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Policy Paper

Innovation in Africa: Evidence and Implications for Growth and the Transition to High-Income Status

By Emmanuel Pinto Moreira & Rishita Mehra

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For today's middle-income countries in Africa, innovation is essential to sustain growth and promote the transition to high-income status. This paper begins by providing an in-depth review of the region's innovation performance during the last three decades. A distinction is made between residents and non-residents, and outcomes at different income levels. Using cross-country regressions, we then study the determinants of innovation and assess the impact of innovation on growth in the region. The analysis shows that the broadband penetration rate (which facilitates the development of knowledge networks) is a highly significant determinant of innovation. In addition, among the three types of intellectual property—patents, trademarks, and industrial design applications—only the last has a positive and significant impact on growth. Based on this analysis, and the broader literature on middle-income traps, we make policy recommendations to promote innovation in terms of both national strategies (with respect, in particular, to protecting intellectual property rights) and regional strategies, with an emphasis on the role of multilateral institutions.

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Policy Center for the New South

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POLICY PAPER

Innovation in Africa: Evidence and Implications for Growth and the Transition to High-Income Status

By

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1. INTRODUCTION

One of the important lessons of the past decades is the pivotal role of innovation in economic growth. Empirical studies have found a robust, positive link between expenditure on research and development (a common proxy used for innovation capacity) and the level of GDP *per capita* or its growth rate[1]. The theoretical basis for this relationship, as discussed in the seminal contributions on endogenous technological change of Romer (1990), Grossman and Helpmann (1991), and Aghion and Howitt (1992), is the impact of innovation on productivity[2].

It has also been argued forcefully that innovation, beyond its broader impact on growth, plays a major role in the transition from middle- to high-income status (see Agénor, 2017, and the references therein). Empirical studies have shown that low-income countries (LICs) can achieve middle-income status by boosting productivity through the adoption, adaptation, or imitation of foreign technology, especially in the manufacturing sector[3]. However, the resulting positive effects on growth tends to dissipate over time, because of the presence of barriers/major constraints when middle-income status has been achieved. At the same time, the transition from middle- to high-income status requires investments that support innovation and facilitate technological upgrading. Put differently, while innovation may have a positive effect on growth at all levels of development, it tends to play a particularly critical role in enhancing the capacity of middle-income countries to transition to high-income status.

These issues are particularly important for Africa. Although many African countries still have low-income status, a number have achieved middle-income status in the last two decades. Currently, 22 African countries are classified lower middle-income, while five are considered upper middle-income[4]. However, the key challenge for these countries is to implement strategies that will ensure sustained levels of economic growth and help them transition from middle- to high-income status, and thus avoid falling into the so-called middle-income trap, characterized by a persistent growth slowdown—itself resulting from a dramatic reduction in productivity growth. As documented by the experience of various countries, escaping from a middle-income trap may prove difficult in the absence of drastic and complementary policy measures[5]. From that perspective, understanding how to promote innovation, as a key driver of productivity growth, is essential for many of today's middle-income countries in Africa.

1. This evidence includes Ang and Madsen (2011), who considered the growth experiences of six Asian miracle economies from 1953 to 2006, Guellec and van Pottelsberghe de la Potterie (2004), who used panel data for 16 OECD countries over the period 1980-1998, and Ulku (2007), who used data for 41 OECD and non-OECD countries, distinguishing between high-income and low-income, large-markets and small-markets subsamples. There is also evidence that the relationship between investment in R&D (as a share of GDP) versus GDP per capita is nonlinear; see Cireri and Maloney (2017).

2. Most studies support the supply-driven approach of innovation-growth nexus (innovation causes economic growth). However, it is also possible that innovation activities are also equally affected by economic growth and other macroeconomic factors. Hence, innovation and economic growth cause each other in the development process; see Agénor and Neanidis (2015).

3. According to the Oslo Manual, innovation can be defined as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method or a new organisational method in business practices, workplace organisations or external relations" (OECD, 2005, p. 46). Note also that we abstract from a discussion of so-called frugal innovation, the impact of which on growth is open to debate; see Box 1.

4. According to the World Bank, as of September 2021, low-income economies are defined as those with a GNI per capita, calculated using the Bank's Atlas method, of $1,035 or less in 2019; lower middle-income economies are those with a GNI per capita between $1,036 and $4,045; upper middle-income economies are those with a GNI per capita between $4,046 and $12,535; high-income economies are those with a GNI per capita of $12,536 or more. Two African countries—Seychelles and Mauritius (until recently)—were classified as high income. See https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

5. The term middle-income trap was coined by Gill et al (2007). For a broad analytical discussion of middle-income traps, see Agénor (2017, 2021).

Box 1: Does Frugal Innovation Promote Growth?

Informal innovation, or so-called frugal innovation, arises from the need to innovate in order to survive. This type of innovation often comes about as a result of a lack of capital, both human and physical, and underdeveloped diffusion systems of foreign and local technology, including knowledge. Innovation that occurs in this way is generally incremental in nature and is often "demand-led learning and non-R&D based, low-cost innovations" (Fu, 2020) because of the constraints mentioned above. This concept of frugal innovation is related to the concept of "under-the-radar innovation", highlighted in research on Asian countries (see Kaplinsky, 2011 and, Fu, 2020). In most developing countries, frugal or under-the-radar innovation occurs mainly in the informal sector. Such innovation is highly prevelant and dynamic, thereby helping which helps those countries overcome problems due to lack of resources in their innovation processes. Frugal innovation or innovation that takes place in the informal sector, helps the day-to-day lives of people who live on or below the poverty line, but, whether this type of (incremental) innovation contributes significantly to medium- and long-term growth remains a matter of debate.

A case in point is Africa, where in countries like Ghana and Tanzania 80% and 89% of "sampled informal firms reported to have introduced innovation in the 2012-2014 period" (Fu, 2020). However, this type of innovation did not appear to have a discernible effect on these countries' income status or development level. Tanzania, for instance, moved from low-income to lower middle-income status only in 2019. More generally, the question of whether frugal innovation or 'innovation under the radar' contributes in a sustained fashion to long-term economic growth may be difficult to establish because of limited data availability and quality.

Historically, innovation in Africa has lagged far behind advanced economies and other developing regions, particularly in Asia. Data from the INSEAD-World Intellectual Property Organization (WIPO) Global Innovation Index (GII) show that global growth in intellectual property (a widely-used proxy for innovation) has been quite sustained in South-East Asian countries (most notably in Korea, Indonesia, and Thailand), China, North America, and Europe, while Africa has been stagnant. In fact, looking at worldwide patents—a common proxy for innovation, as discussed by Kelly *et al* (2020)—Africa's share has actually fallen in recent years. Moreover, a large share of patents granted in African countries are filed by non-residents. Changing these trends is thus a major challenge for the region.

In line with the foregoing discussion, the purpose of this paper is threefold. First, it takes stock of the evidence on Africa's innovation performance (or lack thereof) during the past three decades. Second, it studies the determinants of innovation in the region, using a comprehensive dataset based on the WIPO database. Third, it assesses the impact (or lack thereof) of innovation on growth in the region. In particular, the analysis considers the definition of types of innovation, and how different African countries have performed with respect to these dimensions; the role of the distribution of patents between residents and non-residents in the region, both in general and by types of innovation; and the factors promoting successful innovation in some countries compared to others in the region. It also analyzes the relative importance of innovation as a driver of growth in Africa—together with other determinants including R&D (research and development) expenditure and the number of researchers—and makes policy recommendations to promote innovation through both national strategies (with respect, in particular, to guaranteeing intellectual property rights) and regional strategies, with an emphasis on the role of multilateral institutions.

The paper proceeds as follows. Section 2 looks at the nature of, and evidence on, innovation in Africa. It considers both global trends and the nature of innovation and intellectual property in Africa. Section 3 studies the determinants of innovation and analyses results of survey-based research and econometric regressions that attempt to quantify the relationship between innovation and its determinants. Section 4 analyzes the impact of innovation on growth in Africa, using a set of control variables that are typically used in the literature on growth regressions and studies of the link between innovation and growth. The last section draws together policy lessons aimed at promoting innovation in Africa.

2. INNOVATION IN AFRICA: NATURE AND EVIDENCE

To set the stage for our subsequent quantitative analysis, this section discusses the role of technological innovation in fostering growth and development in today's African countries. We begin by presenting a broad overview of trends in world innovation. We then provide a consistent and comprehensive picture of the state of innovation in the region.

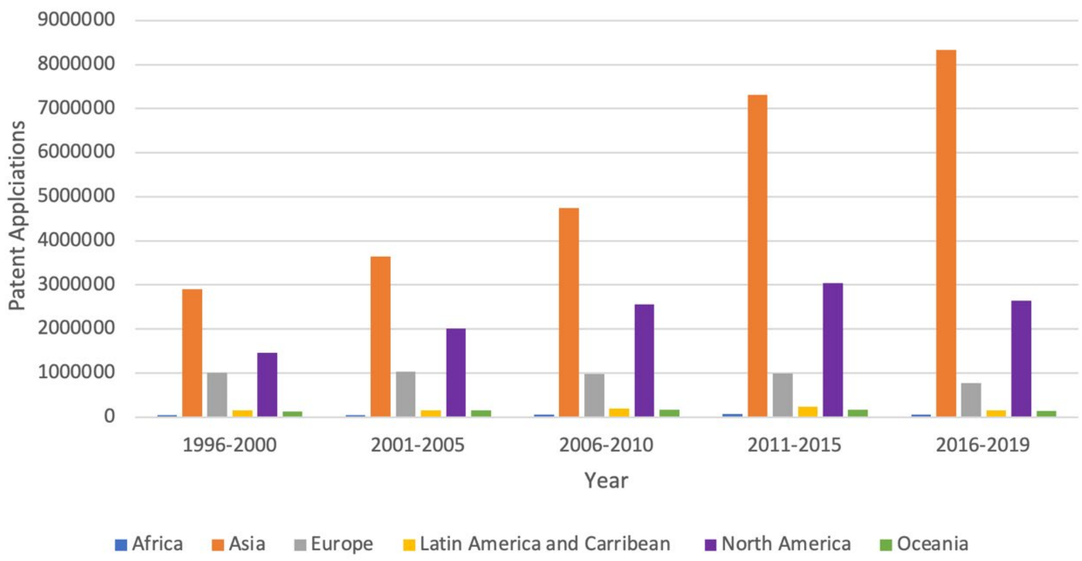
2.1 Trends in World Innovation

To analyze global trends in innovation, a common indicator is the number of patents applied for, or issued. Patents are a good proxy for a country's capacity to innovate because they represent a measure of outcomes.

Figures 1 and 2 show the evolution of total patent applications across the world. Figure 1 depicts trends in absolute numbers, whereas Figure 2 depicts them in *per-capita* terms. Both figures show that, overall, total patent applications increased steadily between 1996 and 2019. Figure 1 also shows that there was a slight dip in absolute numbers for North America in the last period (from 2016-2019), whereas numbers for Europe fell starting from the 2006-2010 period. In Asia, patent applications have increased steadily and are significantly higher than in other regions. This is because of countries such as South Korea, and other countries where patent activity is high, including in China, Taiwan, Singapore, and India, who have promoted the establishment of science and technology clusters (WIPO, 2020). Compared to the rest of the world, outcomes for Latin America and Oceania are low. Patent applications in Africa are negligible compared to the other regions.

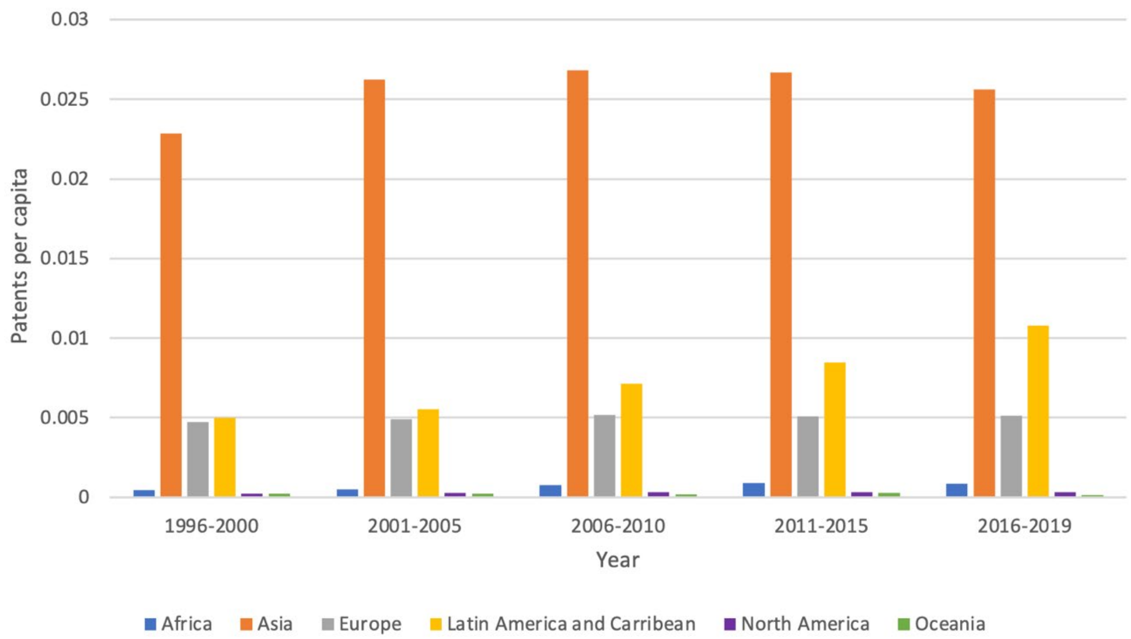
In *per-capita* terms, patent applications fluctuate around the same level for most regions; this is particularly noticeable for Asia. However, the performance of Latin America and the Caribbean has improved over time. Africa's performance has also improved, albeit at a much slower pace, and starting from a much lower base.

Fig.1. World 1996 - 2019 Total Patent Applications



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

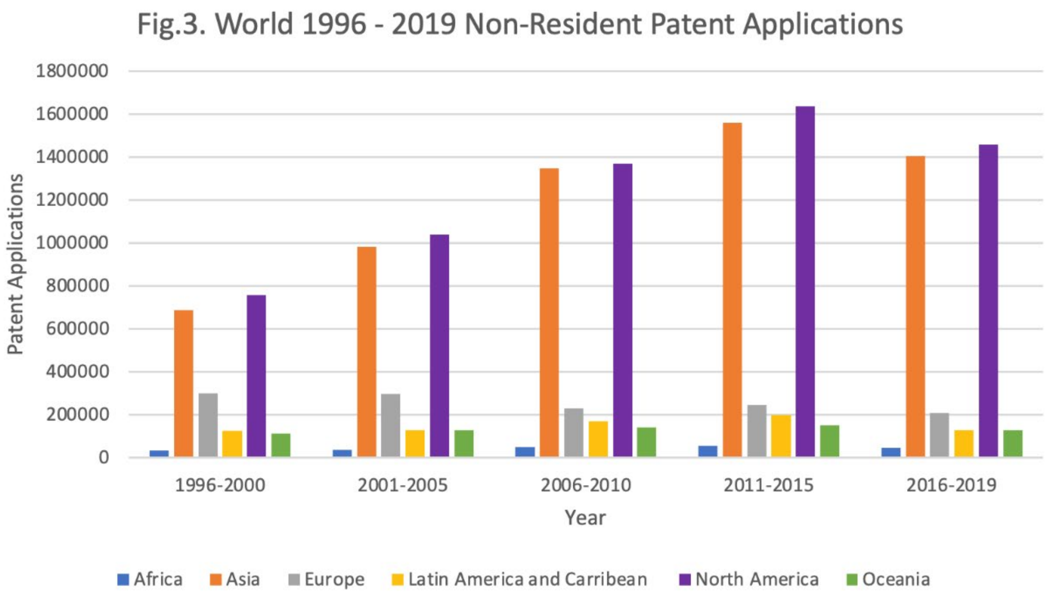
Fig.2. World 1996-2019 Total Patent Applications per capita



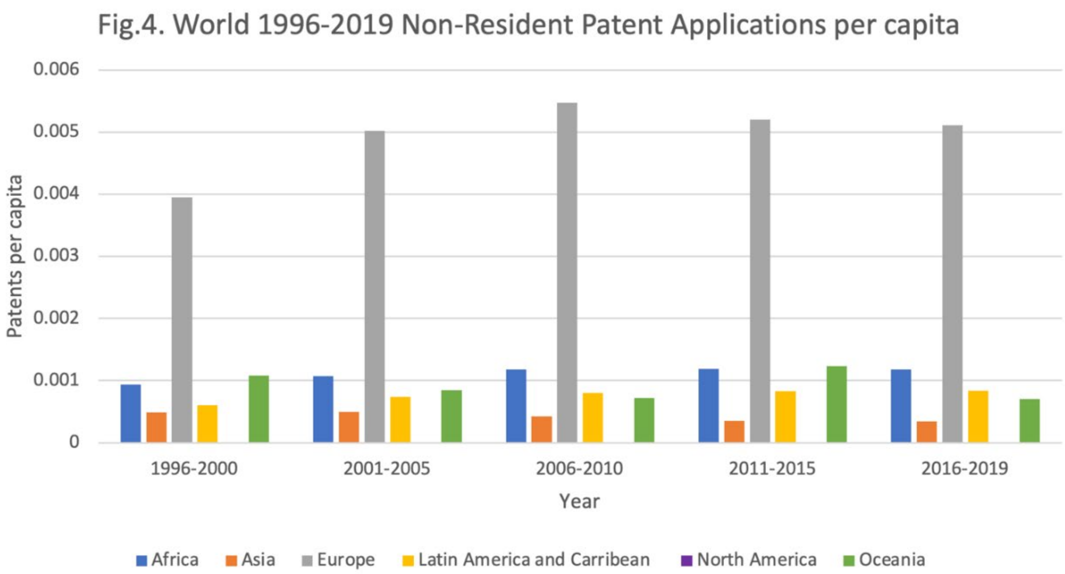
Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Other aspects to consider when looking at patent application data are the source of applications, namely, the distinction between non-resident and resident applications, and to look for differences between regions that are more developed versus those that are not. Figures 3 and 4 illustrate the trends in non-resident applications, while Figures 5 and 6 highlight trends in resident patent applications.

Figures 3 and 4 show the trends for the world in relation to patent applications filed by non-residents in different regions. In absolute numbers, as seen from Figure 3, Asia and North America have performed better than other regions, particularly during the period 1996 to 2015. By contrast, Europe's performance has declined throughout the time period. Outcomes for Africa are relatively weak compared to the other regions, with a slight improvement starting in the 2006-2010 period. In Figure 4, surprisingly, outcomes for Europe are the best whereas those for North America are weak. At the same time, outcomes for Africa are significantly better than in some other regions; this could be due to an increase in investment by pharmaceutical companies in Africa over the last two decades.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figures 5 and 6 illustrate the trends of world regions in resident patent applications. These trends are shown in absolute terms in Figure 5 and in *per-capita* terms in Figure 6. Figure 5 shows that (similar to Figure 1) outcomes for Asia have steadily improved and are significantly better than in other regions. North America's performance has also improved—until the drop in numbers in the last period—broadly similar to Europe. The other regions, Latin America and the Caribbean (LAC), and Africa, have not performed as well as the other regions.

Figure 6, which shows resident *per-capita* patent applications, provides a different picture. North America performs best in this case, with an upward trend which flattens out over the last two periods. Asia's performance has also improved over time. The difference in population between Asia and North America largely explains the difference in outcomes between the absolute and the *per-capita* numbers. Asia started with *per-capita* outcomes that were worse than those of Europe in the first period. Interestingly, since 2000, Asia's performance has surpassed Europe's; this can be explained largely by the dramatic increase in innovation performance in countries such as China and South Korea. By contrast, outcomes for Africa and LAC have remained weak.

Fig.5. World 1996-2019 Resident Patent Applications

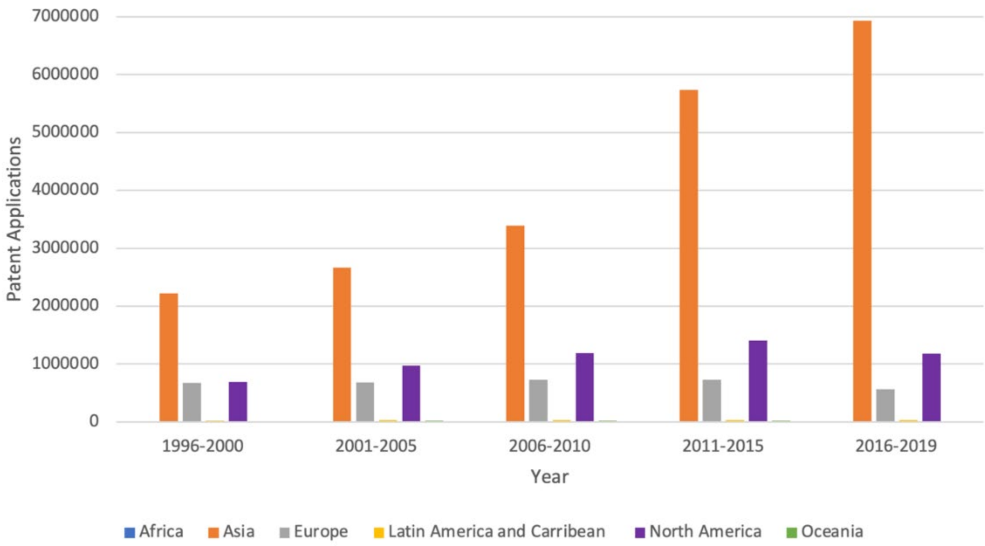
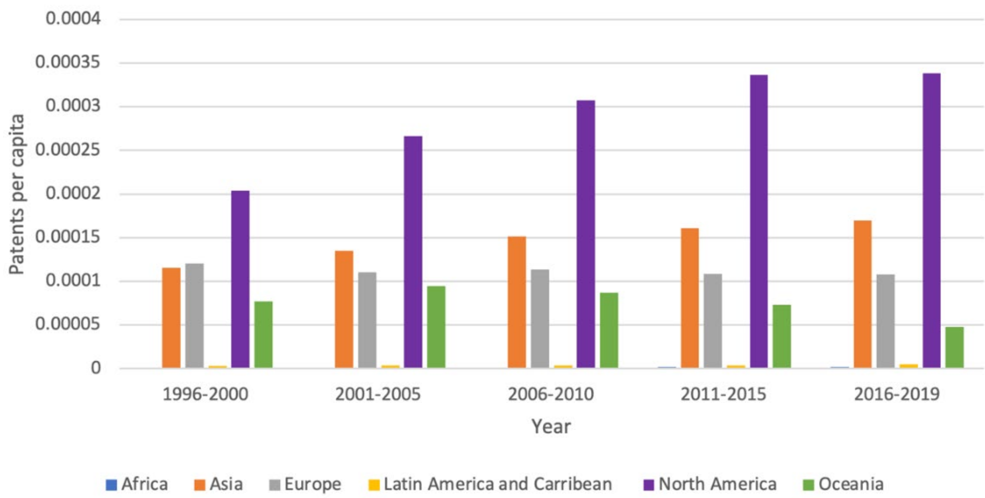


Fig.6. World 1996-2019 Resident Patent Applications per capita



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

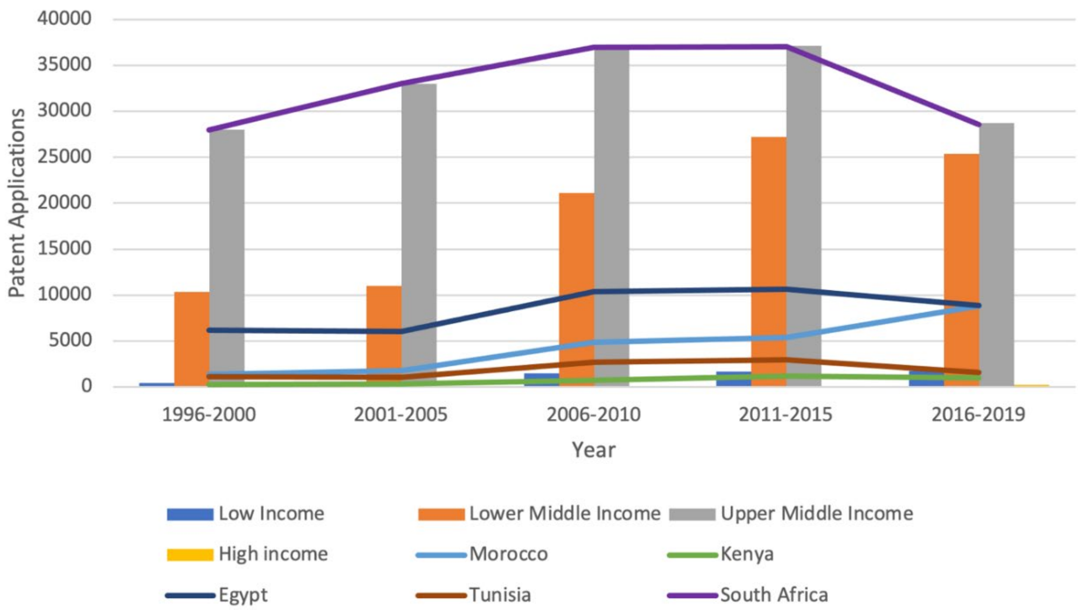
What is important to note from these global comparisons is that resident patent applications are high for some of the most developed regions of the world (North America, Europe), and Asia, in both absolute and *per-capita* terms, compared to regions such as Africa and LAC. But when considering non-resident patent applications, in absolute and *per-capita* terms, these last two regions have higher numbers than the others. This could be due to there being more home-grown innovation taking place in the more developed regions, compared to, in particular, Africa. In South Korea, for instance, the government strongly encouraged domestic companies to innovate. By contrast, in Africa more non-resident patent applications are filed, compared to those of residents; this could be because, over the years, many global pharmaceutical companies have invested in, and moved their operations to, the region.

2.2 Innovation Activity in Africa

To provide a more detailed picture of the state of innovation in Africa, the analysis turns now to the trends in different types of intellectual property (IP) applications. WIPO outlines six different types of IP: copyright, patents, trademarks, industrial design, geographical indicators, and trade secrets (WIPO, n.d.). In this study, we explore the trends in patents, trademarks and industrial design applications in Africa as these are the types of IP most directly related to innovation—compared to copyright applications, which are more related to imitation. While patents (as mentioned above) are defined as an exclusive right granted for an invention, trademarks as defined by WIPO are a "*sign capable of distinguishing the goods or services of one enterprise from those of other enterprises" whereas industrial design is defined as "the ornamental or aesthetic aspect of an article*" (WIPO, n.d.).

Figure 7 shows the patent applications trend in Africa from 1996 to 2019 across different income levels; low, lower middle, upper middle, and high income. The data indicate that, throughout the period, the number of patent applications was highest in upper middle-income countries (UMICs), spearheaded by the number of applications in South Africa. The number of patent applications in the lower middle-income countries (LMICs) has been increasing, with a slight drop in the last sub-period. This trend in LMICs as a group is also present in the data for Egypt, Morocco, and Kenya, which also show a positive trend in terms of patent applications. Low-income countries (LICs) have also followed an upward trend, but their performance has lagged significantly behind that of the MICs. Unsurprisingly, the numbers for the high-income countries are negligible as they consist of Seychelles and Mauritius (until recently), which are both primarily tourist destinations and are thus not highly involved in technological innovation. Overall, although Africa's performance in terms of patent applications lags significantly behind other regions (especially Asia), it has improved over time.

Fig.7. Africa 1996-2019 Total Patent Applications



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figures 8 and 9 show the difference in shares of patent applications across African countries at different income levels at the beginning of the period, 1996-2000, and the end of the period, 2016-2019. At the beginning of the period, the majority of patent applications (72%) were filed by the region's UMICs. Subsequently, LMICs filed around 27% of total patents, with the remaining being filed by the low- and high-income countries. A significant change in the proportions of patent applications being filed can be seen at the end of the period in Figure 9: the proportion of patents filed by LMICs increased to 45%. Interestingly, there was also a slight increase in the proportion of patent filings by low- and high-income countries.

FIG.8. AFRICA PATENT APPLICATIONS 1996-2000

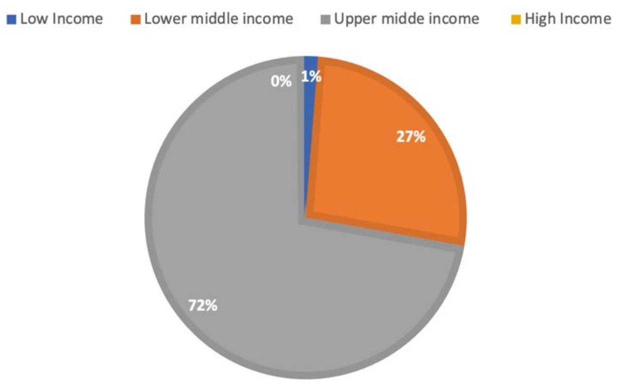
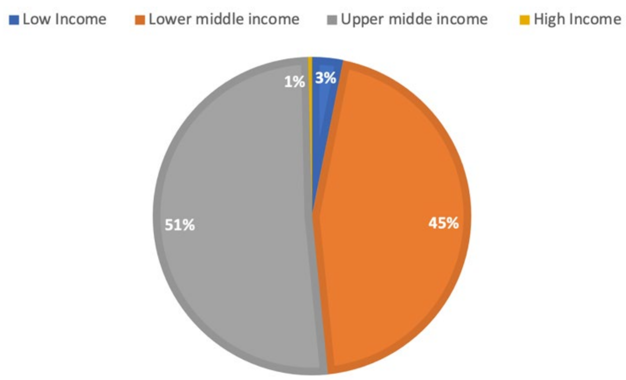
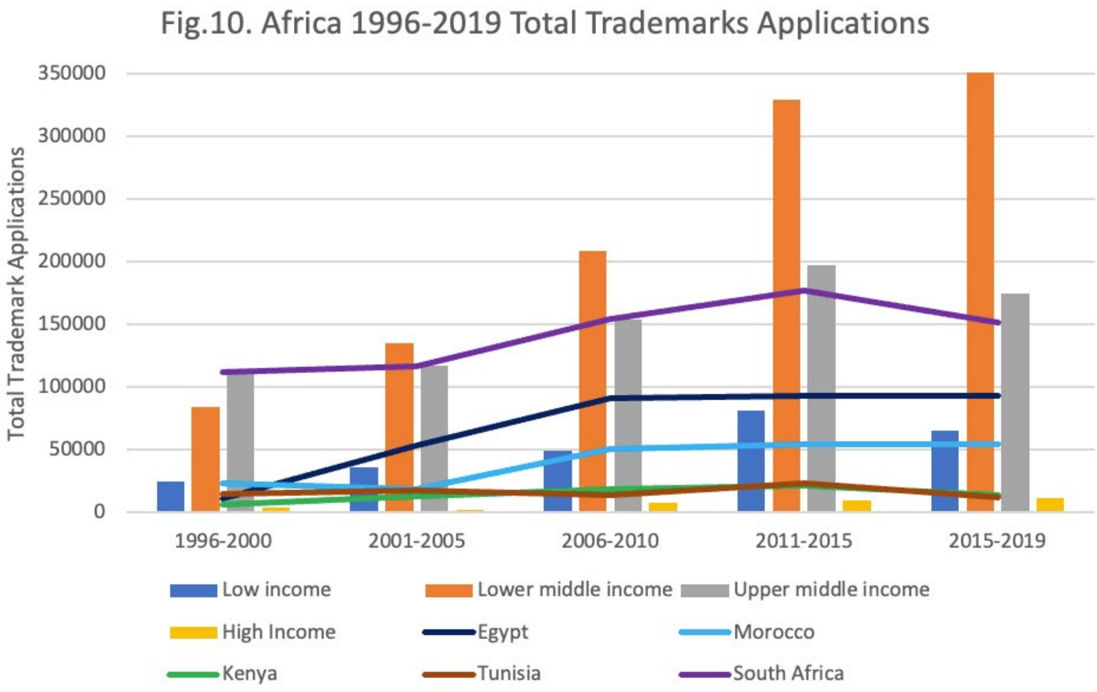


FIG.9. AFRICA PATENT APPLICATIONS 2016-2019



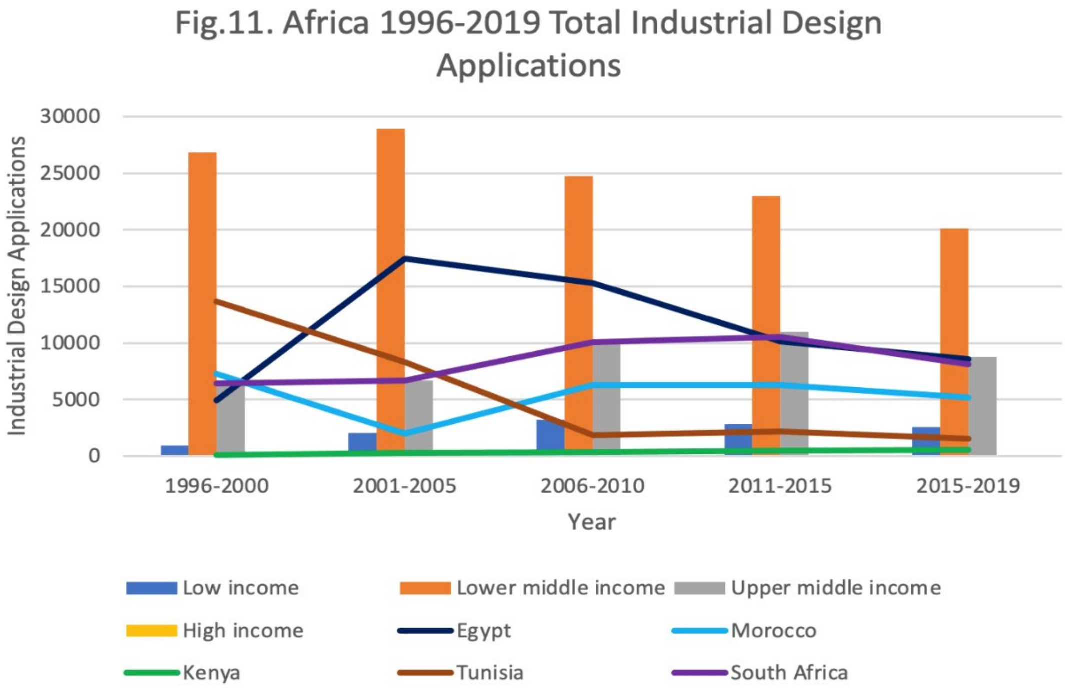
Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figure 10 provides information on trends in trademark applications in Africa from 1996 to 2019 at different income levels. The data show that, overall, trademark applications have increased over time. They are highest in LMICs, followed by UMICs, and then LICs. This upward trend for group averages can also be seen in the data for several individual countries, as is the case for South Africa, Egypt, and Morocco.



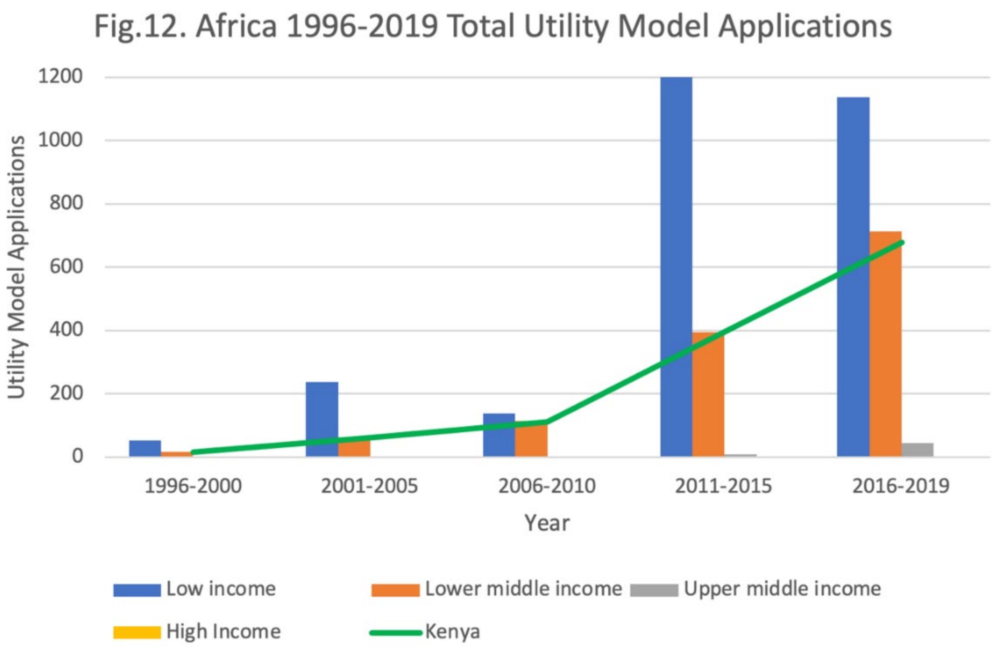
Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figure 11 shows trends in applications for industrial design. These trends are quite different from those reviewed previously. Applications by LICs increased at the beginning of the period but followed a downward trend after 2005. The performance of UMICs has remained weaker than that of LMICs throughout the period, but has improved over time. In the most recent time period (2015-2019) there was a general drop in applications, both in terms of the different groups and individual countries, although in the case of some countries (such as Egypt and Tunisia) the downward trend started in earlier periods.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

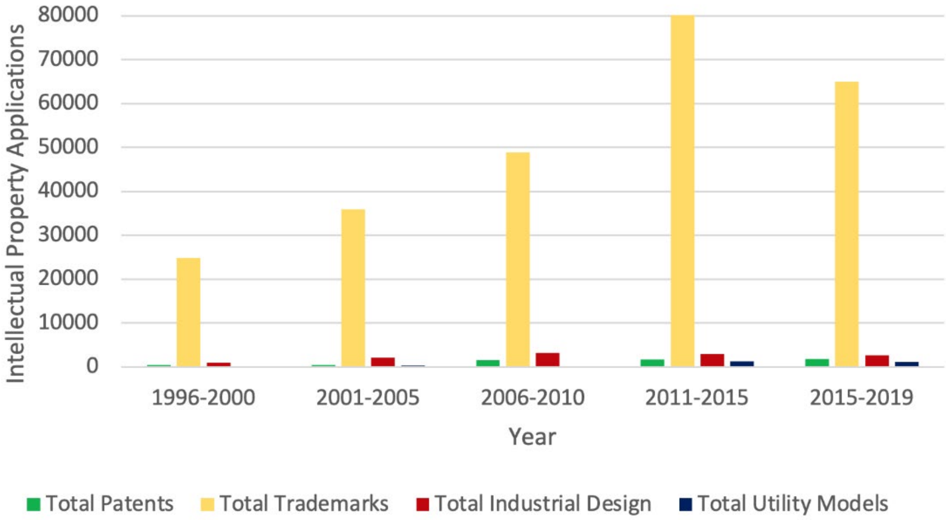
Figure 12 shows trends in applications related to utility models. Utility models are a type of patent application which protect 'minor inventions' and require "compliance with less stringent requirements" (WIPO, n.d.). They are also offered for shorter periods compared to regular patents. The data show that these applications are (almost) non-existent for the high-income countries and the UMICs of the region. They are also the highest for LICs, followed by LMICs. In both cases these applications have followed an upward trend, including for individual countries such as Kenya. The more accessible and affordable nature of utility models could explain why they are more prevalent in LICs, as compared to MICs, in Africa.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

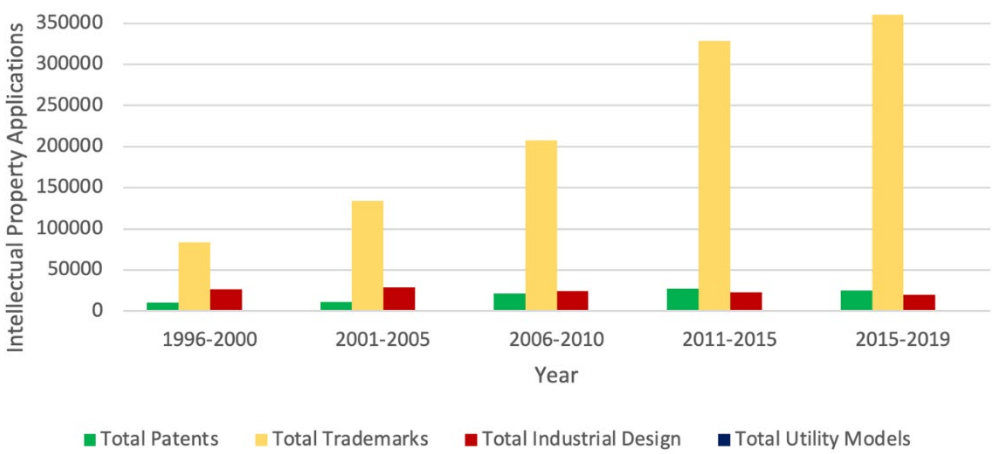
Figures 13, 14, 15, and 16 show the level of investment of the different types of IP at different income levels from 1996-2019 in Africa. The data show clearly that, compared to other types of IP applications, trademarks have the highest numbers across all income levels, with LMICs having the highest number of trademarks. This could reflect the fact that these trademarks relate more to goods and services provided, as compared to innovative or manufacturing activities. A similar trend is visible at different income levels. Although trademarks have the highest number of applications, LICs and UMICs saw a dip in their numbers in the last period under review, 2015-2019. Trademark applications are followed by patent applications and then industrial design applications, which is itself followed by utility model applications across all income levels and time periods. Compared to other income classifications, the numbers for patents are higher and quite prominent in UMICs, relative to the other income groups.

Fig. 13 Africa 1996-2019 Low Income IP Applications

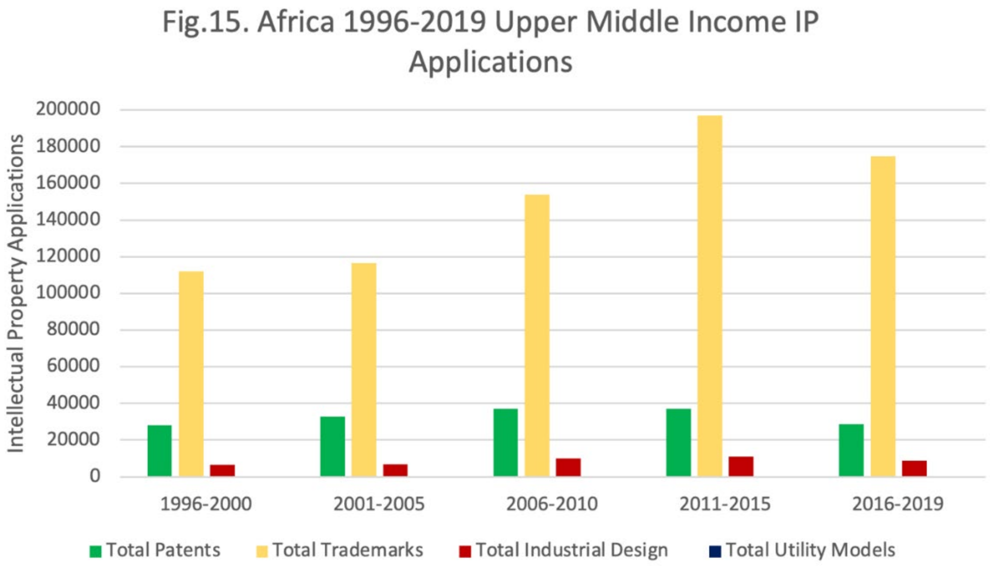


Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Fig.14. Africa 1996-2019 Lower Middle Income IP Applications

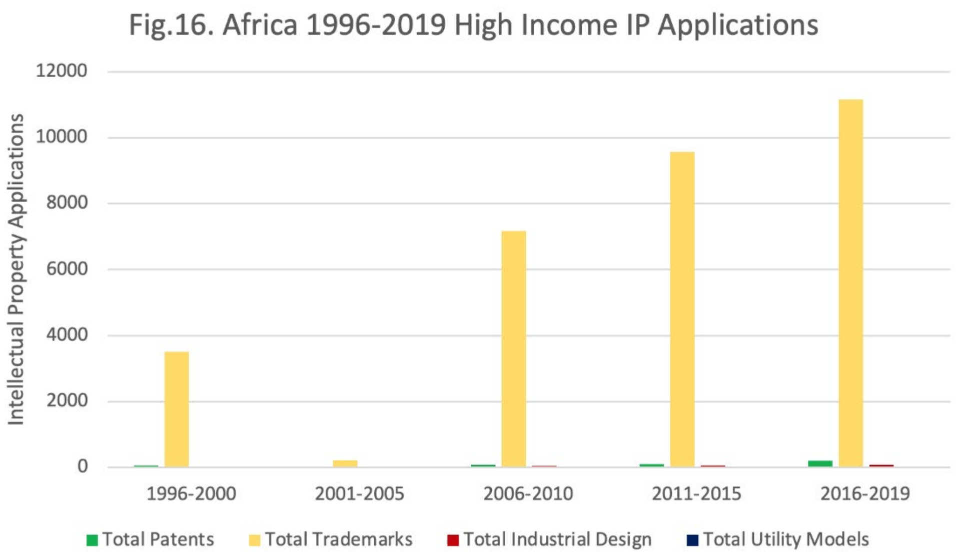


Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figure 16 reiterates the fact that the high-income countries in Africa are predominantly tourist destinations, and so primarily apply for trademarks. However, over the past decade there has also been a slight uptick in patent applications from this group.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

To illustrate the importance of innovation, it is useful to compare the distribution of IP applications by Asia and Africa at the beginning and the end of the period under review. Asia, as a region, has gone through a period of sustained high growth rates, along with an increase in innovation capacity and outcomes; the region accounts for a large number of leading science and technology clusters, based in countries such as Japan, South Korea, China, and India. In many ways, Asia's performance provides a roadmap for Africa's future path.

Figures 17, 18, 19, and 20 illustrate the comparison between the two regions. Figures 17 and 18 provide the distribution of IP applications in Asia in the 1996-2000 period and the 2016-2019 period, respectively. They show clearly that the share of trademarks and patents has fallen in the face of an increase in the share of industrial design and utility model applications. Comparing this to Africa in the same periods, as shown in Figures 19 and 20, the share of trademarks has increased as the shares of patents and industrial design applications have decreased. Indeed, the difference that is most striking between the two regions is that in the span of 20 years, the proportion of trademarks applied for in Asia has fallen significantly, from 48% to 24%, while in Africa that proportion went up, from 75% to 87%. Overall, this comparison suggests that a key characteristic of countries that are growing relatively quickly is that they have a greater proportion of patent applications being filed, compared to other types of IP applications.

FIG.17. ASIA 1996-2000 IP SHARES

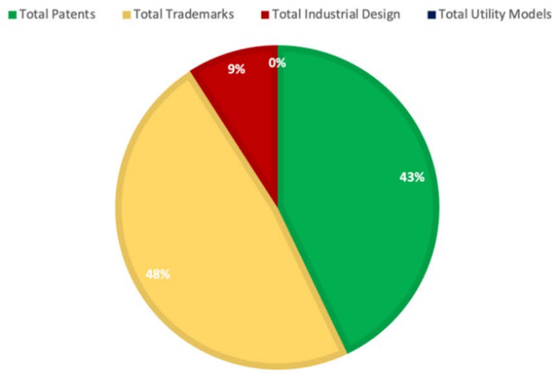


FIG.18. ASIA 2016-2019 IP SHARES

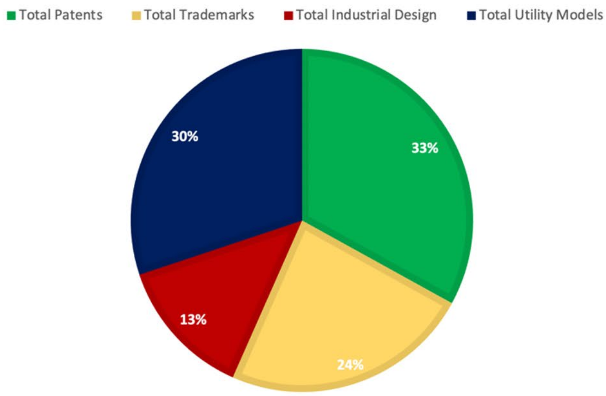


FIG.19. AFRICA 1996-2000 IP SHARES

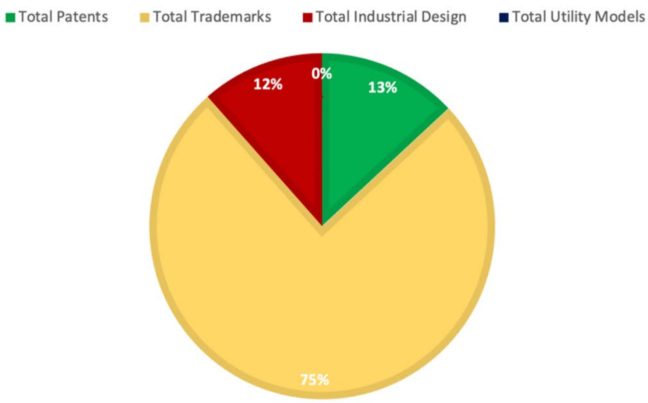
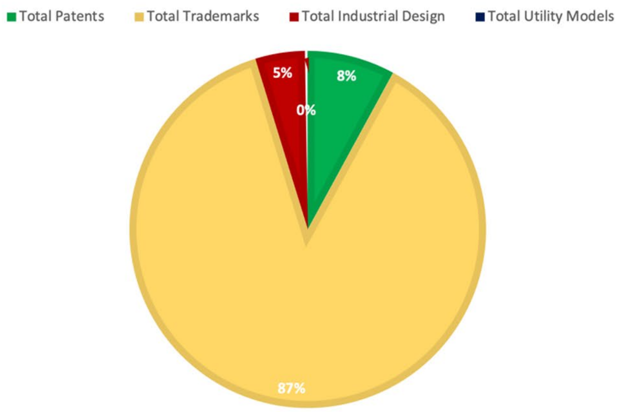


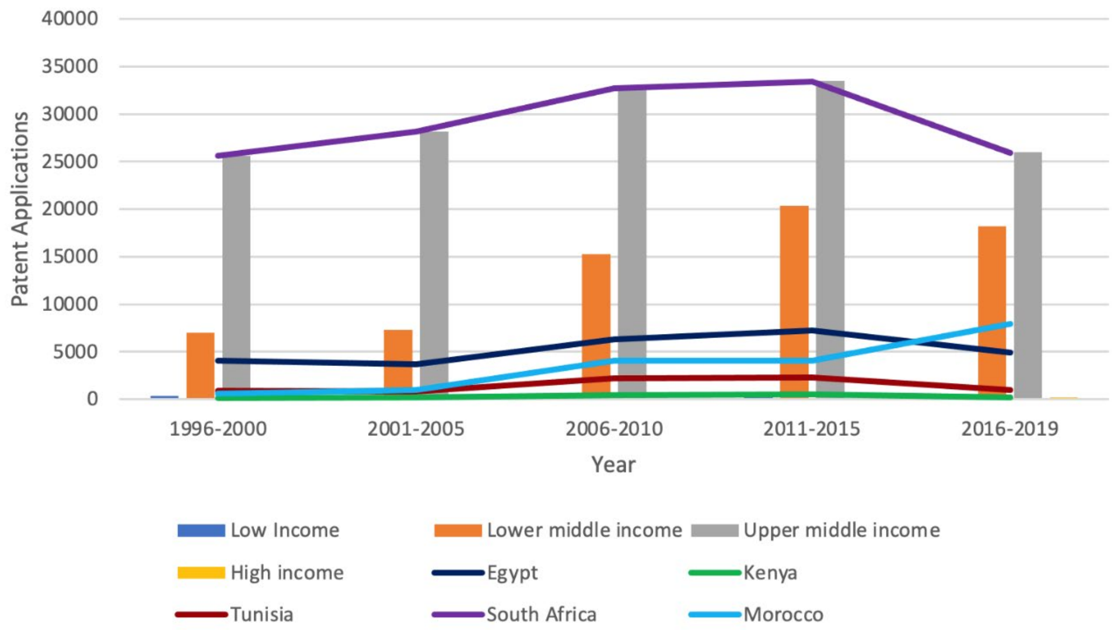
FIG.20. AFRICA 2016-2019 IP SHARES



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

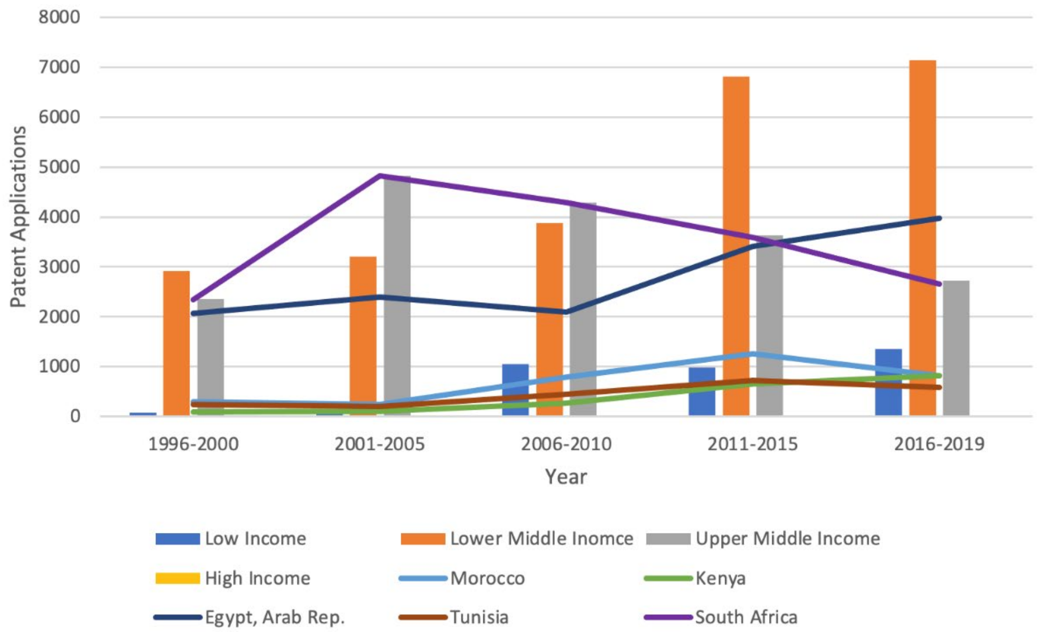
As mentioned previously, it is important to look at the trends in non-resident and resident patent applications to get a better picture of home-grown innovation in Africa. Figure 21 shows the evolution of non-resident patent applications, while Figure 22 illustrates the trends of resident patent applications in Africa, both over the period 1996-2019.

Fig.21 Africa 1996-2019 Total Non-Resident Patent Applications



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Fig.22. Africa 1996-2019 Total Resident Patent Applications



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

Figure 21 shows that the highest number of non-resident applications are made by UMICs, most importantly within that group, by South Africa. Applications by non-residents also dominate in LMICs. Over time, these applications have increased significantly, both for the group as a whole and for individual countries such as Morocco. In parallel, Figure 22 shows that patent applications filed by residents in LMICs have increased over time, particularly between 2006-2010 and 2011-2015. Surprisingly, and somewhat worryingly, the trend has been in the opposite direction for UMICs: the number of patent applications for that group of countries fell continuously after 2001-2005. This is particularly the case for South Africa. Taken at face value, these data suggest that home-grown innovation has become less dynamic for that group of countries. This could reflect growing constraints on R&D activities.

To put these data in perspective, it is worth looking at the differences between Asia and Africa in the shares of non-resident and resident patent applications. Figures 23 and 24, and Figures 25 and 26, show the shares of patent applications between non-residents and residents in Asia and Africa respectively, from 1996-2000 and 2016-2019.

FIG.23. ASIA 1996-2000 NON-RESIDENT/RESIDENT PATENT APPLICATION SHARES

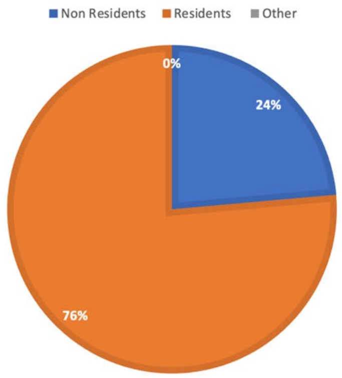


FIG.24 ASIA 2016-2019 NON-RESIDENT/RESIDENTS PATENT APPLICATION SHARES

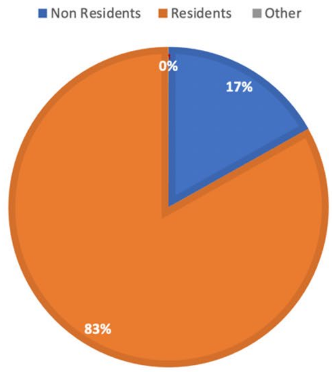


FIG.25. AFRICA 1996-2000 NONRESIDENT/RESIDENT PATENT APPLICATION SHARES

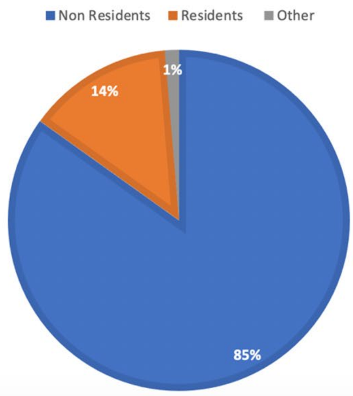
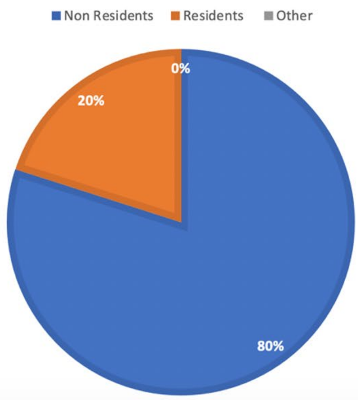


FIG.26. AFRICA 2016-2019 NON-RESIDENT/RESIDENT PATENT APPLICATION SHARES



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

The figures show that Asia started off with a higher share of resident applications, at 76%, and a smaller share of non-resident applications, at 24%. This trend hasn't changed much—except that at the end of the period, the share of resident patent applications had increased to 83%, while the share of non-resident applications had dropped to 17%. There is a blatant difference in these proportions when compared to those for Africa, both at the beginning and the end of the period. Indeed, although the share of resident patent applications increased in Africa, from 14% to 20%, with a concomitant reduction in the share of non-resident patent applications, from 85% to 80%, the share of non-resident patent applications remains extremely significant. Comparing between the two regions shows that the share of resident patent applications make up more than three-quarters of their patent applications at the beginning and the end of the period in Asia, whereas in Africa it is the opposite—the share of non-resident patent applications is more than three-quarters of total patent activity, both at the beginning and the end of the period, although that share is decreasing. Put differently, another characteristic of fast-growing countries is stronger home-grown innovation.

3. DETERMINANTS OF INNOVATION IN AFRICA

The overall picture of innovation in Africa, as the previous discussion shows, is one of relatively weak performance (particularly for home-grown innovation) relative to other regions, The issue that needs to be addressed now is what evidence there is on the key determinants of innovation outcomes in Africa.

3.1 Potential Determinants

Research on the capacity to innovate and innovation outcomes has highlighted the potential impact of several key determinants: R&D expenditure; the quality of human capital; access to advanced infrastructure; access to finance; and the protection of property rights and the quality of governance. We discuss these in turn.

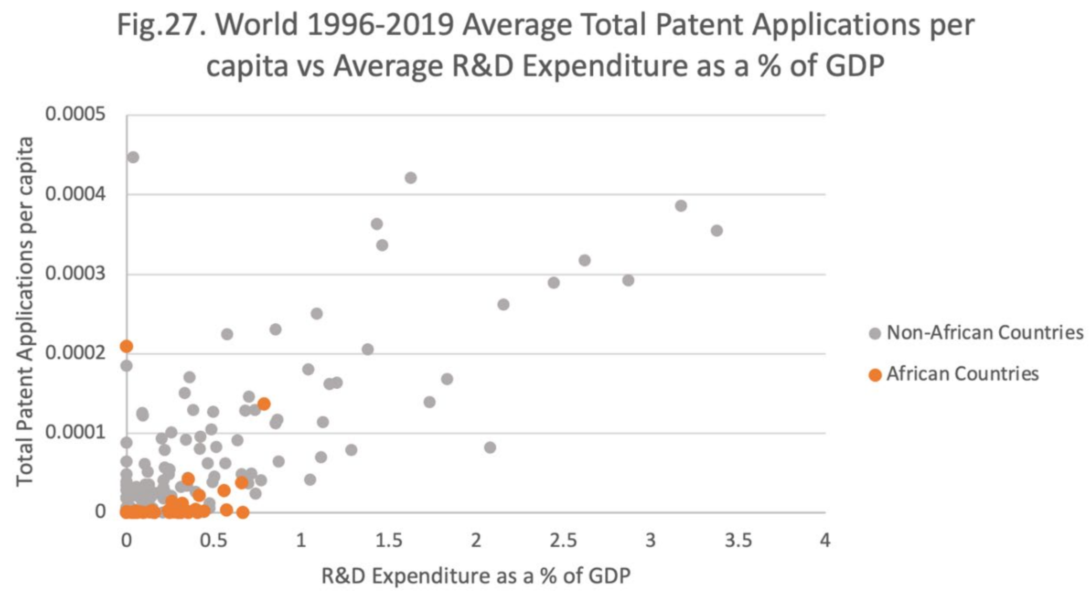
3.1.1 R&D Expenditure

At the level of individual firms, R&D expenditure spending has been shown to be essential to develop new goods and services, and to absorb knowledge from abroad (Cohen and Klepper 1996; Cohen and Levinthal 2000). At the aggregate level, empirical studies have also documented that R&D expenditure, both public and private, is a key determinant of a country's ability to innovate.

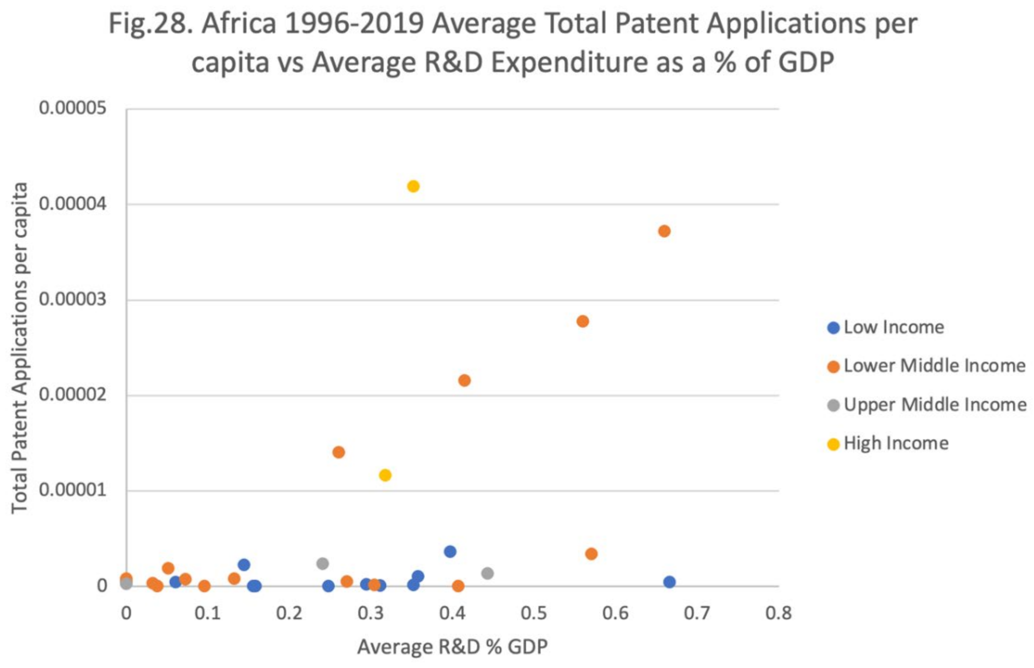
South Korea, which transitioned fairly rapidly from middle- to high-income status, is a good example. In recent decades, South Korea has spent a substantial percentage of its GDP on R&D, compared to other OECD countries. In 2019, that percentage in South Korea stood at 4.6%, second only to Israel, which stood at 4.9% (OECD, 2021). More generally, empirical studies by Goedhuys (2007) for Tanzania, Abdu and Jibir (2017) for Nigeria, Hadhri *et al* (2016) for Lebanon, Protogerou *et al* (2017) for Europe, and Seenaiah and Rath (2018) for India, all found R&D expenditure positively affects a firm's innovation performance. Cross-country studies based on aggregate data, including Agénor and Neanidis (2015), have also found a significant effect of R&D expenditure on innovation outcomes.

In recent years, steps have been taken in Africa to promote R&D expenditure. According to the *African Innovation Outlook* report of 2019 (AIO-3), the African Union (AU) called upon its members to contribute a minimum of 1% of GDP to research and development (AUDA-NEPAD, 2019). According to the AIO-3, in 2019 a few countries were close to achieving that target; Egypt stood at 0.8%, South Africa at 0.82%, and Kenya at 0.98%. When compared to the OECD average of 2.5% in 2019, the 1% target may appear relatively low. However, a comparison of shares of public sector spending on R&D shows that the differences are not as large – at least for some countries. Indeed, while public sector R&D spending averages 0.64% in OECD countries, in Africa this share varied between 0.2% and 0.78% (AUDA-NEPAD, 2019).

Figures 27 and 28 show the relationship between average total patent applications *per capita* and R&D expenditure as a percentage of GDP. Figure 27 provides a global view, while Figure 28 shows the relationship between these two variables in Africa, with a breakdown across income levels. Figure 27 suggests the existence of a positive relationship between the two variables, with the African countries clustered in the bottom left corner. Figure 28 shows that, interestingly, the points for the upper UMICs are at the bottom, with some of the LMICs having a distinct, positive relationship, along with the high-income countries.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

At the same time, it is important to keep in mind that R&D expenditure alone may not be sufficient to have a significant impact on innovation, because other constraints (such as inadequate protection of intellectual property rights, as discussed below) may also be present at the same time. Put differently, it may be the interactions between R&D spending and other variables that matter.

3.1.2 Human Capital

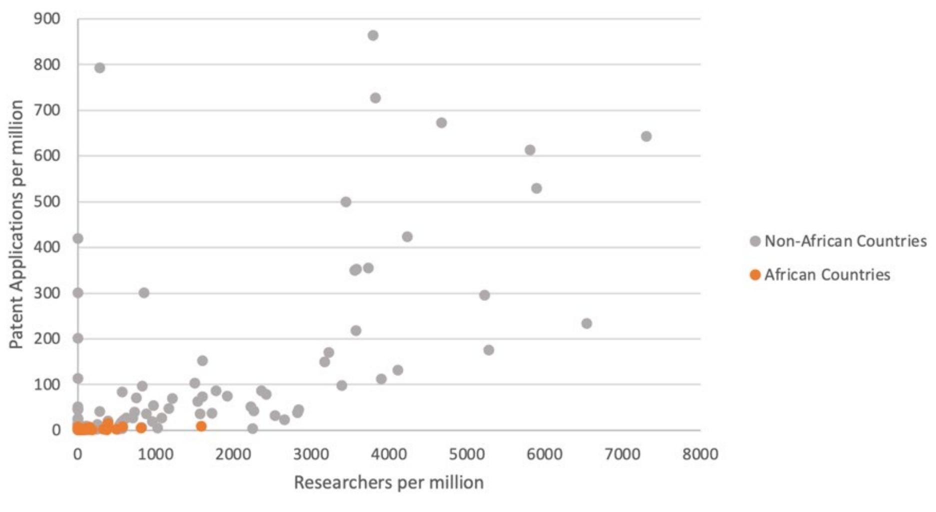
Empirical studies have also documented a positive impact of human capital on the capacity to innovate (see Agénor and Neanidis, 2015). High quality human capital facilitates not only the absorption of foreign knowledge and the adoption of new technology, but also the ability to create new knowledge.

From the perspective of measuring the capacity to innovate, a common indicator of human capital is the number of researchers per million inhabitants. Unlike some other indicators (such as the proportion of individuals with tertiary education), this provides both a quantity and a quality dimension. The premise is that people who have acquired formal education at a high level and are engaged in research are likely to determine the country's pace and quality of innovation.

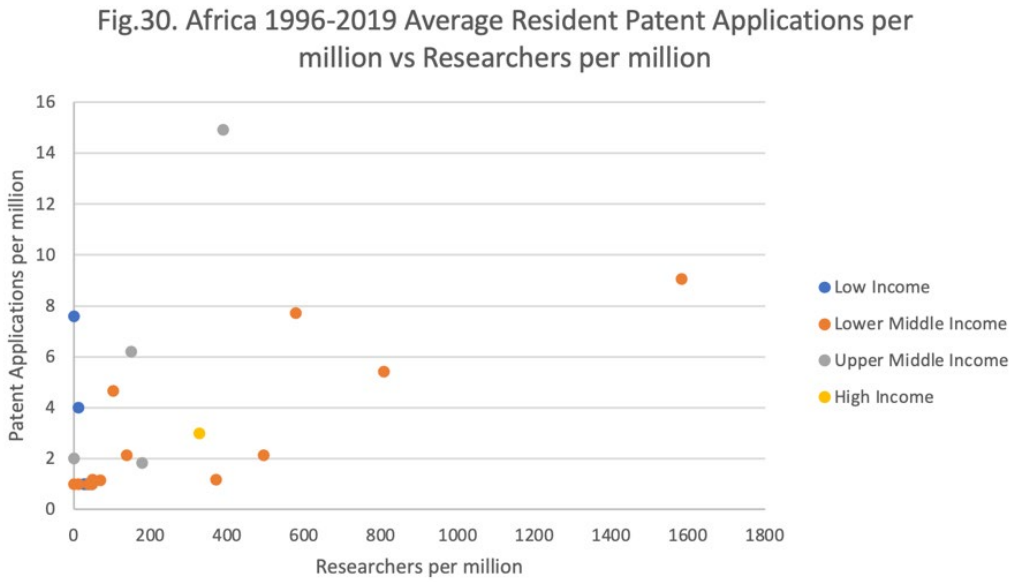
In that respect, there are major differences between Africa and developed countries. Some developed countries have more than 5,000 researchers per million—Sweden has 7593 researchers per million, South Korea has 7514, Germany 5036, and Japan 5305 (AUDA-NEPAD, 2019). In Africa, researcher density varies significantly, from 27 per million in Uganda to 435 in South Africa, 555 in Senegal, and 715 in Egypt (AUDA-NEPAD, 2019).

Figures 29 and 30 shows the relationship between resident patent applications per million and researchers per million. There appears to be a positive relationship between the two variables. In Figure 29, once again, African countries are clustered at the bottom left, which is expected as their researcher numbers are quite low. A weak positive relationship is also discernible in Figure 30 for Africa, particularly for the group of LMICs.

Fig.29. World 1996-2019 Average Resident Patent Applications per million vs Average Researchers per million



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

3.1.3 Access to Advanced infrastructure

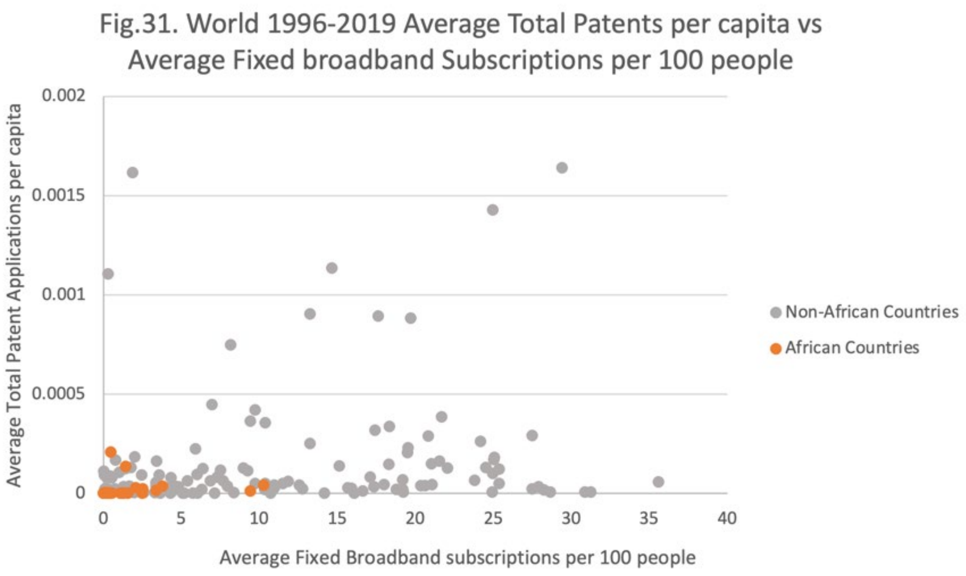
Access to advanced infrastructure, such as high-speed telecommunications and information communication technologies (ICTs), has been documented in some recent studies as a potentially significant determinant of innovation capacity. In particular, the literature has documented the importance of high-speed broadband connections in establishing domestic and international knowledge networks, which promote the diffusion of research, the ability to innovate, and thus growth (Czernich et al, 2011; UNIDO, 2012; Agénor and Canuto, 2015).

Broadband connection may also have an indirect effect on innovation capacity through its impact on the quality of human capital and the proportion of individuals with high level abilities involved in innovation activities (Agénor and Canuto, 2015; Agénor, 2017, 2021).

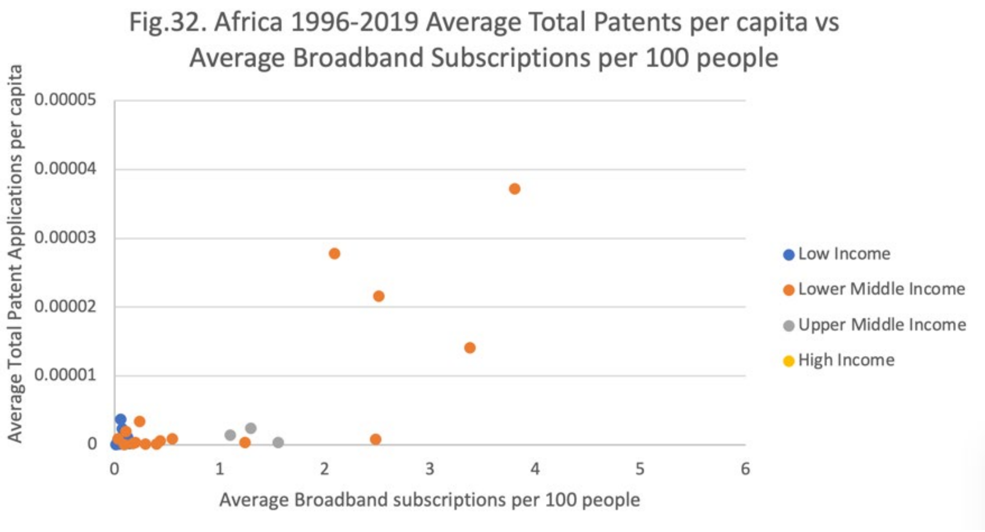
Indeed, the innovation sector may suffer from low levels of productivity because of limited access to appropriate infrastructure. Wages may therefore be constrained, which translates into a fewer individuals employed—and thus poor performance and weak incentives to invest in skills. Consequently, limited access to advanced infrastructure can lead to a misallocation of human capital, as highly talented individuals who have the potential to contribute to the innovation process in an economy by engaging in R&D may choose to work in other domestic industries offering guaranteed higher wages—or may simply leave the country, thereby contributing to the 'brain drain'.

From the perspective of assessing the capacity to innovate, a common indicator of access to advanced infrastructure is the number of fixed broadband subscriptions per 100 individuals. By focusing on the penetration rate of high-speed telecommunication, this provides a good proxy for the diffusion of knowledge, both within and across countries, and the potential creation of knowledge networks.

Figures 31 and 32 show the relationship between average total patents *per capita* and broadband subscriptions per 100 inhabitants. Figure 31 shows at the global level a positive relationship between the two variables with, again, the African countries clustered in the bottom left corner, having low levels of both variables. Figure 32, which shows the relationship between these variables for only the group of African countries, also suggests a weak positive association for LMICs.



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)



Source: Authors' calculations, based on the World Bank Open Database and the World Intellectual Property Organisation (WIPO)

3.1.4 Access to Finance

Several empirical studies have documented that inadequate access to finance can constrain the ability of firms (especially the small- and medium-size firms) to innovate. Countries such as South Korea have successfully transitioned from low- to high-income status through R&D investments and activities by their largest conglomerates, which were financed internally, without much dependence on venture capital markets. However, the broader evidence suggests that limited access to finance, possibly along with shortage of talented labor, can be a significant hurdle to innovation[6].

Inadequate access to finance can constrain innovation because of the difficulty small firms face in obtaining external funding. Many small firms hold intangible assets, which in turn cannot be pledged as collateral for loans. Moreover, in the interest of protecting their intellectual property, small R&D firms may not be completely transparent about the results with their lenders. Smaller firms may thus be tempted to rely on debt finance or their own resources to fund their equity due to insufficient collateral and information asymmetry. Furthermore, the existence of this information asymmetry, and the uncertainty that comes with innovation, may induce investors to require a higher rate of return compared to less risky, more tangible, physical investments. Interactions between limited finance, lack of innovation, and inadequate human capital may have adverse and sustained effects on growth (Agénor and Canuto, 2017)[7].

3.1.5 Property Rights and Governance

Lack of protection of property rights (especially intellectual rights) is a key weakness in many developing countries. According to the OECD (2014, p. 176), for instance, countries such as Morocco fare poorly compared to advanced countries when measured by a 'contract enforcement score' and an intellectual property index. These weaknesses tend to weaken confidence and may have an adverse effect on innovation. Inadequate intellectual property protection may act as a major constraint on the incentives to engage in innovation, because the return to that activity is not certain and because (as noted earlier) firms may be unwilling to offer fully transparent signals about the effectiveness of their intended innovation activities to potential lenders. As a result, this may also make it more difficult to secure access to finance.

The quality of institutions, or governance, may also be a significant determinant of a country's ability to innovate. Poor governance may result in contracts not being fully enforced, and this may create doubt about the rule of law—including to the extent that it applies to the enforcement of intellectual property rights. Knowing this, individuals may be reluctant to engage in R&D activities in the first place. Poor governance may also create a situation in which, on paper, the government spends a lot on R&D, but in practice, because of waste, corruption, and mismanagement, a large fraction of these outlays does not go to its designated purpose. This can explain, as discussed below, why it is the interaction between shares of R&D spending and the quality of government that affects innovation outcomes.

3.2 Formal Empirical Studies

Formal empirical studies of the determinants of innovation in Africa include survey-based studies and cross-country econometric regressions. To illustrate the first type of studies, a recent contribution is discussed. Cross-Country regressions, based on a comprehensive new database, are then presented.

6. See Brown et al (2012) and references therein.

7. Agénor and Canuto (2017) showed that when research activity is dependent on external finance and borrowing and monitoring is expensive, innovation can be negatively impacted by high intermediation costs. Additionally, the high costs of monitoring could, as a consequence, cause investment in skills and innovation to fall as the high costs could lead to lower wages, which reduces the incentive for individuals to invest in skills—thereby reducing the potential labour pool for R&D activities. Thus, in addition to affecting innovation and growth directly, limited access to finance may affect innovation and growth indirectly as well.

3.2.1 Micro-based Studies

One of the most comprehensive micro-based studies available is by Ayalew *et al* (2020)[8]. They investigated the impact at firm level of firm characteristics, openness, and resource-based determinants of innovation using the World Bank's enterprise survey for firms from 28 African countries. Their key finding is that firm size, export intensity, competition, foreign ownership, and resource-based determinants all have significant impacts on a firm's probability to innovate. The result on firm size is consistent with the evidence for non-African countries (see Cohen, 2010).

They also found (not surprisingly, given the evidence reviewed in the previous section) that there were substantial differences among African countries in the level of innovation. More than half of the sampled firms in Namibia, Kenya, Uganda, Sudan, Tanzania, Mauritania, Nigeria, Zambia, and Ghana were able to innovate and introduced a new or significantly improved product or service in the three years before Ayalew et al's (2020) study. By contrast, only around 5% of firms in Lesotho and 20% of firms in Eswatini and Egypt had product innovation over the same period. In addition, Ayalew *et al* (2020) documented a wide range across countries in terms of the proportion of firms that spend on R&D. While 70% of firms in Namibia engaged in R&D spending, only 3% of Senegalese firms did so. At the same time, the econometric analysis revealed that R&D expenditure has a positive and significant impact on a firm's likelihood to innovate.

The results also showed that the age of firms had a statistically significant effect on their probability to innovate. Firms that were more mature, between six and 15 years old, exhibited better innovation performance compared to older firms (over 15 years old) and young firms (up to five years old). It was also found that foreign firms were more likely to innovate compared to domestic firms, which corroborates the discussion in the previous section, which highlighted the fact that the proportion of non-resident patent applications was higher than that of residents. Finally, the study found that a firm's access to credit shows a positive and significant relationship with the probability to innovate, as documented previously by Lorenz (2014) for nine African countries, and that access to human capital—as measured by the ratio of an establishment's labor force (permanent employees), to permanent employees who completed secondary school—was important, but mostly for young firms.

Overall, therefore, the findings in Ayalew *et al* (2020) are consistent with many of the potential determinants highlighted earlier: R&D expenditure, human capital (at least for some types of firms), and access to finance. However, the study did not consider the potential role of two other determinants—access to advanced infrastructure and the protection of property rights and governance. These issues are considered in the new set of cross-country regressions that are reported next.

3.2.2 Cross-Country Regressions

To analyze the impact of the determinants of innovation in Africa, as outlined earlier, we now turn to cross-country regressions. The dependent variable is patents per million, and the regressors are: R&D expenditure as a percentage of GDP; researchers per million; broadband subscriptions per 100 (as a measure of access to advanced infrastructure); an indicator of governance, which was the CPIA property rights and rule-based governance rating (1-6) dataset; and access to credit, measured by the ratio of domestic credit to private sector as a share of GDP[9]. All of these variables

8. See Ayalew et al (2020) for references to other relevant studies, many of which relate to specific countries.

9. Foreign Direct Investment (FDI) has in some studies has been associated with innovation activity. It has not been included in this regression analysis as overall, the existing evidence of its role on innovation in Africa so far does not appear to be strong. However, future research could explore this link further in the context of sub-Saharan African countries.

were obtained from the World Bank Open Database[10]. Interactive terms were also used, along with the linear terms of the variables mentioned above, to investigate the potential interactions between determinants (as discussed earlier) and their impact on innovation outcomes[11]. The analysis is based on panel data and uses pooled OLS and fixed-effects estimation techniques. The regressions were run with two different sample sizes: a sample of 35 countries, and a smaller subsample of 24 countries, for which more data were available.

Table 1 shows the results. It shows that the broadband connection rate is the most significant variable when it comes to the number of patent applications in Africa. The variable is positive and significant at a 1% significance level for both techniques and in both sample sizes—even when the interactive term is introduced, apart from when the pooled OLS regression is run with the smaller sample with the interactive terms, where the broadband connection rate is significant at a 5% level. R&D expenditure as a percentage of GDP is also positive and significant at a 1% significance level when the regression is run using the pooled OLS technique. However, although it remains positive, the R&D variable loses its significance with the fixed-effects method. The governance variable (which, as noted earlier, also accounts for the protection of property rights) is negative and significant at a 5% level only when the interactive term is introduced in the pooled OLS estimation technique, for the smaller sample, but it gains significance in the fixed effects technique, where it is positive and significant at a 10% significance level—apart from the case of the smaller sample, when the interactive term is introduced, where although the coefficient is positive, it is insignificant. The interactive term combines the number of broadband subscriptions per 100 and the governance rating. This term is positive when it is introduced, however it is only significant at a 10% level for the smaller samples of 24 countries. Further, the coefficient of credit access is positive and significant at a 10% significance level, when the regression is estimated using the fixed effects technique for the larger sample of 35 countries. It is also significant at the 10% level for the smaller sample, when the interactive term is not introduced.

In sum, the results show that broadband penetration is the most significant determinant of innovation in Africa. This suggests that knowledge networks are vital to the innovation process of the countries in the region. R&D expenditure also has a positive and significant impact on innovation activity, as do governance and credit access. The favorable impact of the governance variable can be attributed to the fact that (as discussed above), innovators may feel more confident that the rights to their inventions are secure when governance improves. In addition, when broadband subscriptions and governance are interacted, they also have a positive impact on innovation in Africa. This may reflect the fact that when governance improves, there is less waste and corruption in public investment projects, and the provision of advanced infrastructure services may improve as well.

10. Note that while private sector credit as a percentage of GDP is a common measure of financial development, it is not necessarily a good indicator for the type of financial constraints faced by firms engaged in innovation. To assess the importance of these constraints, and their impact on innovation, firm-level data would more appropriate, as in some of the studies mentioned earlier. However, given the macro focus of the present study, the group of countries under consideration, and data limitations, it is the best indicator available. It is also worth noting that in some countries (such as Malaysia), innovation can be financed using standard bank loans.

11. However, the only positive and significant interactive term was the interaction between broadband subscriptions per 100 and governance.

Table 1 - Determinants of Innovation in Africa, Annual Data
Dependent Variable: Patents per million (PATENTSPM)

	Pooled OLS								Fixed Effects							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
C	4.112 (3.657)***	4.115 (3.623)***	4.434 (3.596)***	4.438 (3.568)**	5.787 (3.363)**	5.774 (3.321)***	3.796 (1.958)*	3.7843 (1.941)*	4.043 (1.861)*	4.047 (1.864)*	4.36 (2.070)**	4.363 (2.071)*	5.62 (1.731)*	5.62 (1.732)*	4.931 (1.538)	4.928 -1.538
R&D	50.15 (3.814)***	55.735 (4.858)***	50.986 (3.975)***	56.539 (5.032)**	44.42 (2.885)**	50.84 (3.873)***	56.819 (4.601)***	61.530 (5.675)***	1.950 (0.401)	4.012 (0.789)	1.847 (0.384)	4.295 (0.855)	2.73 (0.499)	4.38 (0.777)	8.932 (1.390)	10.71 (1.708)*
RPM	0.009 (1.353)		0.009 (1.354)		0.01 (1.414)		0.007 (1.113)		0.004 (0.888)		0.005 (1.053)		0 (0.664)		0.004 (0.730)	
BP100	3.528 (2.638)***	3.647 (2.832)***	3.325 (2.431)**	3.444 (2.619)**	3.661 (2.591)**	3.797 (2.774)***	3.225 (2.314)**	3.3242 (2.484)**	3.775 (2.983)**	3.851 (3.208)***	3.506 (2.745)***	3.599 (2.977)***	4.02 (3.040)***	4.08 (3.261)***	3.446 (2.668)***	3.514 (2.875)***
GOV	2.565 (0.924)	2.489 (0.902)	1.788 (0.804)	1.710 (0.773)	5.053 (1.110)	4.9414 (1.093)	-3.05 (-1.964)**	-3.139 (-2.013)**	5.614 (1.757)*	5.599 (1.753)*	4.576 (1.815)*	4.566 (1.812)*	9.44 (1.842)*	9.436 (1.842)*	2.084 (0.972)	2.075 (0.969)
CREDACC	0.000 (0.891)	0.000 (0.873)	0.000 (0.770)	0.000 (0.752)	0.000 (1.097)	0.000 (1.089)	0.000 (1.317)	0.000 (1.313)	0.000 (1.836)*	0.000 (1.828)*	0.000 (1.791)*	0.000 (1.782)*	0.000 (0.843)	0.000 (0.840)	0.000 (1.008)	0.000 (1.005)
BP100xGOV			1.785 (1.078)	1.788 (1.080)			56.55 (1.317)*	56.611 (1.615)*			2.758 (1.259)	2.736 (1.251)			48.48 (1.683)*	48.48 (1.684)*
Total panel observations	840	840	840	840	576	576	576	576	840	840	840	840	576	576	576	576
Cross-sections included	35	35	35	35	24	24	24	24	35	35	35	35	24	24	24	24
Adjusted R-squared	0.014	0.015	0.014	0.015	0.008	0.0098	0.060	0.061	0.126	0.127	0.126	0.127	0.12	0.12	0.15	0.152

Note: All variables are in annual data. Unbalanced annual panel data are used (1996-2019). Two samples are used, one with 35 countries and another smaller sample with 24 countries. The list of the countries is given in the appendix. Regression methods are panel least squares- Pooled OLS and fixed effects. Heteroskedasticity-robust standard errors are used. t-statistics are given in parenthesis. * stands for 10% significance; ** stands for 5% significance; *** stands for 1% significance. PATENTSPM = Patent applications per million residents; R&D= Research and Development expenditure on research as a percentage of GDP; RPM= Researchers in Research and Development per million residents; BP100= Broadband connections per 100 residents; GOV = CPIA Property rights and rule-based governance rating (1-6); CREDACC = Domestic credit to private sector as a percentage of GDP.

4. INNOVATION AND GROWTH IN AFRICA: ECONOMETRIC ANALYSIS

To examine the impact of innovation on growth, we consider the three types of intellectual property mentioned above—patents, industrial design, and trademark applications—and how individually they impact growth in Africa.

4.1 Data and Estimation Techniques

To study the impact of innovation on growth, the dependent variable used is the growth rate of real GDP *per capita*. The core set of regressors in all the regressions are: a measure of investment, gross fixed capital formation as a percentage of GDP; government consumption as a percentage of GDP; inflation, measured using the consumer price index; a governance indicator, the CPIA property rights and governance rating (1-6); credit access (viewed now as a broad proxy for financial development), measured by the ratio of domestic credit to private sector as a share of GDP, as discussed above; a measure of human capital, the literacy rate, which is the percentage of people above 15 years of age; and an indicator of access to infrastructure, the number of fixed broadband subscriptions per 100 people, multiplied by a threshold dummy of 15 connections.

While investment, governance, and broadband penetration are expected to have a positive effect on growth, inflation (which blurs relative price signals for producers), and government consumption (a measure of unproductive spending) are expected to have a negative sign[12]. The lagged GDP *per capita* growth rate is also use as a regressor to account for persistence.

To this core set of control variables used in all regressions, we added: patent applications per million; industrial design applications per million; and trademarks per million. We added these one at a time and together to discern their individual impacts on growth.

As before, the data for all the variables was obtained from the World Bank Open Database and WIPO database. Similarly to the previously reported results regarding the determinants of innovation, the regressions were run using two samples, one with 35 countries and a smaller sub-sample of 24 countries over 24 years, from 1996 to 2019. As we are working with panel data, pooled OLS, fixed effects and the random effects estimation techniques were used, along with heteroskedastic-corrected standard errors to test for the significance of variables[13].

4.2 Regression Results

Table 2 reports the results of the growth regressions that only consider patents per million as a regressor[14]. The results show that the control variables are generally not significant. The lagged GDP *per capita* growth rate is positive and highly significant, at a 1% significance level across both sample sizes. The coefficients of the governance indicator are positive and insignificant across all techniques. Furthermore, government consumption as a percentage of GDP is negative when the regression is estimated with a pooled OLS and a random effects model, which (as noted above) is

12. For a further discussion of the role of these variables in cross-country growth regressions, see Agénor (2004, chapter 13).

13. An alternative regression technique that accounts for heterogeneity and endogeneity could be the Generalised Method of Moments (GMM), as proposed by Arellano and Bond (1991). This methodology allows us to eliminate fixed effects by first differencing and then by using the lagged values of variables as instruments to eliminate possible endogeneity issues. However, given the nature of some of the variables used in regressions (large gaps in annual data), the GMM method may not be satisfactorily applicable to our analysis because their lagged values may not be properly assigned as instrumental variables as required in GMM regressions.

14. The lagged values of patents by 1 and 2 periods were also tried as regressors of growth, to see if patents have a delayed impact on growth. However, using these values did not change the results obtained with the current value of patents and they were therefore not included.

as expected. Further, inflation also has a negative effect (as expected) but is also insignificant. The investment rate is positive and significant at a 5% significance level with the pooled OLS and the random-effects techniques for the larger sample, but it loses its significance when the regression is estimated using the fixed-effects method. The coefficient of the literacy rate is very small and positive in this case, but insignificant across both sample sizes and all the estimation techniques. The broadband penetration rate, accounting for a threshold level of 15% is significant as well for both sample sizes when estimating the impact of the variables using pooled OLS and random effects. This suggests that, above a certain level, broadband contributes to growth in a positive and significant way in Africa—consistent with other studies in the literature (Czernich et al, 2011). Moreover, the coefficient of credit access is positive and significant at a 5% significance level for the larger sample, when the pooled OLS and the random-effects technique is used, and is significant at the same significance level for both sample sizes, when the regression is estimated using fixed effects. Lastly, patents per million do not appear to have a statistically significant effect on growth in the region. In a sense, this is what one would expect; at low- and lower middle-income levels, it is difficult to detect a robust effect of innovation on growth, because at these levels of income, growth may be driven by other factors (commodity exports, imitation of foreign technology, and so on). In addition, it is important to keep in mind that the sample covers a period during which many of today's MICs were actually LICs. So even if innovation start to make an impact on growth once countries reach (upper) middle-income status, a regression based on a sample covering different income levels may not pick up this effect. Unfortunately, it is difficult to run more refined regressions, because of data limitations. Finally, it is also possible that the very type of innovation (for instance, process innovation, as opposed to product innovation) that the region generates is not conducive to a direct effect on growth, or that innovation must reach a certain threshold level to have a discernible impact on growth.

Table 3 considers the impact of industrial design applications on growth. As seen with Table 2 and the impact of patents on growth, lagged GDP growth *per capita* is again positive and highly significant, governance is mostly positive and insignificant in general—except that governance is significant at 10% when the regression is estimated using a pooled OLS and a random-effects regression for the smaller sample of 24 countries. Government consumption is again negative and insignificant, whereas inflation is negative and insignificant too—apart from for the larger sample when the estimation is conducted with the pooled OLS technique. Investment has a positive and significant impact for the larger sample when estimated using the pooled OLS and the random-effects techniques, whereas the coefficient on the literacy rate is positive apart from the case of the larger sample when estimated using the pooled OLS technique, where it is negative but insignificant. The broadband penetration rate over the threshold of 15% is again positive and significant—especially when the regression is estimated using the pooled OLS and the random-effects techniques. Credit access is again positive and is also significant at a 5% significance level for the larger sample across all three estimation techniques, as well as for the smaller sample when estimated using fixed effects. Industrial design applications have a positive and significant impact on growth when the regression is estimated using the fixed-effects technique for the smaller subsample.

Table 2 - Determinants of Economic Growth in Africa - Patents, Annual Data
Dependent Variable: Growth rate of GDP per capita (GDP_GROWTH)

	Pooled OLS		Fixed Effects		Random Effects	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
C	0.782	1.14	0.61	0.978	0.782	1.140
	(1.215)	(1.169)	(1.215)	(0.656)	(1.215)	(1.169)
GDPPCGROWTH(-1)	0.342	0.315	0.255	0.231	0.342	0.321
	(5.059)***	(3.457)***	(3.387)***	(2.247)**	(5.059)***	(3.540)***
GOV	0.073	0.110	0.169	0.104	0.073	0.11
	(0.856)	(1.157)	(1.321)	(0.670)	(0.856)	(1.157)
GOVNCONS	-0.03	-0.026	0.02	0.034	-0.03	-0.03
	(-1.201)	(-0.779)	(0.371)	(0.398)	(-1.201)	(-0.779)
INFL	-0.01	-0.01	0	-0.02	-0.005	-0.013
	(-0.931)	(-1.172)	(-0.803)	(-1.581)	(-0.931)	(-1.172)
INV	0.045	0.037	0.027	0.021	0.045	0.037
	(2.302)**	(1.459)	(0.917)	(0.614)	(2.302)**	(1.459)
LITRATE	0	0.003	0.002	0.004	0	0.030
	(0.074)	(0.852)	(0.405)	(0.870)	(0.074)	(0.852)
BB15	0.055	0.044	0.006	-0.002	0.055	0.044
	(3.357)***	(2.699)***	(0.245)	(-0.086)	(3.357)***	(2.699)***
CREDACC	0.000	0.000	0.000	0.000	0.000	0.000
	(2.087)**	(1.552)	(2.261)**	(2.060)**	(2.085)**	(1.552)
PATENTSPM	0	0	-0.01	-0.016	0	0
	(-0.838)	(-1.076)	(-1.416)	(-1.587)	(-0.838)	(-1.076)
Total panel observations	647	469	647	469	647	469
Cross-sections included	33	22	33	22	33	22
Adjusted R-squared	0.151	0.123	0.168	0.143	0.151	0.123

Note: All variables are in annual data. Unbalanced annual panel data are used (1996-2019). Two samples are used, one with 35 countries and another smaller sample with 24 countries. The list of the countries is given in the appendix. Regression methods are panel least squares-Pooled OLS and fixed effects. Heteroskedasticity-robust standard errors are used. t-statistics are given in parenthesis. * stands for 10% significance; ** stands for 5% significance; *** stands for 1% significance. GDPPCGROWTH= Gross Domestic Product per capita measured as an annual percentage change; GOV= CPIA Property rights and rule-based governance rating (1-6) ; GOVNCONS= General government final consumption expenditure as a percentage of GDP ; INFL= Inflation as measured by the consumer price index as an annual percentage ; INV= Gross fixed capital formation as a percentage of GDP; LITRATE= Literacy rate of adults as a percentage of people aged 15 and above ; BB15= Fixed broadband subscriptions per 100 residents when the value was greater than 15; CREDACC= Domestic credit to private sector as a percentage of GDP; PATENTSPM = Patent applications per million residents.

Table 3 - Determinants of Economic Growth in Africa - Industrial Design, Annual Data
Dependent Variable: Growth rate of GDP per capita (GDP_GROWTH)

	Pooled OLS		Fixed Effects		Random Effects	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
C	0.744	1.081	0.451	0.730	0.744	1.08
	(1.158)	(1.110)	(0.405)	(0.485)	(1.158)	(1.110)
GDPPCGROWTH(-1)	0.342	0.317	0.255	0.23	0.342	0.32
	(5.062)***	(3.486)***	(3.378)***	(2.235)**	(5.062)***	(3.486)***
GOV	0.099	0.146	0.169	0.104	0.099	0.15
	(1.175)	(1.571)*	(1.318)	(0.668)	(1.175)	(1.571)*
GOVNCONS	-0.027	-0.03	0.022	0.038	-0.03	-0.03
	(-1.247)	(-0.867)	(0.408)	(0.440)	(-1.247)	(-0.867)
INFL	-0.006	-0.02	0	-0.02	-0.006	-0.02
	(-0.962)	(-1.436)	(-0.746)	(-1.549)	(-0.962)	(-1.436)
INV	0.044	0.037	0.024	0.017	0.044	0.037
	(2.240)**	(1.482)	(0.824)	(0.493)	(2.240)**	(1.482)
LITRATE	-0.0002	0.003	0.001	0.003	0	0
	(-0.056)	(0.613)	(0.369)	(0.834)	(-0.056)	(0.613)
BB15	0.055	0.045	-0.005	-0.015	0.055	0.05
	(3.238)***	(2.654)***	(-0.229)	(-0.604)	(3.238)***	(2.654)***
CREDACC	0.000	0.000	0.000	0.000	0.000	0.000
	(2.065)**	(1.499)	(2.229)**	(2.006)**	(2.065)**	(1.496)
INDUSDESPM	0.003	0.002	0.005	0.006	0.003	0
	(1.174)	(0.822)	(1.551)	(1.700)*	(1.174)	(0.822)
Total panel observations	647	469	647	469	647	469
Cross-sections included	33	22	33	22	33	22
Adjusted R-squared	0.152	0.122	0.168	0.143	0.152	0.12

Note: All variables are in annual data. Unbalanced annual panel data are used (1996-2019). Two samples are used, one with 35 countries and another smaller sample with 24 countries. The list of the countries is given in the appendix. Regression methods are panel least squares-Pooled OLS and fixed effects. Heteroskedasticity-robust standard errors are used. t-statistics are given in parenthesis. * stands for 10% significance; ** stands for 5% significance; *** stands for 1% significance. GDPPCGROWTH= Gross Domestic Product per capita measured as an annual percentage change; GOV= CPIA Property rights and rule-based governance rating (1-6) ; GOVNCONS= General government final consumption expenditure as a percentage of GDP ; INFL= Inflation as measured by the consumer price index as an annual percentage ; INV= Gross fixed capital formation as a percentage of GDP; LITRATE= Literacy rate of adults as a percentage of people aged 15 and above ; BB15= Fixed broadband subscriptions per 100 residents when the value was greater than 15; CREDACC= Domestic credit to private sector as a percentage of GDP; INDUSAPPSPM= Industrial design applications per million residents.

Table 4 shows the impact of trademark applications on growth. As with the cases above, GDP *per capita* lagged by one period is highly significant across both samples and different estimation techniques. Again, governance is positive and insignificant, whereas government consumption as a percentage of GDP is negative and insignificant. Inflation is also negative and insignificant in all cases. Investment is positive and significant for the larger sample, at a 5% significance level for the pooled OLS and the random-effects methods, and at a 10% level for the fixed-effects estimation technique, as compared to the smaller sample, where it is still positive but not significant. The coefficient of the literacy rate again is small and positive, but insignificant. The threshold-based broadband penetration rate is again positive and significant for both estimation techniques of the pooled OLS and the random effects. Similar to the previous cases, credit access has a positive and significant coefficient at a 5% significance level for the smaller sample when estimated using the fixed-effects method, and for the larger sample for all estimation techniques. Lastly, trademarks per million has a negative but insignificant impact on growth.

Table 5 sets out the impact of the three types of IP considered in this paper as regressors of GDP *per capita* growth. As in previous cases, GDP *per capita* lagged by one period is positive and highly significant at a 1% level across all estimation techniques—apart from the smaller sample with the fixed effects method, where it is significant at a 5% level. Further, governance is positive across all techniques, and is significant at a 10% level for the larger sample when the fixed-effects technique is used. Both government consumption as a percentage of GDP and inflation are negative and insignificant across all samples and estimation techniques. On the other hand, investment is positive for both samples and over all estimation techniques, and is significant at a 5% level when the larger sample is considered using the pooled OLS and the random-effects estimation techniques.

The literacy rate, again, has a small but positive coefficient that is insignificant. The broadband penetration rate of over 15% is again positive and is also significant at a 10% and 5% level for both samples when considering both sample sizes, 35 countries and 24 countries, respectively. Credit access in this case is surprisingly negative, and is significant at a 5% level when the regressions are run using the fixed-effects method, and for the larger sample using the pooled OLS and the random effects method at a 10% level. From the IP types, it can be seen that patent and trademark applications are small and positive, but insignificant. By contrast, industrial design applications are positive and significant across all estimation techniques and sample sizes. Indeed, it is significant at a 5% level when the fixed-effects method is employed for the larger sample with the pooled OLS and the random-effects method, and is significant at a 10% level for the smaller sample for those methods.

It is interesting to point out that that the type of IP applied for from African countries is mainly trademarks (as discussed above). However, this does not appear to have a robust impact on growth when considered individually or with the other types of IP. This could indicate that trademark applications do not really contribute to growth in general, or that they only do so in some countries but not others, implying that on average no discernible effect can be picked up in a regression involving a large number of low- and middle-income countries.

Table 4 - Determinants of Economic Growth in Africa - Trademarks , Annual Data
Dependent Variable: Growth rate of GDP per capita (GDP_GROWTH)

	Pooled OLS		Fixed Effects		Random Effects	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
C	0.781	1.116	0.613	0.957	0.781	1.116
	(1.211)	(1.149)	(0.546)	(0.632)	(1.211)	(1.149)
GDPPCGROWTH(-1)	0.342	0.316	0.254	0.229	0.342	0.316
	(5.062)***	(3.474)***	(3.372)***	(2.222)**	(5.062)***	(3.474)***
GOV	0.075	0.119	0.174	0.108	0.075	0.119
	(0.876)	(1.235)	(1.362)	(0.700)	(0.876)	(1.235)
GOVNCONS	-0.027	-0.027	0.019	0.031	-0.027	-0.027
	(-1.203)	(-0.802)	(0.340)	(0.363)	(-1.203)	(-0.802)
INFL	-0.006	-0.015	-0.005	-0.019	-0.006	-0.015
	(-1.004)	(-1.377)	(-0.789)	(-1.548)	(-1.004)	(-1.377)
INV	0.046	0.038	0.026	0.02	0.046	0.038
	(2.319)**	(1.530)	(0.883)*	(0.594)	(2.319)**	(1.530)
LITRATE	0.00	0.003	0.001	0.003	0.00	0.003
	(-0.008)	(0.714)	(0.291)	(0.777)	(0.008)	(0.714)
BB15	0.069	0.062	0.021	0.016	0.069	0.062
	(2.199)**	(1.808)*	(0.684)	(0.460)	(2.199)**	(1.808)*
CREDACC	0.000	0.000	0.000	0.000	0.000	0.000
	(2.070)**	(1.509)	(2.173)**	(1.960)**	(2.070)**	(1.509)
TRADEMARKSPM	-0.0002	-0.0002	-0.0005	-0.0005	-0.0002	-0.0003
	(-0.522)	(-0.565)	(-1.028)	(-1.0.36)	(-0.522)	(-0.565)
Total panel observations	647	469	673	469	647	469
Cross-sections included	33	22	33	22	33	22
Adjusted R-squared	0.151	0.123	0.168	0.144	0.151	0.122

Note: All variables are in annual data. Unbalanced annual panel data are used (1996-2019). Two samples are used, one with 35 countries and another smaller sample with 24 countries. The list of the countries is given in the appendix. Regression methods are panel least squares- Pooled OLS and fixed effects. Heteroskedasticity-robust standard errors are used. t-statistics are given in parenthesis. * stands for 10% significance; ** stands for 5% significance; *** stands for 1% significance. GDPPCGROWTH= Gross Domestic Product per capita measured as an annual percentage change; GOV= CPIA Property rights and rule-based governance rating (1-6) ; GOVNCONS= General government final consumption expenditure as a percentage of GDP ; INFL= Inflation as measured by the consumer price index as an annual percentage ; INV= Gross fixed capital formation as a percentage of GDP; LITRATE= Literacy rate of adults as a percentage of people aged 15 and above ; BB15= Fixed broadband subscriptions per 100 residents when the value was greater than 15; CREDACC= Domestic credit to private sector as a percentage of GDP ; TRADEMARKSPM= Trademark applications per million residents.

Table 5 - Determinants of Economic Growth in Africa - Intellectual Property, Annual Data
Dependent Variable: Growth rate of GDP per capita (GDP_GROWTH)

	Pooled OLS		Fixed Effects		Random Effects	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
C	0.913	1.27	0.916	0.999	0.913	1.270
	(1.408)	(1.292)	(0.828)	(0.681)	(1.408)	(1.292)
GDPPCGROWTH(-1)	0.343	0.318	0.246	0.225	0.343	0.318
	(5.172)***	(3.568)***	(3.434)***	(2.311)**	(5.172)***	(3.568)***
GOV	0.101	0.132	0.233	0.169	0.101	0.132
	(1.116)	(1.288)	(1.892)*	(1.128)	(1.116)	(1.288)
GOVNCONS	-0.02	-0.020	0.033	0.053	-0.02	-0.02
	(-0.931)	(-0.611)	(0.64)	(0.647)	(-0.931)	(-0.511)
INFL	-0.006	-0.014	-0.005	-0.02	-0.006	-0.014
	(-1.074)	(-1.192)	(-0.913)	(-1.582)	(-1.074)	(-1.192)
INV	0.044	0.033	0.031	0.027	0.044	0.033
	(2.243)**	(1.352)	(1.120)	(0.812)	(2.243)**	(1.352)
LITRATE	0.001	0.004	0.003	0.005	0.001	0.004
	(0.243)	(1.073)	(0.706)	(1.234)	(0.243)	(1.073)
BB15	0.088	0.069	0.009	0.004	0.088	0.069
	(2.372)**	(1.804)*	(0.256)	(0.107)	(2.372)**	(1.804)*
CREDACC	-0.015	-0.013	-0.042	-0.033	-0.015	-0.013
	(-1.694)*	(-1.206)	(-3.301)***	(-2.572)***	(-1.694)*	(-1.206)
PATENTSPM	0.009	0.005	0.020	0.013	0.009	0.005
	(1.132)	(0.598)	(1.273)	(0.930)	(1.132)	(0.589)
TRADEMARKSPM	0.000	0.000	0.000	0.000	0.000	0.000
	(0.228)	(0.161)	(0.035)	(-0.162)	(0.228)	(0.161)
INDUSAPPSPM	0.005	0.004	0.009	0.009	0.005	0.004
	(2.172)**	(1.762)*	(2.540)**	(2.493)**	(2.172)**	(1.762)*
Total panel observations	647	469	647	469	647	469
Cross-sections included	33	22	33	22	33	22
Adjusted R-squared	0.165	0.142	0.234	0.211	0.165	0.142

Note: All variables are in annual data. Unbalanced annual panel data are used (1996-2019). Two samples are used, one with 35 countries and another smaller sample with 24 countries. The list of the countries is given in the appendix. Regression methods are panel least squares-Pooled OLS and fixed effects. Heteroskedasticity-robust standard errors are used. t-statistics are given in parenthesis. * stands for 10% significance; ** stands for 5% significance; *** stands for 1% significance. GDPPCGROWTH= Gross Domestic Product per capita measured as an annual percentage change; GOV= CPIA Property rights and rule-based governance rating (1-6) ; GOVNCONS= General government final consumption expenditure as a percentage of GDP ; INFL= Inflation as measured by the consumer price index as an annual percentage ; INV= Gross fixed capital formation as a percentage of GDP; LITRATE= Literacy rate of adults as a percentage of people aged 15 and above ; BB15= Fixed broadband subscriptions per 100 residents when the value was greater than 15; CREDACC= Domestic credit to private sector as a percentage of GDP ; PATENTSPM = Patent applications per million residents; TRADEMARKSPM= Trademark applications per million residents; INDUSAPPSPM= Industrial design applications per million residents.

Overall, the growth regressions show that in Africa, given the sample under consideration, the most important determinants of growth are the (public and private) investment rate, access to credit, and the threshold-based broadband penetration rate. Other standard regressors, such as government consumption or inflation, do not appear to have a robust effect. Intellectual property in the form of industrial design applications has a positive and significant impact on growth when considered as a regressor along with the other types of IP. However, on its own, it does appear to contribute to growth. Trademarks may be a type of IP that does not contribute significantly to growth as it relates to goods and services, rather than contributing to the economy in a monetary or tangible way, which could be more impactful on growth for countries that are at a lower income level. Lastly, patents were found to have an insignificant effect on growth. This could be for several reasons, both economic and statistical, as discussed above. In particular, it could be that patents require a threshold to impact growth positively in countries at middle-income status. Additionally, several different types of patents are issued, including utility patents, design patents, and plant patents (Fundingcircle.com, 2020), which could each have different impacts on growth, and different types of patents may be applied for in different countries and regions, based on their development or innovation level, which could in turn impact the results.

5. PROMOTING INNOVATION IN AFRICA: POLICY LESSONS

As noted in the introduction, for today's UMICs in Africa, promoting innovation is essential to ensure the transition to high-income status[15]. Based on the foregoing analysis, and the literature on avoiding middle-income traps (Agénor, 2017, 2021), the following policy recommendations to promote innovation in Africa, at national and regional levels, can be put forward.

5.1 National Policies

First, government subsidies targeted to R&D may be needed to promote specific activities with a potentially high social marginal returns. To the extent that they help to prop up wages in the innovation sector and reduce the inherent degree of uncertainty associated with the returns to innovation, public subsidies can also help to mitigate the misallocation of talent alluded to earlier. However, it is important to ensure that subsidies are allocated efficiently and adequately, otherwise they are unlikely to have any significant impact on growth, as documented in the growth regressions discussed above.

Second, ensuring the protection of property rights is important to promote innovation. Lack of protection of intellectual property rights may act as a deterrent to individuals and prevent them from engaging, in the first place, in innovation activities. From that perspective, significant progress is needed in Africa. Securing intellectual property rights requires not only development of new legislation, but also raising awareness of existing laws.

Third, improving access to advanced infrastructure is important to promote innovation. As we have noted, lack of access to advanced infrastructure may be a major barrier to the development of national and international knowledge networks.

15. While essential, promoting innovation is not the only policy that today's UMICs in Africa must implement to facilitate their transition from middle- to high-income status, and (equally important for the region) create quality jobs. These other policies include measures aimed at transforming the agricultural sector, encouraging industrial diversification, reforming labor markets, promoting regional integration, and reducing income and gender equality. See UNIDO (2009), African Development Bank (2017), and Agénor (2021), for more detailed discussions of these policies.

Fourth, access to finance must be improved. As we have discussed, and as documented in the micro-based studies reviewed above, financial constraints have a significant impact on the ability of firms to innovate. The regression results corroborate the view that access to finance could be important to promote innovation in Africa. Improving access to finance may actually be a partial substitute for the provision of public subsidies, which may be more difficult to target and allocate efficiently.

Fifth, governments should promote a culture of innovation. For many observers, one of South Africa's greatest strengths, is that it has a strong innovation culture. But in other countries, governments have a role to play. Tunisia's Startup Act is an example[16]. More generally, technology ecosystems across Africa have grown rapidly in the past few years, boosted by venture funds, development finance, corporate involvement, and ever-growing, innovative communities[17]. In 2019, there were 618 active tech hubs, compared to 442 in 2018[18]. Nigeria and South Africa remain the most advanced ecosystems, with 85 and 80 active tech hubs respectively, offering well-established collaborations and investment networks. Other countries in the region could follow a similar path, perhaps by promoting more integrated national tech hubs, or multi-stakeholder ecosystems, as recommended by the World Bank, based on a study of the comparative success of some African tech clusters. The evidence suggests that multi-stakeholder ecosystems work better than initiatives led by government, the private sector, or academia alone[19].

16. See https://qz.com/africa/1252113/tunisia-startup-act-to-boost-african-tech-ecosystem-and-innovation/. Another example is the Startup-Chile program; see Box 2.

17. See https://www.gsma.com/mobilefordevelopment/blog/618-active-tech-hubs-the-backbone-of-africas-tech-ecosystem/.

18. The hubs categories have been predominantly based on the types of support or facility offered to entrepreneurs, and include incubators, accelerators, university-based innovation hubs, maker spaces, technology parks, and co-working spaces.

19. See http://wbgfiles.worldbank.org/documents/dec/Tech-Hubs-in-Africa.html.

Box 2: The Start-Up Chile program

Start-Up Chile (http://startupchile.org/) is an innovation promotion program inspired by Silicon Valley in the United States, and based in Santiago, Chile. The program's objective is to make Chile the primary center of innovation in Latin America. Participants are also expected to organize and participate actively in local training activities for entrepreneur networks.

The program was launched by the Chilean government, through *InnovaChile* and CORFO. The Ministry of Economy, the Ministry of Foreign Affairs, and the Ministry of Interior fund the program, which provides interest-free and non-equity funds up to US$40,000 to pre-selected start-up companies.

Selected companies are invited to participate in a 24-week program in Santiago, where they get sponsorship and access to offices, and meet with potential investors. Although national start-ups can participate in the program, most come from different parts of the world (Canada, other countries in Latin America, New Zealand, Singapore, etc.). These companies are initially invited for a period of six months; the government takes care of all administrative procedures. If a company decides to stay, getting a new visa is easy and inexpensive.

The cost of skilled labor (engineers) is relatively low, and so is the cost of a two-bedroom apartment. The physical concentration of startup companies and their integration into the local environment aims to create synergies to stimulate innovation and the transmission of knowledge.

The program started in 2010 with 22 start-ups from 14 countries. Since then, the program has received thousands of applications from more than 110 countries. As of September 2021, 1,960 applications had been approved, 54% of which remain active. Among the approved projects, 22% were from the United States, 19% from Chile, 7% from Argentina, 6% from India, and 4% from Brazil.

An important point to note about the above policies is that they are likely to need joint implementation to generate tangible results. For instance, subsidies to innovation are unlikely to work if the binding constraint on productivity growth in the innovation sector is related to another factor, namely (based on the regression results), a lack of access to advanced infrastructure. Without improvements in the culture of innovation, greater access to broadband may not have a discernible impact on performance. At the same time, it is also important to recognize that combining policies may be a drain on (limited) administrative resources and improvements in governance may be required to ensure effective implementation.

5.2 Regional Policies and the Role of Multilateral Institutions

The foregoing discussion has emphasized a related set of policies that should be implemented at national level to promote innovation. However, three of these policies could also be implemented fruitfully at regional level: fostering an innovation culture, improving access to finance, and providing greater access to advanced infrastructure.

To promote the culture to innovate, regional tech hubs should be promoted, as well as national tech hubs. In recent years, more than 400 tech hubs have sprung up across Africa, with Lagos, Nairobi, and Cape Town emerging as internationally recognized technology centers[20]. These cities now host thousands of startups, along with the incubators, accelerators, innovation hubs, maker spaces, technology parks, and co-working spaces that support them. This process could be further supported by multilateral institutions.

To promote access to the ‘right type’ of finance to support innovation, namely, venture capital, regional financial markets (in countries such as Nigeria, South Africa, and Morocco, the latter with a particular focus on francophone Africa) could be further developed, again with the support of multilateral institutions. Casablanca, in particular, has seen relatively rapid growth of venture capital markets in recent years.

To promote greater access to advanced infrastructure, regional investment programs could be further strengthened, again with the support of multilateral institutions. The evidence shows clearly that boosting connectivity can increase research activity and spur innovation, by promoting knowledge networks.

20. These cities are part of the so-called innovation quadrangle, Nigeria, South Africa, Egypt and Kenya.

References

Abdu M, Jibir A. (2017) Determinants of firms' innovation in Nigeria. Kasetsart J. Soc. Sci. https://doi.org/10.1016/j.kjss.2017.07.006.

African Development Bank. (2015) Growth, Poverty and Inequality Nexus: Overcoming Barriers to Sustainable Development, African Development Report, AfDB Publications

——. (2017) Industrialize Africa: Strategies, Policies, Institutions, and Financing, AfDB Publications (Abidjan: 2017).

Agénor, P-R. (2004) The Economics of Adjustment and Growth, Harvard University Press.

—— (2017) "Caught in the Middle? The Economics of Middle-Income Traps," Journal of Economic Surveys, 31 (July 2017), 771-91.

——. (2021). "Avoiding the Middle-Income Trap: Analytical Insights, Successful Experiences, and Policy Lessons for Africa." in Avoiding the Middle-Income Trap: Analytical Insights, Successful Experiences, and Policy Lessons for Africa, ed. by Emmanuel Pinto Moreira, African Development Bank (Abidjan).

Agénor, P.-R., and O Canuto (2015) "Middle-Income Growth Traps," Research in Economics, 69, 641-60.

——. (2017). "Access to Finance, Product Innovation, and Middle-Income Traps," Research in Economics, 71, 337-55.

Aghion, P., and Howitt, P., (2009). The Economics of Growth, MIT Press (Cambridge, Mass.: 2009).

Aghion, P., Howitt, P., and Mayer-Foulkes, D., (2005) "The Effect of Financial Development on Convergence: Theory and Evidence," Quarterly Journal of Economics, 120, 173-222.

AUDA-NEPAD, (2019). African Innovation Outlook 2019, AUDA-NEPAD, Johannesburg ISBN: 978-1-928527-21-3

Ayalew, et al., (2020). "The Determinants of Firms' Innovation in Africa," Journal of Industry, Competition and Trade, 20, 527-67.

Brown, J R., Martinsson, G., and Petersen, BC., (2012). "Do Financing Constraints Matter for R&D?," European Economic Review, 56, 1512-29.

Cohen W M. (2010). Fifty years of empirical studies of innovative activity and performance. In: Handbook of the Economics of Innovation, Elsevier, North-Holland, vol 1.

Cohen WM, Klepper S,(1996). Firm size and the nature of innovation within industries: the case of process and product R&D. Rev Econ Stat 78:232–243

Cohen WM, Levinthal DA, (2000). Absorptive capacity: a new perspective on learning and innovation. In: Strategic Learning in a Knowledge Economy. Elsevier, 39-67.

Cornell University, INSEAD, and WIPO (2020). The Global Innovation Index 2020: Who Will Finance Innovation? Ithaca, Fontainebleau, and Geneva.

Czernich, N. et al. (2011). "Broadband Infrastructure and Economic Growth," Economic Journal, 121, 505-32.

Databank.worldbank.org. (2019). [online] Available at: https://databank.worldbank.org/data/download/poverty/33EF03BB-9722-4AE2-ABC7-AA2972D68AFE/Archives-2019/Global_POVEQ_GHA.pdf.

Fu, X., (2020). Innovation under the radar : the nature and sources of innovation in Africa. 1st ed. New York: Cambridge University Press.

Fundingcircle.com. (2020). Funding Circle: Fast, Affordable Small Business Finance. [online] Available at: https://www.fundingcircle.com/us/resources/types-of-patents.

Gill, et al. (2007). An East Asian Renaissance: Ideas for Economic Growth, World Bank (Washington, DC).

Goedhuys M, (2007). Learning, product innovation, and firm heterogeneity in developing countries; Evidence from Tanzania. Ind Corp Chang 16:269-92.

Hadhri W, Arvanitis R, M'Henni H, (2016). Determinants of innovation activities in small and open economies: the Lebanese business sector. Journal of Innovation Economics & Management 21:77-107.

Lorenz E. (2014). Do credit constrained firms in Africa innovate less? A study based on nine African nations, GREDEG working papers no. 2014-29.

MDS Events. (2019). Timeline of Revolutions. [online] Available at: https://manufacturingdata.io/newsroom/timeline-of-revolutions/.

Morck R, Yeung B, (2001). The economic determinants of innovation. Industry Canada vol 25 Nelson RR, Phelps ES (1966) Investment in humans, technological diffusion, and economic growth. Am EconRev 56:69-75.

OECD. (2014). Perspectives on Global Development: Boosting Productivity to Meet the Middle-Income Challenge, OECD (Paris).

——. (2021). Gross domestic spending on R&D (indicator). doi: 10.1787/d8b068b4-en

OECD/Eurostat. (2005). Oslo Manual: Guidelines for collecting and interpreting innovation data. 3rd Edition, OECD, Paris

Protogerou A, Caloghirou Y, Vonortas NS (2017). Determinants of young firms' innovative performance: empirical evidence from Europe. Res Policy 46:1312-26.

Scene, U. and Scene, U., (n.d). The Second Industrial Revolution, 1870-1914. [online] US History Scene. Available at: https://ushistoryscene.com/article/second-industrial-revolution/.

Seenaiah K, Rath BN, (2018). Determinants of innovation in selected manufacturing firms in India: role of R&D and exports. Science, Technology and Society 23:65-84.

UNIDO. (2009). Breaking In and Moving Up: New Industrial Challenges for the Bottom Billion and the Middle-Income Countries, Industrial Development Report, United Nations (Vienna).

——. (2012). Networks for Prosperity: Connecting Development Knowledge Beyond 2015,
United Nations Wipo. [online] Available at: https://www.wipo.int/patents/en/topics/utility_models.html.

Wipo.int. (n.d). What is Intellectual Property (IP)?. [online] Available at: https://www.wipo.int/about-ip/en/.

Appendix

Group of 35 Countries:

Algeria
Angola
Botswana
Burkina Faso
Burundi
Cabo Verde
Congo
Cote d'Ivoire
Djibouti
Egypt
Eswatini
Ethiopia
Gambia
Ghana
Kenya
Lesotho
Libya
Madagascar
Malawi
Mali
Mauritius
Morocco
Mozambique
Namibia
Nigeria
Rwanda
Sao Tome and Principe
Seychelles
South Africa
Sudan
Tanzania
Tunisia
Uganda
Zambia
Zimbabwe

Group of 24 Countries:

Algeria
Botswana
Burkina Faso
Egypt
Ethiopia
Kenya
Madagascar
Malawi
Mali
Mauritius
Morocco
Mozambique
Namibia
Nigeria
Rwanda
Sao Tome and Principe
Seychelles
South Africa
Sudan
Tanzania
Tunisia
Uganda
Zambia
Zimbabwe

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Dr. Emmanuel Pinto Moreira is Senior Fellow at Policy Center for the New South and the Director of the Economic Department of the African Development Bank. He is in charge of establishing a strong department as well as genuinely conducting policy dialogue with policy makers of the region while heavily focusing on new growth strategies, challenges facing middle income countries, fiscal policies and debt reduction strategies. He served previously as regional lead economist for the MENA region at the World Bank. His mission was geared towards first conducting policy dialogue with Maghreb authorities' and helping them design their vision papers; second, he provided strategic advice on major economic challenges facing these countries, more precisely. Furthermore, Dr. Pinto Moreira was in charge of preparing country reports on the macroeconomic perspectives of 18 countries, and reviewing reports on Economics and Finance of the MENA region; he also managed the knowledge program for the MENA region. As a team leader of the Global Practice in charge of Macroeconomics, Trade and Investment (MTI), Dr. Pinto Moreira was in charge of conceiving the working agenda for economists and guaranteeing deliverables that are insightful and have sound impact on countries' development. He has published numerous research papers in the areas of growth policies, trade and competitiveness, public financial management, fiscal and exchange rate policies. Before joining the World Bank, Dr. Pinto Moreira worked at the International Monetary Fund as a senior economist within the Middle East and Central Asia with a focus on fiscal policies. He was also a senior advisor to the executive director of the 24 French-speaking African countries. Dr. Pinto Moreira holds a Master degree and received his PhD in Macroeconomics from University of Lorraine in France. As a professor, Dr. Pinto Moreira taught undergraduate students Macroeconomics, Statistics, Econometrics, and Microeconomics at both the University of Nancy and the University of Metz.

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