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CHANGE

Vaccine Manufacturing in Africa: What It Takes and Why It Matters

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Foreword by Tony Blair

The continent of Africa is home to more than 1 billion people. Health systems are often fragile and disease is prevalent. Its lack of manufacturing capacity means it can produce less than 1 per cent of its vaccine needs, with the situation set to become even more acute in the future as populations grow.

With Covid-19, lacking the capacity to manufacture its own vaccines has left the continent dependent on external suppliers and, as a result, disproportionately affected by vaccine nationalism, stockpiling and disturbances to international supply chains. In turn, these have affected African governments' abilities to implement their rollouts, protect their populations and ultimately rejoin the global economy.

This dependency is a serious challenge for Africa's health resilience. Given the certainty of future global pandemics, even in the midst of the current crisis, it must be addressed urgently.

In the current crisis, the focus of Africa's leaders and institutions is, understandably, on saving lives now. The efforts of the African Union, African Vaccine Acquisition Task Team and African Export-Import Bank show the potential impact of pooled funding and purchasing of Covid-19 vaccines. Governments need to improve logistics and optimise distribution of the vaccines they have access to. My Institute has made recommendations on these issues, including on the importance of data capture which, as Rwanda's experience shows, plays a critical role.

Beyond the immediate term, we must recognise that the imbalance between vaccine demand and supply can only be remedied by Africa transitioning from a position of dependency to one of homegrown capacity for manufacturing and distribution, with the aim of becoming vaccine self-sufficient.

This will not be an easy or swift process. The challenges around financing, technology transfer, market development and skills development, to name but a few, are numerous and substantial.

Sustained cooperation between African governments, the private sector and other stakeholders, acting on a regional and continental basis, will be necessary, supported by global bodies and partners.

As a first step, we suggest that, as a matter of urgency, Africa's policymakers should mandate an apex body to jointly determine focus areas for an Africa-wide vaccine-manufacturing industrial strategy. The continent's leading institutions such as the African Union Commission Department of Trade and Industry, African Development Bank, African Export-Import Bank and Africa Centres for Disease Control and Prevention should be empowered to pool their expertise and coordinate this effort. Finance will be key, and exploring investment consolidation, perhaps through a pooled manufacturing investment fund, should be a priority. Beyond finance, this body can look at other issues around the ecosystem that are needed to support vaccine manufacturing, such as assessing models for manufacturing, developing

plans to strengthen the value chain and working with biotech businesses to scope the technical expertise necessary.

With every day that passes, the end of the Covid-19 pandemic draws closer – but so does the next global pandemic. It's time then to start preparing for it.

Tony Blair

Executive Chairman

Executive Summary

Africa is home to 17 per cent of the world's population but, due to a lack of manufacturing capacity, can currently produce only 1 per cent of its vaccine needs. Only seven African countries have companies operating across the vaccine-manufacturing value chain, and of these, only one – Senegal – exports a WHO pre-qualified vaccine; most do not export at all. The uneven distribution of manufacturing and financing capabilities globally has led to an unequal distribution of global access to Covid-19 vaccines, with African countries largely reliant on external suppliers. This dependency is driving delays and uncertainty, which in turn affects governments' abilities to implement vaccine rollouts, protect their populations and ultimately rejoin the global economy.

In this paper, we argue that the goal should be transitioning the continent from dependency towards greater self-sufficiency and security of supply. We also make key recommendations for policymakers on how to grow vaccine-manufacturing capacity across Africa.

The health implications of vaccine shortages and setbacks in Africa are significant. Most countries follow a tiered prioritisation list whereby the highest risk and most vulnerable populations – especially frontline health-care workers – are vaccinated first. The longer those populations must wait for a vaccine, the more susceptible they are to contracting Covid-19. Delays in accessing vaccines mean the virus will continue to spread among the population at large, causing needless excess morbidity and mortality – not only from the virus, but also from the indirect effects of the pandemic on essential health services.

To nurture the industrial potential and develop vaccine-manufacturing capacity on the continent, there are a number of challenges that need to be overcome, including the substantial investment required, market dynamics and time.

But the potential benefits are profound – both for responding to Covid-19 and for preparing for inevitable future pandemics.

To achieve this goal, we recommend that policymakers should mandate an apex body with five key points of focus for developing an Africa-wide vaccine-manufacturing industrial strategy:

1. exploring financing options
2. assessing the viability of proposed manufacturing models
3. developing plans to strengthen the value chain
4. working with biotech businesses to assess the level of expertise required to drive local manufacture
5. working towards improving demand certainty.

Covid-19 and Africa's Vaccine Manufacturing Capacity

Africa is home to more than 17 per cent of the world's population, with sub-Saharan Africa alone projected to account for the majority of global population growth over the next few decades. This reality, coupled with weaker health systems and a disproportionate disease burden on the continent, means that, even beyond Covid-19, vaccines are likely to be a crucial element of disease security for its people going forward. However, the African Vaccine Manufacturing Initiative (AVMI) estimates that the continent can currently produce less than 1 per cent of its vaccine needs.¹ This demand/supply imbalance is likely to become even more acute in the future if it is not addressed now. The goal should be transitioning the continent from dependency to agency and security of supply.

Africa's existing vaccine market, estimated at \$1.3 billion, is expected to reach a value of up to \$2.35 billion by 2030, supported by population growth, expanded vaccination, new products being required and countries graduating from the Global Vaccine Alliance's (Gavi) low-cost scheme to buying directly. That said, most African countries' markets are too small to support manufacturing, meaning a continental or regional strategy is needed to support manufacturing.

The table below (Figure 1) shows existing sites for vaccine manufacture in Africa. However, it is important to highlight that capabilities across these sites vary. It can be seen from the table below that most manufacturing efforts are in fill and finish and pack and label while commitments for research and development are severely lacking.

Figure 1 – Companies in Africa operating across the vaccine-manufacturing value chain

Manufacturer	Products	R&D	Manufacturing of drug substance	Fill & finish	Pack & label	Import for sale
IP Dakar	 Yellow Fever		●	●	●	
Vacsera	 BCG, Tuberculin, Tetanus, DTP, Typhoid, Cholera			●	●	
IP Tunis	 BCG		●	●		
Biovac	 BCG ⁶ , Measles ⁶ , Pneumococcal conj.3, Hepatitis B3, Hexavalent Vaccine ⁷		●	●	●	●
Aspen	 Covid-19 candidate			●	●	
IP Maroc	 BCG, DT, Yellow Fever, Typhoid, Influenza, Rabies					●
EPH	 Plan to produce vaccines		●		●	●
Biovaccines	 Plan to produce Hepatitis-B Plan to produce Tetanus Plan to produce DTP+Hep-B Plan to produce Yellow Fever Plan to produce Measles		●			
Innovative Biotech	 HIV	●			●	
IP Algeria	 Rabies		●			●

Key: ● Work completed ● Work in progress or planning

Source: McKinsey, FCDO, Press, Manufacturers' websites.

Only seven African countries have companies operating across the vaccine-manufacturing value chain (ranging from manufacturing to fill and finish and onto distribution). Of these, only one exports a WHO pre-qualified vaccine, while most do not export at all. Vaccine manufacturers on the continent have struggled to survive for several reasons, with high production costs being a leading factor. Issues around quality assurance and poor regulation are also key challenges. Procurement is dominated by Gavi and UNICEF, which collectively supply 45 out of 54 African countries.

- **South Africa** has historically led much of Africa's vaccine production through its public-private partnership with Biovac, which currently manufactures several products. Currently, South Africa has two Covid-19 vaccine production agreements: one between Aspen Pharmacare and Johnson & Johnson, and another between Biovac and ImmunityBio (the former could start production in the second quarter of 2021² while the latter vaccine is still in trial stage). Sanofi and Pfizer have spent at least five years investing in the Biovac Institute of South Africa by modernising its production site, transferring technology and upskilling staff; only now is the plant capable of diversifying from packaging into fill and finish, and it is still some way off fully integrated manufacture. South Africa's partial ownership of Biovac as part of a public private partnership (PPP) has enabled the country to manufacture vaccines and shows the relevance of such strategic PPPs to ramp up vaccine manufacturing. Scaling up is a necessity in order to improve procurement of vaccines going forward. For example, Biovac is planning to fill 4 million doses of Hexaxim (a combination vaccine used for diphtheria, tetanus, pertussis, hepatitis B and other diseases) in 2021, compared to the Serum Institute of India, which produces more than 70 million doses a month and is the global leader in vaccine production by volume.
- **Senegal** has a single vaccine manufacturer, the Institut Pasteur de Dakar, which is the only WHO pre-qualified vaccine manufacturer in Africa. It currently produces small quantities of yellow fever vaccines with active plans to expand manufacturing capacity through a new facility called AfricAmaril and developing other products. Currently the Institut Pasteur de Dakar is one of the only facilities on the continent manufacturing diagnostics for Covid-19, including low-cost antigen rapid diagnostic tests through its partnership with British company Mologic and South Korea's Bionote. The existing relationships with the EU for talent-exchange programmes and experienced scientists being made available to the Institut are also promising for research and development aspects of the vaccine value chain.
- Some other countries, like **Nigeria**, are rapidly developing capacity and readiness to manufacture vaccines. Nigeria has historically manufactured a number of vaccine products and is looking to revive the industry by leveraging PPPs and private-sector investment. It has been investing heavily in R&D to advance its capacity in anticipation of the HIV vaccine value chain area. The federal government has announced a plan and committed 10 billion naira (\$26,315,789) to set up a vaccine production company in Nigeria to boost local Covid-19 vaccine production. While this is an important step in the right direction, the lack of any human vaccine production in recent years will make the set-up more challenging in terms of access to manufacturing expertise.
- Many other countries – including Morocco, Egypt, Tunisia and Ethiopia – are among those

positioned to fill and finish. **Egypt** has a long-established government-owned vaccine manufacturer and is reportedly close to finalising a deal with Sinovac to produce the latter's Covid-19 vaccine; it has also expressed interest in exporting to other African countries once it begins production.³ In addition, the Egypt Drug Authority (EDA) has given approval to start producing the first experimental doses of the Egyptian Covid-19 vaccine, Covi Vax. Meanwhile, the company Vacsera has largely focused on downstream production, such as the fill and finish and pack and label aspects of the five categories depicted in Figure 1.

- **Morocco** has a large local pharmaceutical-manufacturing industry. The government has recently signalled interest in expanded vaccine production. Moroccan pharmaceutical manufacturer Galenica has signed a deal with the Russian Direct Investment Fund (RDIF) to produce Russian Covid-19 vaccines. In addition, Morocco and China National Biotec Group Company Limited (CNBG) signed two cooperation agreements on Covid-19 vaccine trials to allow Morocco to produce a vaccine. Due to the presence of multinational corporations for general pharma manufacturing, there is availability of some pharmaceutical expertise.

The Impact on Africa

The uneven distribution of manufacturing and financing capabilities globally has led to an unequal distribution of global access to Covid-19 vaccines. While production components – such as glass vials, filters and tubing – and fill-and-finish steps are completed in different countries around the world, most vaccines will be manufactured in the United States and Europe.⁴ High- and upper-middle-income countries, which represent one-fifth of the world’s population, have a home advantage and have secured more than 6 billion of the total 8.6 billion Covid-19 doses purchased globally as of mid-March 2021. Lower-middle- and low-income countries, which represent four-fifths of the global population, have secured just 2.6 billion doses, 1.1 billion of which are part of the COVAX scheme.⁵

Evolving global supply constraints affect the world’s vaccine drive but have a disproportionate impact on African countries. Their dependency on external suppliers is driving delays and uncertainty, which in turn affect governments’ abilities to implement vaccine rollouts, protect their populations and ultimately rejoin the global economy. The gap between high- and low-income countries is widening. As the United States prepares to start returning to normal with widespread adult vaccination by July 2021, African countries are not projected to achieve broad access until 2024 or later. Constrained global production is having a disproportionate impact on Africa, as dependence on external suppliers subjects it to the consequences of vaccine nationalism and stockpiling as well as international supply-chain disturbances. Delays and uncertainty around vaccine arrivals will result in negative health and economic outcomes that are felt on the continent and beyond. Manufacturing and supply capacity in Africa must be addressed urgently to prevent this from happening again in a future pandemic – which is inevitable.

Most African countries are relying on multilateral financing and procurement mechanisms to access the Covid-19 vaccine market. The COVAX facility intends to provide 90 million doses to Africa by June, or enough supply to cover 3 per cent of the continent’s population. As of late March 2021, 17 per cent of those doses had been delivered. From June to December, COVAX aims to provide an additional 510 million doses to cover a total of 20 per cent of the population. Still, there is a billion-dose gap to achieve 60 per cent population immunity among the continent’s 1.3 billion people. To help fill that gap, the African Vaccine Acquisition Task Team (AVATT) financing and procurement mechanism, set up by the African Union (AU), has secured 970 million doses,⁶ though it has yet to deliver any. Some direct bilateral agreements are also expected; as of late March, bilateral donations or purchases accounted for 40 per cent of the approximately 25 million total vaccines received in Africa. On 28 March, AVATT announced a new deal with Johnson & Johnson (J&J) that will give AU countries access to 220 million doses of the single-shot J&J vaccines, with an option to secure 180 million more, thanks to a \$2 billion facility approved by the African Export-Import Bank (Afreximbank). These will be produced at South Africa’s Aspen Pharmacare production plant.

These secured targets and timelines are based on assumptions that manufacturers can increase the scale of production fast enough to meet demand, that there are no breakdowns in the supply chains, and that countries where vaccines are produced do not block exports. In the US, Washington's use of the Defense Production Act (DPA) has been cited as an issue that constrains the global supply chain for vaccine manufacturing and will therefore impact the ability of manufacturers outside the US to fulfil demand. But the European Union and India have also announced restrictions. Citing domestic needs and the fact they have already exported an estimated 44 per cent of all locally produced vaccines, the government of India is now more engaged in controlling the export of vaccines from the Serum Institute of India (SII), one of the world's largest manufacturers of the Oxford University/AstraZeneca vaccines. In November 2020 the Serum Institute announced it was scaling up production capacity from 1.6 to 2.5 billion doses per year.⁷ COVAX, which had secured agreements that 20 per cent of its global portfolio would come from the SII, has now informed its recipient countries to expect significant delays in AstraZeneca shipments.⁸ Of the doses secured by the African Union before this latest announcement by AVATT, 52 per cent were expected from SII.

Therefore even as we look to developing capacity for new vaccine production, one of the ways to increase current global health resilience is to allow Africa – even with the limited existing capacity it has – to participate in some aspects of Covid-19 vaccine formulation, such as filling and packaging.

The health implications of vaccine shortages and setbacks in Africa are significant. Most countries follow a tiered prioritisation list whereby the highest risk and most vulnerable populations – especially frontline health-care workers – are vaccinated first. The longer those populations must wait for a vaccine, the more susceptible they are to contracting Covid-19. Moreover, there is already a significant shortage of health-care workers in Africa, with just 1.3 workers per 1,000 people – well below the Sustainable Development Goals target of 4.5.⁹ If workers in hospitals and clinics become ill, there are even fewer resources to tend to sick patients. The continent cannot afford to lose health-care workers to Covid-19.

Delays in accessing vaccines mean the virus will continue to spread among the population at large, causing needless excess morbidity and mortality – not only from the virus, but also from the indirect effects of the pandemic on essential health services. Of 18 AU member states surveyed in November 2020, 22 per cent of respondents from these countries reported that they or a household member had skipped or delayed health services since the start of the pandemic and 38 per cent had experienced difficulty accessing medication.¹⁰ The 2020 World Malaria Report says gains made in eliminating malaria in the past 20 years have been hindered due to disruptions to routine programmes like net and medicine deliveries during the pandemic.¹¹

What Covid-19 has made clear is that no one is safe unless everyone is safe. Coupled with the moral arguments supporting universal vaccine access, there is also the self-interest imperative. If sections of

the world population are left unvaccinated, there is a risk that diseases will offer up new mutations that may exceed the defensive capabilities of vaccinated populations.

The economic consequences of delayed vaccine supply to Africa are also dire. The continent is familiar with the impact of disease burden on the economy. With more than 200 million cases of malaria in Africa in 2019, the disease is estimated to cost billions of dollars in lost productivity every year.¹² If Covid-19 becomes endemic, which it could the longer it takes to protect the population through vaccination, the associated losses in economic activity will too. The global drop in demand for goods and services together with border closures, lockdowns and other restrictions enacted to get the virus under control in 2020 resulted in a 3.7 per cent contraction of GDP in sub-Saharan Africa. Per capita income fell by 6.1 per cent, thrusting tens of millions of people into extreme poverty. Weak economic activity combined with pandemic-related spending led to government debt rising 8 points on average to 70 per cent of GDP.¹³ Should virus containment measures continuously need to be imposed, Africa will continue to experience significant economic blows. There is also a real possibility that countries that have not achieved population immunity will be dislocated from the global economic system as it reopens, and will find themselves subjected to restrictions on business travel, border closures and a slowdown in investments. A recent study commissioned by the International Chamber of Commerce¹⁴ highlights the impact on global trade, especially as globalised supply chains mean many producers in industries such as textiles, automobiles and retail rely on intermediate goods produced in countries that are yet to secure equitable vaccine access. Inaction around vaccine availability will have impacts not just on demand but also supply chains globally.

Africa's lack of its own vaccine production capacity represents a serious lack of resilience that has had a major impact on African countries. This must be addressed urgently, to prevent a repeat in future pandemics – which are inevitable.

The Path to Scaling Up Africa's Manufacturing Capacity

To nurture the potential above and develop manufacturing capacity on the continent, there are a number of challenges that need to be overcome:

- **Establishing vaccine manufacturing capacity is a substantial investment.** A 2015 study jointly supported by WHO and UNIDO¹⁵ estimated the cost of building a manufacturing facility at between \$60 million and \$130 million. More recently, Morena Makhoana, CEO of Biovac, has estimated that a facility capable of producing up to 1 billion doses would cost between \$200 million and \$336 million.¹⁶ Furthermore, as we have seen with large, state-backed investments and grants to manufacturers for production of Covid-19 vaccines in richer countries, African manufacturers are likely to face an uneven playing field and higher unit-production costs unless similar support is replicated.
- **The current market dynamics mean that even though Africa has the greatest demand, it largely does not pay for its vaccines itself.** Most African countries rely on support from international partners like Gavi, UN agencies and others. As countries' income levels rise and they lose access to the lower prices offered by Gavi, however, the prices that countries must pay for vaccines will rise. This begs the question of whether countries will be willing to make the large expenditures required to meet their needs. The fact that any African producers are most likely to have to negotiate the bulk of the demand for African markets with international donors is also a key factor to consider – these current buyers will need to commit to vaccines produced on the continent to make investments in African vaccine manufacturing viable. Governments and partners will need to consider regional instead of national markets and long-term contracts to generate confidence for investment in new capacity. Demand certainty also affects production: vaccine plants have high operating standards and complex processes that are likely to be badly affected if production is not continuous and predictable.
- **Time is also a factor.** UNIDO estimates that even modest vaccine-manufacturing facilities – with low volume capacities of less than 10 million doses a year using antigen (an essential component in vaccine manufacture) imported from abroad rather than fermented in the country – would take between two-and-a-half and five years to build. When domestic antigen fermentation is considered, which is essential for achieving fully integrated, self-sufficiency in production, construction time can extend beyond seven years.
- **Domestic public- and private-sector commitment is necessary.** The need for manufacturing capacity in Africa is a point that has been made repeatedly by political leaders, including in the 2011-2020 Global Vaccine Action Plan endorsed by all Member States of the World Health Assembly and the 2016 Addis Ababa Declaration endorsed by all African governments. In 2018 the

East African Community hosted the East African Vaccine Symposium under the banner of “Vaccine Production in Africa for Africa”, stressing the “strategic importance of local production”. UNIDO says that “demonstrable, long-term political support is vital”. Covid-19 has galvanised leaders around the manufacturing question but this momentum needs to be maintained. The AU has announced a vaccine summit in April 2021 to bring stakeholders together to consider a framework for pushing vaccine manufacture on the continent. These efforts need to be supported and sustained.

- **Technology transfer, skills development, regulation and quality control represent significant hurdles to be surmounted.** In November 2020 Aspen announced that its Johnson & Johnson vaccine will be produced in South Africa. While it is unlikely to significantly improve supply on the continent, it is a first important step in knowledge transfer. Leading global health voices, including the AU, Africa CDC, WHO, India and South Africa are now calling for transfer of intellectual property from the Global North to ensure equitable access to vaccines. Multinational corporations must safeguard their IP rights as per the World Trade Organisation’s Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement. Africa CDC Director, John Nkengasong has called for a short-term abolishment of the TRIPS Agreement but wider questions should be asked around long-term solutions for sustainable IP transfer. Moisi et al highlight a framework to aid these considerations. ¹⁷

Case Study: Serum Institute of India

India’s Serum Institute, which is currently one of the major global producers of the Covid-19 Vaccine, reached this level thanks in no small part to the Meningitis Vaccine Project (MVP), a collaboration in which it participated with African public-health officials, the WHO, PATH and investors to produce meningitis vaccines for Africa. The product was launched in a mass vaccination campaign in 2010 and significantly helped to reduce the incidence of meningitis A on the continent. It significantly boosted the Serum Institute’s technical capabilities and demonstrates the potential for successful collaboration between local manufacturers and international partners to develop vaccines.

Recommendations for Policymakers

Dealing With the Current Crisis

The efforts of the AU, AVATT and Afreximbank provide good reason to believe the continent can make further gains with more pooled funding and purchasing of Covid-19 vaccines. Governments have also got to work on improving logistics and optimising distribution of the vaccines they have access to. The Tony Blair Institute for Global Change (TBI) has provided recommendations on some of these vaccine logistics challenges in our work.

Policymakers need to further explore how to support the existing facilities in Africa to participate in the current production of Covid-19 vaccines by seeking to integrate, where possible, the capabilities of different countries into the global production chain. South Africa and Egypt have made some significant strides in this area, with deals signed for production of Covid-19 vaccines. Senegal's Institut Pasteur de Dakar, which is the only WHO-prequalified vaccine manufacturer in Africa, currently only produces small quantities of yellow fever vaccines and needs support to capitalise on its expertise to participate in current Covid-19 vaccine production.

Preparing for the Next Crisis

Vaccine manufacturing in Africa requires cooperation between governments, the private sector and other stakeholders on financing, regulation, licensing, infrastructure, technological adoption and communication.

Policymakers should mandate an apex body to ascertain and jointly determine focus areas for an Africa-wide vaccine manufacturing industrial strategy. The African Union has already taken the lead with its upcoming vaccine-manufacturing meeting to discuss the issues in April 2021. We recommend that instead of creating brand-new structures, policymakers on the continent should consider empowering existing structures (the African Union Commission Department of Trade and Industry, AfDB, Afreximbank and Africa CDC, for example) to pool together the necessary expertise and coordinate this effort. We recommend that various agencies are allowed to lead on a specific aspect of the plan based on their technical expertise. The agenda needs to be set as soon as possible with stakeholders mapped and allocated responsibilities for various aspects.

This apex body should look at key issues around the ecosystem that are needed to support vaccine manufacturing, including:

1. **Exploring financing options.** As has been the case with significant buyer consolidation through COVAX, the AU, Afreximbank and other African agencies throughout the Covid-19 pandemic, the continent should explore investment consolidation, perhaps through a pooled manufacturing investment fund. This will help ensure there is a coherent continent-wide industrial strategy that allows each country to focus on its relative advantages. Private-sector participation is likely to be essential, although some governmental and/or multilateral agency financing will very likely be required to de-risk the investments. Work needs to start now to map and engage these actors, along with any technical assistance required to put financing deals together.
2. **Assessing the viability of various models for manufacturing that have been proposed** – for example, manufacturing hubs, cross-country value chains with countries engaging in different aspects of the value chain according to their varying capabilities outlined above, and others. The UK Foreign, Commonwealth & Development Office’s Manufacturing Africa programme has recommended potential models to aid the realisation of Africa’s vaccine-manufacturing hubs. A UK government-funded study for the Developing Countries Vaccine Manufacturers Network, presented in March 2021, provides some detailed analysis on the markets, potential manufacturing models and investment opportunities on the continent. ¹⁸
3. **Developing plans to strengthen the value chain**, for instance, raw materials, production, storage and distribution. This should include supporting enablers like information and R&D transfer, harmonising regulations and so on.
4. **Working with biotech businesses to assess the level of technical expertise required** to drive local manufacture and establish a strategy with pathways for strengthening these capabilities on the continent.
5. **Working towards improving demand certainty** by engaging the current main buyers of vaccines for the continent and establishing protocols for longer supply offtake and distribution contracts between manufacturers and African governments. This will become even more important as more and more countries graduate from the Gavi scheme and start buying more vaccines directly themselves.

Footnotes

1. ^ https://dcmn.net/IMG/pdf/26th_wiliam.pdf
2. ^ <https://www.reuters.com/article/aspn-pharmacare-results-idUSL8N2L961U>
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7. ^ <https://www.businesstoday.in/current/corporate/serum-institute-to-double-covishield-vaccine-production-to-100-million-month/story/423301.html>
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