Machinery	Factory production Mechanization Productivity, timekeeping and timesaving Local networks	Cotton Iron
Second: Age of steam and railways, 1829	Steam engines and machinery Iron and coal mining Railway construction Rolling stock production	Economies of agglomeration, industrial cities and national markets Scale as progress Standardization of parts Energy when needed (steam)	Cotton Iron
Third: Age of steel, electricity and heavy engineering, 1875	Cheap steel Steam engines for steel ships Heavy chemistry and civil engineering Electrical equipment Copper and cables Canned and bottled food Paper and packaging	Large steel structures Economies of scale of plants and vertical integration Distribution of power for industry (electricity) Science as a productive force Worldwide networks Universal standardization Cost accounting	Copper
Fourth: Age of oil, automobiles and mass production, 1908	Mass-produced automobiles Cheap oil and oil fuels Petrochemicals (synthetics) Internal combustion engine Home electrical appliances Refrigerated and frozen foods	Mass production and markets Economies of scale Horizontal integration Standardization of products Energy intensity Synthetic materials Functional specialization Suburbanization Global agreements	Oil
Fifth: Digital revolution (age of ICT), 1971	Cheaper microelectronics ICT and the Internet Control instruments Biotechnology and new materials	Information intensity and instant communications Knowledge as capital Digital platforms and social media Connectivity and mobility Electronic commerce and electronic government Segmentation of markets Economies of scope Flat organizations and network structures Global value chains Millennium Development Goals	Data Oil
Sixth: Industry 4.0, 2010	Artificial intelligence, Internet of things, robotics, drones, three-dimensional printing and blockchain technology Smart production Smart cities Renewable energy	Automation Digital integration Niche markets Local production on demand Sustainability Sustainable Development Goals	Data Renewable energy sources

Source: UNCTAD, based on Perez, 2002.
Note: The starting date of each revolution is indicative, given that they are processes that unfold over many years.

new technologies are combined with existing ones in more traditional sectors. This process usually starts in industries that are more complex and in which fewer developing countries are engaged. It also requires an enabling infrastructure and the necessary skills. In developing countries, two issues are particularly challenging with regard to the broader use and adoption of new technologies, namely, upgrading digital infrastructure and enhancing technical skill levels. Second, such deployment requires changes in social behaviour and institutions and there may be significant inertia in these areas. It may therefore take several years for changes to play out. Figure 6.2 illustrates this uneven deployment. In countries at the centre of the technological–economic paradigm, the deployment of new technology in production sectors is accompanied by the roll-out of the required infrastructure and changes in consumption patterns. Once a technological revolution matures, financial capital starts to look for new opportunities to achieve higher returns, either by extending the paradigm to other countries or investing in an emerging technological revolution. This in turn creates the sequencing of waves of technological revolutions, which reach developing countries out of synchronization and with a delay. The deployment of the infrastructure required under the paradigm and changes in consumption patterns, such as seen in the use of smart telephones and electronic commerce, tend to be the first changes that reach countries at the periphery. The deployment of new technologies in sectors of production is the last stage and may occur first through foreign direct investment and begin to be integrated into domestic firms only after further delays.

Perez (2002) notes that the initial push to improve infrastructure and change consumption patterns is usually driven by foreign firms seeking to expand their markets. The deployment of new technological paradigms in developing countries also depends on how attractive these countries may be to international investors and firms. The result is a patchwork of elements of

Figure 6.2 Technological revolutions: Uneven deployment



Source: UNCTAD, based on Perez, 2002.

different technological–economic paradigms in various sectors of an economy. In many commodity dependent developing countries, a large share of the agricultural sector, namely, the subsistence agriculture subsector, may be operating under technologies, rules and expectations that resemble those in the period before the industrial revolution. In contrast, in major cities, innovation hubs promote the dissemination of the newest technologies of artificial intelligence, robotics and three-dimensional printing. This mismatch of paradigms creates new challenges for interventions that seek to promote structural transformation. For example, in Ethiopia, in garment factories installed through foreign direct investment in industrial parks, a key area of required training for new workers, usually from rural areas, is in soft skills related to work ethics in the factory environment, timekeeping and productivity,[65] all of which were elements of the first technological revolution. The level of technological development in communications, transport and energy-related infrastructure with regard to the different paradigms helps to assess the levels in commodity dependent developing countries (table 6.2). In many of these countries, universal access to electricity has not yet been achieved and the network of roads and ports remains weak, placing them in the fourth technological revolution. At the same time, countries have leapfrogged the installation of analog telephony to deploy digital infrastructure.

Most commodity dependent developing countries have weak infrastructure for high-speed fixed Internet connections, such as fibreoptic and broadband or high-speed mobile connections, and such digital infrastructure is not broadly available to large shares of the population (table 6.3). Digital

Table 6.2 **Technological revolutions: Changes in infrastructure**

Revolution	Communications	Transport	Energy
First: Industrial revolution		Canals and waterways Turnpike roads	Water power (highly improved water wheels)
Second: Age of steam and railways	Worldwide postal service National telegraph	Railways Large seaports and depots	Municipal gas
Third: Age of steel, electricity and heavy engineering	Worldwide telegraph National telephone	Worldwide shipping Worldwide railways Large bridges and tunnels	Electricity for illumination and industrial use
Fourth: Age of oil, automobiles and mass production	Worldwide analog telecommunications (telephone, telex, cablegram), wired and wireless	Networks of roads, highways, seaports and airports	Electricity for residential and industrial use
Fifth: Digital revolution	Worldwide digital telecommunications (cable, fibreoptics, radio, satellite) Internet, email, other electronic services	High-speed physical (land, air, water) transport links	Multiple source, flexible use electricity networks
Sixth: Industry 4.0	Broadband Internet Mobile Internet, smart telephones	Faster physical transport links (hyperloops, space flights) Driverless cars	Renewable energy Electric cars

Source: UNCTAD, based on Perez, 2002.

65 Based on the findings in UNCTAD, 2020a.

Table 6.3 **Gaps in access to digital infrastructure**

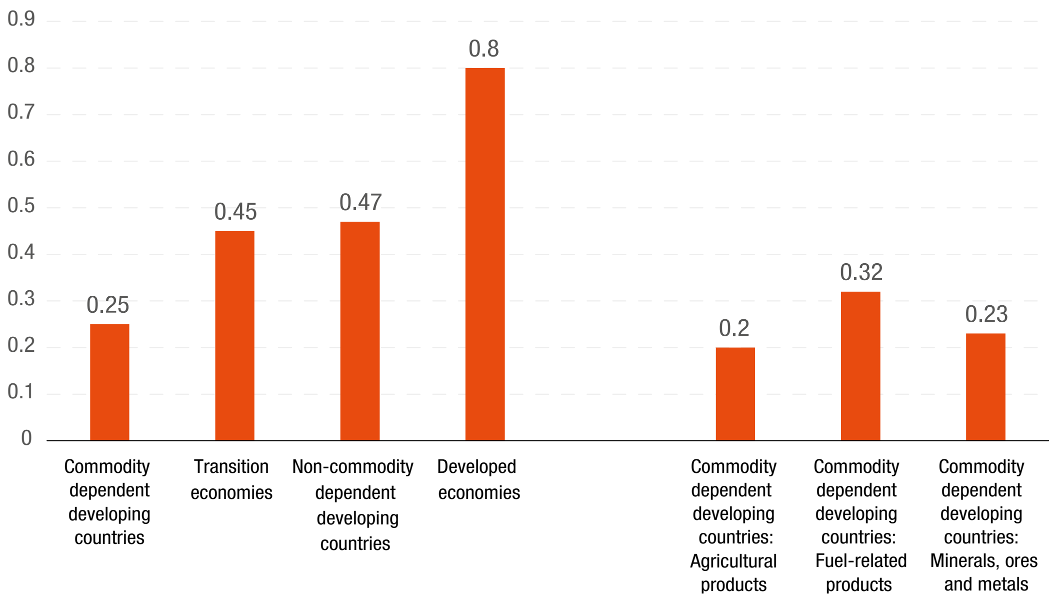
Indicator	Commodity dependent developing countries	Non-commodity dependent developing countries	Transition economies	Developed countries
Average share of households with a computer at home (percentage)	17.8	25.1	52.4	65.5
Average active mobile broadband subscriptions per 100 inhabitants	56.8	78.0	76.0	110.1
Average share of households with Internet access at home (percentage)	21.7	36.2	60.9	80.5
Average mobile cellular subscriptions per 100 inhabitants	96.4	121.9	120.9	122.7

Source: UNCTAD calculations, based on data from the International Telecommunication Union.

and frontier technologies require technological literacy and skills and these are usually at a lower level in developing countries. The development of skills for the use of digital technologies requires people to be exposed to such technologies and actively engaged in learning by using, which may be a challenge in low-income commodity dependent developing countries with high rates of illiteracy among the population.[66]

The UNCTAD frontier technology readiness index suggests that commodity dependent developing countries are less prepared to adopt and adapt these technologies than non-commodity dependent developing countries, transition economies and developed countries (figure 6.3).

Figure 6.3 **Frontier technology readiness index**



Source: UNCTAD calculations, based on UNCTAD, 2021.
Note: The index is computed based on indicators under the following five areas: deployment of ICT; skills; research and development activity; industrial activity; and access to finance.

66 As discussed in UNCTAD, 2021, higher poverty rates and lower levels of Internet access and digital skills are three key barriers in developing countries in harnessing digital frontier technologies for sustainable development.

Among commodity dependent developing countries, those that depend mainly on agricultural products are less prepared than those that depend on fuel-related products and on minerals, ores and metals.

6.3 Potential impacts of digitalization and Industry 4.0 on commodity sectors and related global value chains

Digitalization and the adoption of a wide range of frontier technologies, from renewable energy to the Internet of things and big data, will profoundly affect the demand and supply of commodities, increase demand for energy produced by green technologies and reduce the costs associated with extracting and producing commodities. Such technologies are expected to impact commodity sectors and related global value chains regardless of the capacity of commodity dependent developing countries to use, adopt and adapt them. Therefore, policymakers and other stakeholders in these countries should be aware of the potential impacts of these technologies, to better prepare and make efforts to take advantage of such changes.

Metals, minerals and rare earth elements are critical commodities for green technologies (Bailey et al., 2020; Sovacool et al., 2020). Accelerations in the deployment of green technologies such as wind power, solar power and energy storage significantly influence the commodity market. Demand for minerals such as lithium, cobalt and rare earth elements, as well as for aluminium, copper, indium, iron, lead, silver and bauxite, may increase from the substantial shift to low-carbon technologies (Church and Crawford, 2020; World Bank, 2017). Any move to a more renewable energy-intensive economy will result in a greater overall demand for metals (Church and Crawford, 2020; Dutta et al., 2016). For example, with regard to energy storage technologies, the future of transportation in the next few decades, not only the number of vehicles on the road but also the extent to which they will be fully electric, will determine future demand for the relevant minerals and metals. The World Bank (2017) estimates that demand for the metals required for supplying energy storage technologies, including aluminium, cobalt, iron, lead, lithium, manganese and nickel, could increase by 1,000 per cent through 2050 if the international community stays on track to meet the goal in the Paris Agreement under the United Nations Framework Convention on Climate Change of holding the increase in the global average temperature to below 2°C above pre-industrial levels. The Institute for Sustainable Futures (2019) estimates the annual demand for minerals and metals if the global average temperature increase is limited to 1.5°C above pre-industrial levels, showing that demand for some metals exceeds current production levels (table 6.4). This growing demand can serve as an economic opportunity for those countries that have major reserves of these commodities.

On the supply side, frontier technologies can be deployed to extract new commodities whose extraction was not previously economical. For example, advances in biotechnology such as biorefining techniques have facilitated the "sequential extraction of the major components of red algal biomass as commodity products such as pigments, lipid, agar, minerals and energy-dense substrate (cellulose)" and the "large-scale production of marine macroalgae, mainly for human consumption, has given rise to their consideration as a non-lignocellulosic feedstock for the production of renewable fuels [yet making biofuel] from algal biomass requires the coproduction of additional useful biochemical components that are unique to algae" (Baghel et al., 2015). Findings from new studies may form the basis for starting new ocean-based bioindustries, thereby minimizing "dependence on terrestrial resources for food, feed, energy and chemicals" (Baghel et al., 2015). There are also new technologies that may significantly change the way lithium is extracted, minimizing water use and speeding up the recovery process (Doyle, 2019; UNCTAD, 2020b).

Table 6.4 **Estimated annual demand from renewable energy and storage compared with current production**

	Total demand (tons)	Total demand: Share of annual production (percentage)	Year of peak demand	Leading economies in share of reserves (percentage)
Cobalt	1 966 469	1 788	2050	Democratic Republic of the Congo (49), Australia (17), Cuba (7), Zambia (4), Canada (4), Russian Federation (4)
Lithium	4 112 867	8 845	2050	Chile (47), Australia (17)
Nickel	6 581 326	313	2050	Brazil (16), Cuba (7), Indonesia (6), Philippines (6)
Tellurium	834	199	2035	China (21), Peru (12), United States (11), Canada (3)

Source: Institute for Sustainable Futures, 2019.
Note: Data are from 2017. The Plurinational State of Bolivia has identified large resources of lithium but data on reserves are not available (see UNCTAD, 2020b).

6.3.1 Commodity value chains

Frontier technologies, including the Internet of things, blockchain, robotics and drones, are expected to lead to profound transformations in global commodity value chains, resulting in continuous improvements, as follows:

(a) Reduced transaction costs: For example, in developing countries, transactions in the cocoa sector are mainly performed in cash and smallholders and buying companies may be subject to robberies, fraud and thefts; in this regard, blockchain technology-enabled payment services would allow buyers to access the digital records of payments made to farmers.[67] For example, digital payments may be used to purchase inputs, help reduce the time spent travelling to make payments, ensure better control over the finances of farmers and enable access to financing mechanisms (Quayson et al., 2020).

(b) Increased efficiency and profitability: The Internet of things provides possibilities for setting up a decentralized grid of smart sensors reporting in real time on the status of the soil, weather conditions and other relevant parameters and supplying such information to a central computer serving as a cyberagronomist to analyse and predict crop conditions and advise farmers on the best use of water, fertilizer and other inputs, in order for farmers to use the data to monitor variability in crop health and make timely management decisions, to increase input use efficiency, crop yields, quality and profitability (Ananthi et al., 2017). In commodity dependent developing countries, this technology is currently more applicable to large agricultural producers, given the many challenges for smallholders, such as with regard to affordability, ICT access and digital capacity with regard to the use of applications.

(c) Improved transparency, traceability and reliability: For example, FAO, in collaboration with the International Telecommunication Union, has conducted a pilot project on livestock using blockchain technology to create a database for traceability. Participating farmers were registered and their livestock was tagged with radio frequency identification-enabled tags linked to the database. Farmers inputted data into the system on breed type, feed type,

67 As with other digital technologies, the use of blockchain in applications for smallholders needs to include considerations of their literacy levels, including technological literacy, and of the fact that they may be in remote areas in which there is poor or no Internet coverage. The use of blockchain may be a challenge but identifying practical ways for smallholders to harness the benefits could help.

geography, incidences of disease and remedies, and potential buyers could review the information prior to purchase (UNCTAD, 2020c).

These examples show some of the benefits that new technologies can bring to commodity value chains. At the same time, in the deployment of technology and innovation, it is crucial for technological solutions to be economically feasible, as well as available, affordable and accessible (for example, in terms of language and content), and that there is awareness of the benefits and ability to use them among intended users.

6.3.2 Commodity trade

Commodity trading "has traditionally relied on vast paper trails to execute, authenticate and process each transaction" (Fraenkel, 2018). The industry has lagged behind other sectors in using digital solutions but is catching up in digitalizing and in adopting new technologies (Amic, 2020). Frontier technologies can be used for the following:

(a) Optimizing transaction effectiveness and transparency: Blockchain technology can serve as a natural fit solution for trading applications. For example, in a hypothetical scenario of soybean trade from the United States to China, the estimated savings through the use of blockchain technology were 2.3 cents per bushel of soybeans and a reduction of 41 per cent in the total time required, including for documentation and transit, which is significant for agribusinesses and other agricultural stakeholders evaluating the benefits of adopting such technology in the international trade of commodities (Lakkakula et al., 2020). Smart contracts using blockchain technology, which are executed automatically when predefined conditions are met, may be leveraged to automate trading agreements since their use enables trading functions involving the transfer of information and value that provide transparent and reliably auditable information trails (Dekker and Andrikopoulos, 2020; Khan et al., 2020; UNCTAD, 2020c).

(b) Processing data and forecasting commodity prices: The trade of commodities faces significant price volatility from speculators that purchase assets for a short time with the expectation of profiting from price fluctuations and that may never deliver the commodity (Pham, 2020). The United States Commodity Futures Trading Commission (2019) states that automated trading increased in 2013–2018 and, in 2018, constituted over 70 per cent of futures markets in energy products, metals, grains and oilseeds. Artificial intelligence, in particular machine-learning algorithms, can be employed to associate trade patterns with fundamentals and price movements, to help reduce noise, improve the decision-making process, optimize hedging programmes for improved risk reduction and portfolio optimization and improve efficiency across the commodity industry (Commodity Technology Advisory, 2018; Paranjape, 2019). However, it is important to closely follow the application of frontier technologies in this area since a lack of transparency in the use of artificial intelligence algorithms can have unintended consequences that may strengthen the position of commodity speculators, with significant impacts on small producers in developing countries.

These examples show some of the benefits that new technologies can bring to the trade of commodities.[68]

6.3.3 Commodity sectors and climate change

In 2019, total annual global greenhouse gas emissions reached a record high of 59.1 gigatons of carbon dioxide equivalent and production, transportation, processing and consumption in commodity sectors were among the main sources of these emissions (UNCTAD, 2019a; United

68 The use of frontier technologies also raises questions about the regulation of the digital economy, in particular with regard to intellectual property, data privacy rights, competition and consumer protection.

Nations Environment Programme, 2020). Frontier technologies can help improve the resilience of commodity sectors to climate change and strengthen their contribution to sustainable development. Smart water management, specific environmental monitoring and enforcement and enhanced weather and disaster prediction and response are some examples of the potential of these technologies to support climate change mitigation and adaptation.

The mining sector, including the extraction, processing, refining and transportation of raw materials, is energy intensive and can have a long-term impact on the environment (Azadi et al., 2020; United Nations Climate Change Secretariat, 2018). Estimates suggest that, in 2018, the contribution of primary minerals and metals production corresponded to approximately 10 per cent of total global energy-related greenhouse gas emissions (Azadi et al., 2020). Low-carbon technologies, particularly solar photovoltaic technologies, play a significant role in decarbonizing electricity production in the mining industry. The adoption of emissions-efficient and cost-efficient solar photovoltaic cells may bolster energy security and support commodity sectors in remote areas that are not connected to national power grids. For example, in Burkina Faso in 2018, an isolated and off-grid gold mine installed a solar photovoltaic plant to add to the existing electricity system that relied on heavy fuel oil (Liedtke, 2018). Many renewable energy installations at mining sites are in different stages of planning (Rocky Mountain Institute, 2021).

Blockchain technology has the potential to help reduce the carbon footprint of the commodity sector. For example, in Kenya, the global low carbon tea project is attempting to formulate a resilient and low-carbon tea value chain using such technology. Activities include a feasibility study and pilot testing of the technology in the sector, which is expected to support production in the tea value chain and the traceability and transparency of emissions. The project can help increase trust among consumers and retailers and tea promoted as a carbon sink could also give growers potential access to carbon markets, bringing economic incentives for small-scale tea producers (UNCTAD, 2020c).

6.4 Windows of opportunity in deploying digital technology and preparing for Industry 4.0

Digitalization and the drive to adopt digital and frontier technologies in electronic commerce and global value chains can open new windows of opportunity in developing countries, including commodity dependent developing countries, to catch up and narrow the technological gap with developed countries. There are opportunities to leapfrog in communications and energy-related infrastructure, facilitate trade and promote financial inclusion, all of which are indispensable in realizing the potential for diversification and structural transformation in commodity dependent developing countries.

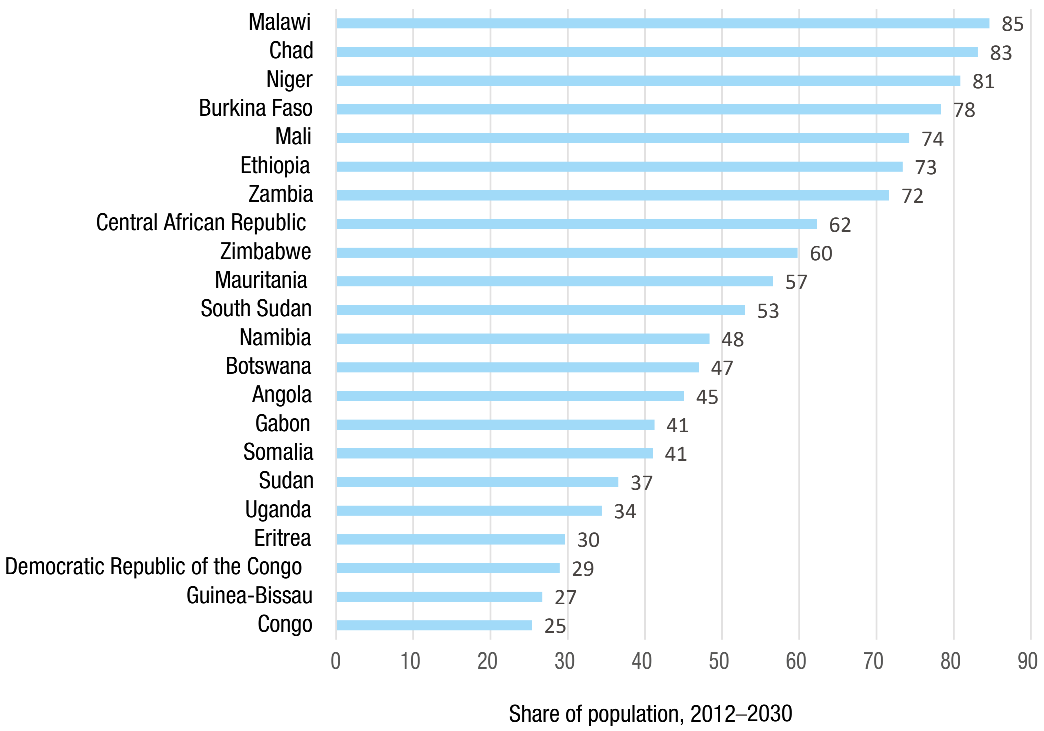
6.4.1 Leapfrogging in infrastructure

Frontier technologies offer economically viable alternatives to costly investment in infrastructure related to traditional technological paradigms. An example of the potential for leapfrogging is in the development of decentralized renewable energy systems. Low-cost, high-efficiency solar panels are available for household rooftop installations and village-level mini-grids and microgrids. The cost of solar cells has decreased by a factor of more than 100 in the last 40 years (UNCTAD, 2018). Such price decreases have significantly improved affordability. For example, in Rwanda, projects have been implemented to provide rent-to-own plans for rooftop solar energy systems for households at low prices, such as $6 per month over two years (*Taarifa*, 2017). Further price declines are expected in the near future due to additional frontier technology breakthroughs in the design and manufacture of photovoltaic cells and battery storage systems and possibly even the advent of printed organic solar cells (UNCTAD, 2018). Cost reductions represent an opportunity for electrification in rural areas, in particular in developing countries, through off-grid and mini-grid solutions. For example, an analysis using geospatial data shows that to bring electricity to all households in sub-Saharan Africa by 2030, the most cost-effective mix of conventional and renewable energy technologies for several countries would be off-grid and mini-grid solar photovoltaic solutions. Such technology could serve a large share of the population at a lower cost in Chad, Malawi and the Niger (figure 6.4).

6.4.2 Facilitating trade

The potential of frontier technologies to increase efficiency in global commodity value chains was highlighted in the previous sections. The potential to take advantage of such opportunities varies by the technology used. Those technologies that require greater capital, such as robotics and the Internet of things, may be more challenging to diffuse in low-income country settings than those that are mainly digital, such as blockchain technology, artificial intelligence and digital platforms. However, the network nature of digital technologies, in which the value of an application's use increases with the number of users, creates incentives for the diffusion of technology from firms in developed countries to those in developing countries. The efficiency gains of digitalization may be greater in developing countries, due to the higher cost of trade in these countries; on average

Figure 6.4 **Population that could be served by mini-grid and off-grid solar photovoltaic solutions, to bring electricity to all by 2030**
(Percentage)



Source: UNCTAD calculations, based on data from the United Nations open-source spatial electrification tool.

Note: Figures are estimates. The scenario assumes 22 kWh of electricity consumption per household per year, a grid electricity cost of $0.1 per kWh and a diesel price of $0.7 per litre.

1.8 times higher than in developed countries (UNCTAD, 2017). Logistics and supply chains between firms in developed countries have already adopted digitalization and have greater efficiency than logistics and supply chains between firms in developing countries. Therefore, more opportunities for gains can lead to diffusion from the centre to the periphery and increasingly towards countries with more potential gains.

There are straightforward opportunities in the digitalization of trade and logistics-related documents. There are not many more opportunities to expand markets in developed countries, given that digitalization is already a mature innovation. Companies in developed countries seeking to grow market share and profitability may have incentives to enter developing country markets. This is an area in which firms in developed countries already have significant experience and there is therefore a relatively low risk of implementation of applications for clients in developing countries. This offers an opportunity in commodity dependent developing countries for local firms and other actors in the logistics sector and for firms engaged in global supply chains, including relevant government agencies, to further digitalize and to increase efficiency and reduce operational costs. The digitalization of trade and logistics-related documents also offers local technology development firms the opportunity to enter this segment and increase their technical capacities. Firms from developed countries need local knowledge to adapt solutions to local situations, including localizing the language used and adapting technology to the existing levels of infrastructure and of the technology skills of users. Local technology firms could provide this knowledge and there is therefore potential for partnerships between firms from developed countries and local technology firms in commodity dependent developing countries.

The use of emerging and frontier technologies in the trade of commodities also offers the opportunity to adopt and develop solutions in commodity dependent developing countries. Such technologies are still in an installation phase, that is, still being adopted in firms and sectors in countries that are at the centre of their development, such as China and the United States. There is therefore less pressure to seek markets in developing countries, given that there is still significant space for market development in originating countries. However, many digitalization solutions already incorporate such new technologies, for example in the scanning of documents and digital signatures and privacy services, which could facilitate the diffusion of the technologies in developing countries in logistics firms and supply chains. Therefore, firms in commodity dependent developing countries can place themselves in a good position with regard to such new technologies, as early adopters.

Digitalization and frontier technologies also offer Governments an opportunity to build national capacity in the provision and regulation of digital services. Governments are key actors in the digitalization of trade, due to the need to exchange trade-related documents between agencies. For example, UNCTAD has been at the forefront of delivering technical tools to developing countries, such as the use of single windows, through the ASYCUDA programme and trade information portals, with a wealth of knowledge that can assist countries in the use of emerging technologies. Other providers of technological solutions also have significant incentives to engage with Governments, which requires building the capacity of Governments to engage in digital trade. If properly managed, such knowledge could spill over to other areas of government services and help improve the delivery of public services in commodity dependent developing countries.

Some structural and non-structural factors may facilitate the adoption and development of frontier technologies in commodity dependent developing countries. For example, with the coming into force of the African Continental Free Trade Area, there are many incentives for Governments and innovators in Africa to adopt technologies for improving trade logistics and supply chains. The African Continental Free Trade Area is expected to increase intraregional trade, yet many of its benefits will be better realized if not only trade tariffs but overall trade costs are reduced, and doing so requires the improvement of logistics between countries, along with the reduction of trade costs (UNCTAD, 2019b). Digital solutions using frontier technologies can help deliver such improvements, which provides incentives for their adoption. Another factor to be considered is the important role of China in commodity value chains and its position of leadership in many of the new technologies associated with Industry 4.0 (UNCTAD, 2021). Under the appropriate policies, this can help in facilitating the diffusion of such technologies to firms in countries that are partners with China, including many commodity dependent developing countries.

6.4.3 Challenges

Developing countries face many challenges in using, adopting and adapting frontier technologies (UNCTAD, 2021). Such challenges are all relevant in commodity dependent developing countries. With regard to the deployment of such technologies on the production side, there are five main challenges in these countries, as follows:

(a) Changes in demographics, given that, by 2050, most of the increase in the global population will be in sub-Saharan Africa, with an increase of 1 billion people and, in general, firms in Africa may have fewer incentives to use automation as a form of labour cost savings. Capital-intensive commodity sectors such as large-scale mining and the petroleum industry may not be affected, given that they already have high ratios of capital to labour, but this surplus labour will not assist with the technological upgrades also required in other sectors of the economies of commodity dependent developing countries;

(b) The technological gap, given that there are several and increasing disparities between developed countries and developing countries in their production structures and the risk that most commodity dependent developing countries will fall behind in the adoption of Industry 4.0 technologies, widening the technological gap;

(c) The pace of diversification, which is slow in many developing countries, in particular commodity dependent developing countries. In this regard, experience with common technologies used in manufacturing can help firms to adopt and adapt new technologies;

(d) Fewer public and private resources to fund research and innovation in developing countries, in particular the least developed countries;

(e) Stringent intellectual property protection that poses barriers to the wide diffusion of technological know-how.

Finally, with regard to user perspectives in the adoption of new technologies, the challenges in many commodity dependent developing countries are related to low levels of digital skills and access to ICT infrastructure.

6.5 Promoting structural transformation through economic diversification and technological upgrading

There are many distinct patterns of technological upgrading and structural transformation; policy options to promote such transformation should therefore be context-specific and informed by the structural conditions and priorities in a country.[69]

This section proposes a strategy of innovation comprising the following three steps to promote technological upgrading and structural transformation in commodity dependent developing

69 UNCTAD, 2020d, discusses some of the issues related to technological change and Industry 4.0 and states that "the advent of new technologies puts a premium on the systemic coherence of the policy framework", along with skills acquisition, technological upgrading and incremental innovation.

countries: promote economic diversification; promote the implementation of the digital revolution, that is, the current technological–economic paradigm; and prepare the environment for the implementation of Industry 4.0 technologies and try to enter possible value chains related to this paradigm. The strategy should be guided by national development plans and national development objectives and priorities and may involve the following three stages: identification of opportunities; design of policy instruments; and implementation (figure 6.5).

The first stage, that is, the identification of opportunities, should be a Government-led process with the participation of the main actors in the innovation ecosystem, namely, the private sector, universities, the financial sector and civil society. The private sector is fundamental as it has productive capacities and is positioned to identify opportunities for innovation.

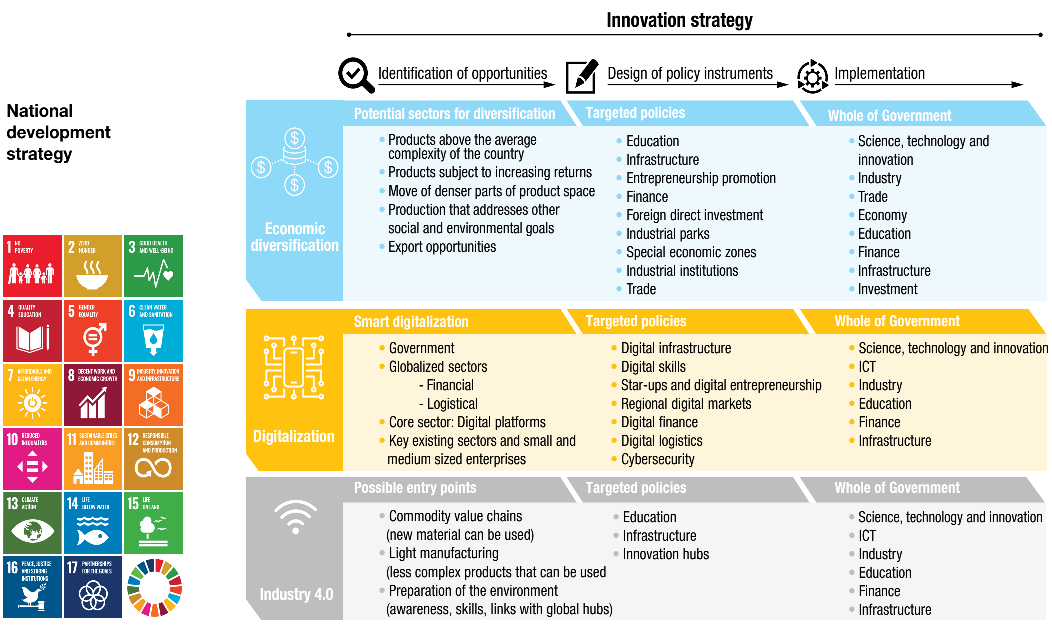
With regard to diversification, commodity dependent developing countries should identify new potential sectors for diversification that are realistically viable, given current technological and productive capacity, and will bring more benefits. This process may help to identify the products that are subject to increasing returns (since productivity increases with increased production), which means that primary products, or commodities, are not included, and to identify the sectors that:

(a) Are close in the current national production space and that are more complex than the average level of production in the country, in order to increase the level of technological development; the more complex the product, the higher the level of government support that will be required;

(b) Are in the densest parts of the product space, in order to facilitate future diversification;

(c) Address other social and environmental goals, such as sectors that employ more women or sectors that use less water or have less of an impact on climate change;

Figure 6.5 Promoting structural transformation through technological transformation



Source: UNCTAD.

(d) Have the greatest export opportunities in terms of global demand and with regard to which the country can leverage traditional trading partners or regional trade integration. In addition, the main markets for the potential new products for diversification could be identified and this could inform trade policies.

With regard to digitalization, the suggestion is to implement a smart digitalization strategy by focusing on first, the digitalization of public services to promote inclusion; second, the sectors that are globalized and are already more exposed to digitalization, which include the financial sector (focusing on digital financing and digital inclusion) and the logistical sector; and third, the core sectors of the digital revolution, namely, digital platforms. The goal is to foster an ecosystem of digital innovation on the supply side, including finance, entrepreneurship, infrastructure and skills. The demand side should also be strengthened, by focusing on promoting the digitalization of key traditional sectors of the economy and of small and medium-sized enterprises. This should also include the promotion of competition and a level playing field in the digital economy, with competition frameworks and enforcement adapted to the features and business models of digital platforms (UNCTAD, 2019c).

With regard to Industry 4.0, the suggestion is to identify the possible new products that are part of the value chains of the core products of the new technological paradigm. These have a significant potential to allow for the achievement of productivity gains. The focus could be on identifying opportunities in two areas, as follows:

(a) Commodity value chains: Opportunities in new materials that will be used by the core products of Industry 4.0, such as cobalt, lithium and nickel used to make batteries for electric vehicles;

(b) Less-complex manufactured products used in the products of frontier technologies: Opportunities such as with regard to blockchain mining, which uses specialized computers that are relatively easy to assemble.

In the consideration of both digitalization and Industry 4.0, other social, economic and environmental goals should also be taken into account, to align the choice of potential new sectors with the national development strategy and the Sustainable Development Goals. This stage should also include the preparation of the environment for the new paradigm, including by raising awareness, building skills and promoting links with global and regional hubs.

The second stage is the design of policy instruments. The key consideration is that they should be targeted and should promote innovation in the identified sectors; either diversification into the sector (product innovation) or the improvement of production in the sector (process innovation). Targeted policy instruments with regard to diversification include those related to education, infrastructure, entrepreneurship, finance, foreign direct investment, industrial parks, special economic zones, industrial institutions and trade. For example, a targeted policy instrument in education could be related to the training of engineers and computer scientists in specific technologies and applications relevant to the targeted sectors. Targeted policy instruments with regard to digitalization include those related to digital infrastructure, digital skills, start-ups and digital entrepreneurship, regional digital markets, digital finance, digital logistics and cybersecurity. Targeted policy instruments with regard to Industry 4.0 include those related to education, infrastructure and innovation hubs. (With regard to targeted policy instruments related to facilitating innovation in selected sectors, see chapter 5).

The third stage is implementation. This should be the business of the whole of Government, including different ministries and agencies that will be engaged in each of the steps. The design and implementation of science, technology and innovation policy instruments become complex because of the systemic nature of the policy objectives and the Sustainable Development Goals.

The complexity is also due to the diversity of the actors involved and the diversity of the policy instruments, including those designed for other issues but which unintentionally affect innovation, such as exchange rate and other macroeconomic policies that affect export competitiveness, including that of new products, as well as policies that affect the import of technology.

6.6 Conclusion

It is critical to fast track the deployment of digital and frontier technologies in commodity dependent developing countries, to promote structural transformation. Inequalities in technological access and use are due to existing inequalities in the economic and social dimensions. If developing countries miss the current wave of technological change, they may fall further behind and this could exacerbate the global challenges they face, from climate change to migration pressures, conflicts and pandemics. Commodity dependent developing countries risk remaining in the commodity dependence trap and paying the costs of associated challenges. Many of these countries have an opportunity to leverage primary commodities to fuel the ongoing and upcoming technological revolutions, as highlighted in this chapter. They can also leapfrog in the use of some existing technologies, such as digitalization, to increase efficiency and reduce transaction costs. For success in this area, Governments and the private sector will need to work together, in particular to ensure that new sectors are created and that existing market failures are addressed. Therefore, although commodity dependent developing countries face challenges that limit the extent to which they may benefit from past and current technological developments, there are opportunities to reduce the technological gaps between more technologically advanced countries and commodity dependent developing countries.

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CHAPTER

7

Conclusion and Policy Recommendations

Most developing countries are commodity dependent and their movements into and out of commodity dependence are not random. Commodity dependent developing countries tend to remain dependent for a long time. They appear to be trapped. Indeed, historical data and the specific country examples in chapter 2 show that, once a country is commodity dependent, the likelihood of becoming non-dependent is very low. This is a serious problem as commodity dependence is associated with many socioeconomic challenges, as discussed in chapter 1 of this report. In this context, central to the report is the question of whether innovation and the adoption of more sophisticated technologies could help commodity dependent developing countries to move out of the commodity dependence trap. This would imply that commodity dependent developing countries use innovation and technology to transform their economies, by expanding production and exports beyond the commodity sector. Indeed, commodity dependent developing countries need to go through a process of technology-enabled structural transformation whereby new sectors such as manufacturing and high-value services become more important, making commodities less central to the economy. Why this process needs to take place, if commodity dependent developing countries are to become less dependent on the commodity sector, is shown in chapter 3.

How technology could enable the process of structural transformation is discussed in chapters 4 to 6 in some detail. In chapter 4, the highlight is the main technological challenge facing commodity dependent developing countries, namely their position very far from the technological frontier. This limits the capacity of these countries to harness technological opportunities that could allow them to diversify their economies. In this regard, some policies are proposed in chapter 5 that may help commodity dependent developing countries to chart a way out of commodity dependence. However, the emphasis in the chapter is on the complexity of such an exercise. Policies and actions would depend on what pathway a country follows: vertical or horizontal diversification; or strengthening forward or backward linkages. Whether a country depends on extractive or soft commodities also matters. That is why it is important to consider different successful cases of diversification in different sectors to identify what has worked for those countries.

It is then argued in chapter 6 that, even though commodity dependent developing countries are lagging behind other groups of countries, in terms of technological capabilities, there are opportunities they can take advantage of. These include leveraging subsoil assets in the strategic commodities that are fuelling the current technological revolution, to derive more revenue out of them. These commodities include, among others, lithium deposits in Chile, cobalt in the Democratic Republic of Congo, manganese in South Africa, natural graphite in Brazil and nickel in Indonesia. Commodity dependent developing countries can also leapfrog existing technologies to put in place more efficient productive systems. E-commerce, blockchain and Internet of things-enabled smart agriculture are some of the technologies that could be brought to bear on the weak position of commodity dependent developing countries in the technological space.

Many suggestions are provided in the report regarding policies that would help commodity dependent developing countries in the transformation process towards more diversified and less commodity dependent economies. Some key suggestions are highlighted below, focusing on actions at the national, regional and international levels. This discussion is not meant to be comprehensive. The objective is to highlight some measures that seem to be essential to any strategy aimed at enabling commodity dependent developing countries to move out of the commodity dependence trap.

Measures at the national level

As is made clear in chapter 2, the first and most important action to address the commodity dependence trap at the national level is to have a clear and strong political commitment to move out of commodity dependence. This should be coupled with a long-term vision that spells out key objectives and actions to achieve them, keeping in mind a country's specific circumstances. Illustrative examples in chapter 2 show that countries have been commodity dependent for more than half a century, with some of them even becoming more commodity dependent over time. Empirical findings show that, if no strong action is taken and the right measures are not put in place to change the status quo, these countries will remain commodity dependent for centuries. Time by itself will not take them out of the dependence trap. Countries willing to move forward may learn from successful cases discussed in chapters 2 and 5.

It is important to demonstrate that the commodity dependence trap can be overcome. Costa Rica was long dependent on agriculture commodities until the 1980s, but then succeeded in building a diversified economy, both within the agriculture and non-agriculture sectors. Indonesia used its oil revenue windfalls to invest in agriculture and other non-commodity sectors. Currently, Indonesia is a relatively diversified economy. Oman used its oil revenues to build refineries and other manufactured products downstream the oil value chain. Malaysia also diversified away from rubber and palm oil into the production of manufactured products, such as rubber-based tires and medical gloves. Botswana managed to move up the diamond value chain by adding value to raw diamonds through cutting and polishing activities within the country.

One factor is common to all these successful cases: the active role played by public interventions. In every case discussed in the report, public interventions played a central role in bringing about a strong commitment to change from the status quo and putting in place the resources needed to move forward. Hence, escaping from the commodity dependence trap should be, first and foremost, a political decision by leaders who look beyond their political terms. Indeed, success comes late, hence the need for a long-term political vision.

Technology and innovation play a central role in the process of economic transformation. As commodity dependent developing countries are characterized by weak technological capabilities, moving towards the creation of new products close to their position in the product space may not be the right strategy. These countries might need to jump to much more sophisticated technologies that allow production of goods that are competitive in world markets. Firms, the central agents of innovation and technology adoption, might not be able to make such jumps without public intervention. In this regard, it is incumbent on Governments to create the necessary conditions to make this jump possible. More importantly, Governments should ensure that a country has the ecosystem necessary to allow innovation and technology adoption. The existence of hard infrastructure, such as reliable electricity and Internet connection, and soft infrastructure such as rules and regulations governing innovation and technology adoption, creation and strengthening of institutions of research and development, and macroeconomic stability, are all necessary for a successful, technology-based economic transformation.

Measures at the regional level

Regional integration could be key to a country’s economic transformation. One important transmission channel discussed in this report is scale economies made possible by regional integration. Considering that firms and farms in commodity dependent developing countries are generally small, they might not have the required size to adopt the right technologies needed to produce competitively and export into international markets. Moreover, small firms might have limited capacity to innovate, absorb and adapt technologies. By widening markets, regional integration attracts more foreign direct investment, one of the vehicles through which technology is transmitted. Moreover, as discussed in chapter 5, regional integration fosters productivity increases through a better allocation of productive resources. Indeed, trade integration reallocates market shares towards exporters, the most productive firms, increasing aggregate productivity. This is an important effect as the structural transformation needed to overcome commodity dependence relies, in part, on an improvement in resource allocation from low productivity to high productivity sectors of the economy, as amply discussed in chapter 3.

Trade integration can also significantly enable technological upgrading by firms competing for larger markets. If technology allows exporting firms to be more competitive in cost and quality, technology adoption becomes a question of whether the cost of acquisition of a technology is lower than the expected value of benefits of the technology. The example of Argentinian firms upgrading their technology after import tariffs in Brazil dropped following the creation of MERCOSUR illustrates this point. In fact, if better technologies allow firms to enhance their product quality, they may benefit not only through more exports to regional and international markets but also through higher export prices.

Measures at the international level

At the international level, there are two factors that are key to successful diversification: losers and winners from commodity dependence, and the issue of technology transfer. Each is briefly discussed below.

As discussed in the report, commodity dependent developing countries generally derive limited benefits from their commodities compared to other participants in the commodity value chain. Most commodity dependent developing countries participate only at the extraction stage of a commodity, both in the extractives and soft commodity sectors. For example, the bulk of the oil exports of Nigeria is crude oil, and the country imports refined oil for consumption. Cocoa and coffee producers export raw cocoa and coffee, and import chocolate and instant coffee, respectively. Copper is exported raw and exporting countries such as Zambia import copper-made electric wires. By failing to add value to their raw commodities, commodity dependent developing countries forgo all the benefits they would capture if they internalized the value chain. Put differently, remaining in the commodity dependence trap implies that countries other than commodity dependent developing countries benefit from value addition to raw commodities. A study by UNCTAD (2018) that analyses the coffee value chain shows that the producer price represents 2.8 per cent of the final consumer price. The retailer captures 48 per cent of the total value and the roaster, 14.8 per cent. This revenue allocation is so skewed against producers that it raises the issue of the sustainability of coffee supply. This picture is similar for cocoa and for most other commodities.

It is important to consider the strong concentration of coffee and cocoa markets at every step of the value chain, except for the production stage. There are 25 million producers and workers involved in coffee production, in contrast to five traders controlling 40 per cent of world coffee trade and two roasters controlling 25 per cent of global coffee roasting. Internalizing the coffee value chain in producing countries, even partly, would change the modalities of global commodities trade as it currently stands. Redistributing benefits from global players to producing countries will not be easy unless the more powerful value chain players are willing to lose part of their traditional benefits. It is not clear what incentives would push them to give up their benefits on their own. Therefore, it is reasonable to assume that only coordinated action by producing countries, or negotiation through existing international cooperation mechanisms, would change the status quo.

Related to the issue of losers and winners from the status quo is technology transfer. Considering their weak technological capabilities, commodity dependent developing countries will need to acquire technologies from abroad. Current practices with respect to technology transfer are, however, not conducive to a large-scale transfer of technology to developing countries. Limited financial resources to acquire technologies and the rules governing the protection of intellectual property would drastically limit the access to technology of commodity dependent developing countries. This, again, illustrates the need for an international framework for technology transfer towards commodity dependent developing countries. Such a framework could be modelled along the lines of the Technology Mechanism, under the Paris Agreement on climate change

(UNCTAD, 2019), and its two components, namely the Technology Executive Committee and the Climate Technology Centre and Network.

Technology transfer would not only focus on strengthening national capacities to use and maintain equipment but also adapt technologies to local contexts. If the Paris Agreement were to be the model framework, developed countries would be required to provide and report on technology transfer and capacity-building support to commodity dependent developing countries, based on the needs assessment of each commodity dependent developing country – that is, technology needs assessments in the context of the Paris Agreement. Financing could be channelled through special funds created to this effect, as is the case with the Paris Agreement. Indeed, many dedicated multilateral and bilateral funds have been created as conduits for climate finance (ibid.).

In this report, the empirical foundations for the analysis and the specific country examples of commodity dependent countries, and how technology could support policies to exit the commodity dependence trap are presented and assessed in detail. The expectation is that the suggested policy measures represent practical guidance for commodity dependent developing countries to succeed in transforming their economies away from dependence.

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