Innovation and Africa: Much to Gain, Nothing to Lose!

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Abstract This paper provides quantitative evidence suggesting the current wave of technological innovation provides major opportunities for transforming the continent economy. The absence of strong incumbents and an increasingly young and technology-prone population seem factors that can facilitate the diffusion of innovation, based on the experience of mobile telephony—one of the few innovations for which we have data that we can use to build a cross-country panel. We use the Howitt-Aghion's model of creative destruction as an analytical framework for our estimates. Based on our estimates we simulate innovation paths for Africa and OECD for the next 20 years. Finally, we use employment simulations to show that Africa's cannot deal with its huge demographic by relying on industry-led growth only. Innovation can generate the productivity improvements needed to generate jobs in agriculture, services, as well as industry.

1 Introduction

Africa faces a formidable unemployment challenge. Its demographic profile implies a major surge in the share of working-age population in the next two decades, while overall population will continue to grow rapidly. The issue on whether the continent's current economic growth trends will be sufficient to absorb at least a significant portion of the projected labor supply increase has been amply discussed, with an overwhelming negative answer.[1] This paper claims that innovation could

[1]See for instance Louise Fox, Alun Thomas, and Clairy Haines, "Structural Transformation in Employment and Productivity: What Can Africa Hope For?" (2017).

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constitute the key to exploiting the continent's demographic profile as an opportunity for economic transformation. In particular, we aim at conveying three messages:

- The new wave of technological innovation, the so-called Fourth Industrial Revolution (FIR), provides a major opportunity for transforming the continent and generating the needed jobs, without necessarily following the structural change pattern experienced in South East Asia and Europe.
- We provide quantitative evidence to support the idea that the continent may be in a good position to exploit innovation-related opportunities thanks to: (a) relatively small and weak "incumbent" sectors; and (b) its young and therefore technological-prone population. However, in order to exploit these relative advantages, the continent needs to make important efforts to develop its human capital and the skills that can favor the adoption of new technologies. Moreover, policies should resist the temptation to protect sectors that could come under threat by the diffusion of innovation.
- Show that Africa would not succeed to absorb a significant portion of the projected increase in its labor supply, even if the employment in industry were to grow at an average rate twice as high as that experienced by the Asian Tigers during the last 25 years. Thus, Africa cannot afford missing the opportunities offered by the FIR, and should embrace, not resist, the ongoing wave of technological innovation. Relying on old-fashioned industrialization will nor deliver the needed jobs, even under most optimistic assumptions on industrial growth.

  In the remaining of the paper, we will first discuss the main features of the innovations that constitute the FIR and how it has affected Africa so far. Second, we briefly illustrate the analytical model that we use to provide quantitative evidence on the prospects for innovation diffusion in Africa. Third, we discuss the evidence from a cross-country panel data set and we use the estimates parameters of the model to simulate the diffusion path of new technologies in Africa and in the OECD countries. Fourth, we show the results from an employment simulation that suggests industrial development cannot be the main driver of the large employment growth needed to match the projected increases in labor supply. Finally, we try to draw a few policy implications from the analysis and quantitative evidence we present.

2 Innovation and the New Global Economy

There has been much talk about the Fourth Industrial Revolution (FIR) and its impact on the global economy. The basic idea is that the new wave of technological innovation would not only shift the production-possibility frontier through substantial gains in total factor productivity, but would also radically alter consumption, communication, and social organization patterns.[2]

It is clear that the new wave of innovation has a huge potential for improving productivity and living conditions. However, these benefits are unlikely to materialize without causing major disruptions. Vast portions of the existing productive capacity will become obsolete and many assets will become stranded. For instance, driverless cars and their sharing are likely to make individual car ownership obsolete, the way in which typewriters disappeared quickly in the early 1980s, or the production of cameras and fax machines did in the last decade. Similar changes are likely to take place in other key sectors, such as energy with the demise of traditional grids in favor of mini generation-consumption grids, and the financial sector with the demise of traditional banking as the result of the adoption of block-chain technology that can eliminate information asymmetries.

The process is unlikely to be smooth because of its very nature and dimensions. It is difficult to imagine that the automotive industry will reconvert to the new consumption and production models in its totality. There will be winners and losers. There will be a major impact on employment levels and on the skills that will be required. Many workers will not be able to re-tool themselves toward the skills required by the new production model.

Clearly, the adoption of new technologies will face opposition. In fact, this has already been the case for driverless cars on security grounds, which is difficult to make sense of, if one thinks of how unsecure traditional cars are. The diffusion of Uber or Uber-like services has encountered major hurdles in France, Italy, and most recently, Egypt, because of pressures from taxi drivers, who have managed to influence regulations in their favor.

These oppositions have the potential to slow down the pace of innovation. Their strength and their likelihood to be effective in slowing down the innovation will crucially depend on:

- How large the sector that comes under threat is relative to a country's economy.
- How young is a country's workforce. The younger the easier to adapt to the new skill requirements. Old dogs do not learn new tricks!

3 Innovation and Africa

The notion that Africa is technological prone has been already discussed in the literature, but always with anecdotic evidence.[3]

The mobile-banking revolution, in particular the fact that Africa appears the most mobile-banked continent in the world, seems to be behind this idea. There are no

[2]See "The Fourth Industrial Revolution," by Klaus Schwab (2016).

[3]See for instance the WEF report, "The Future of Jobs and Skills in Africa: Preparing the Region for the Fourth Industrial Revolution" (2017).

doubts mobile banking is transforming the continent, by connecting previously excluded Africans to the formal financial sector and making a difference in providing opportunities for market participation even to people in most remote areas of the continent.

The continent is also seeing the onset and rapid expansion of, eHealth, edTech, agriTech, three solutions specifically adapted to the local needs related to some of the greatest challenges Africa faces: health, education and food security.

Drone technology already helps to deliver medical goods and constitute a possible solution to the medical infrastructure deficiency, for instance, in Rwanda. This technology already helps to maintain portions of the electric-power grid that come under threat from the tropical vegetation in Cote d'Ivoire.

Well-structured web-based classes make basic education now affordable not only in the urban slums but also in the remote areas of Kenya.

On-line platforms provide now customized advice on planting patterns and timing to many farmers in Nigeria. The map below provides a sense of the extent to which innovation has spread around the continent. New technologies, such as block chain, in addition to limit information asymmetries in financial markets, can have a favorable impact on governance and corruption. Their use in managing public resources would greatly increase accountability by virtually making transparent and openly accessible all government transactions.

Even plain-vanilla digitalization of payments businesses and people make to government has proved to have a favorable impact on reducing the scope for corruption. For instance in Tanzania it has already:

- Empowered its tourism sector by **reducing economic leakage from cash payments, such as conservation-park entry fees, by over 40 percent,** supporting investment and employment.
- Cut bureaucratic inefficiencies, including **reducing import customs clearance times from nine days to less than one day.**
- Increased transparency between citizens and governments in **tax payments, by providing electronic proof of payments and protecting people against fraud.**

The literature appears to explain the somewhat unexpected "blossoming" of creative applications of new-technologies in part of the continent with a more flexible regulatory environment than in industrial countries, where for instance the use of drones for delivering goods or gathering economic-relevant data is hampered by strict security requirements.

However, to our knowledge, the literature does not provide quantitative evidence in support of this hypothesis. This paper makes a step in this direction by providing both an analytical framework and empirical evidence on the issue. However, we need a caveat. By no means, we want to suggest the picture for the continent is uniform and that innovation has blossomed and spread evenly everywhere. As the map shows,[4] there are encouraging signs in a few countries, but there are many

[4]Desjardins J (2017).

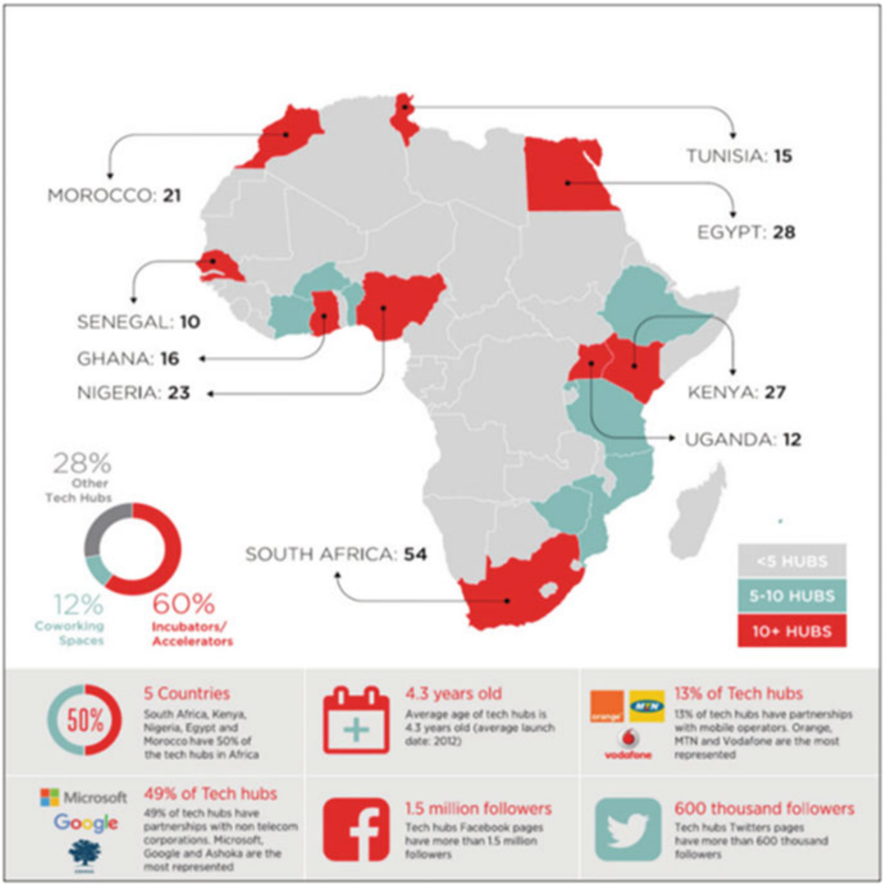

Fig. 1 Africa: 314 Active∗ Tech Hubs in 93 Cities in 42 Countries. Source: https://www.visualcapitalist.com/africa-exploding-tech-startup-ecosystem/

countries that lag behind and do not appear quite technology prone (Fig. 1). In what follows, we will try to provide quantitative evidence to assess the opportunities that innovation offers to Africa and the challenges it faces in order to seize them.

4 The Modeling Strategy

We can think of the FIR as propelled by Information and Communication Technology (ICT)—the archetypal General Purpose Technology (GPT)—that applies to a broad range of productive processes. In particular, ICT has proved: (a) to be pervasive with the potential to change all the sectors of the economy; (b) to take time to exploit its potential; and (c) to span new products and processes, i.e. it generates a broad range of new productive innovations.

Following the Aghion-Howitt model,[5] we can think of a two-stage process. In the first stage (Phase I), the new GPT, here the ICT, becomes exogenously available, but enterprises need to find ways to exploit it by diverting resources to research. The second phase (Phase II) is when the new product-specific innovation becomes available because of the research effort that took place in "Phase I". The literature characterizes the "Phase I" as "*creative destruction*" because it results in an aggregate output contraction. Phase II, instead, is a boom-driven period that lasts until a new superior GPT arrives, and a slump occurs again.

To understand both the opportunities and the challenges the FIR presents to Africa we introduce in the model institutional factors that can affect the research effort in the first Phase and therefore the rate at which the GPT is applied to production. In particular, we assume the rate of diffusion/application of the GPT is μz where μ is a constant and z the "research effort" is:

$$z = \alpha + \beta \text{ Man} + \gamma \text{ Dem} + \delta \text{ Edu} + \varepsilon,$$

Where Man, is a proxy of the size of incumbents (e.g. the share of traditional manufacturing in GDP); Dem is the share of young population over the total; Edu is a proxy of how skilled the work force is. The assumption here is that the larger the incumbent sector, the stronger the opposition toward "destructive innovations" will be, through for instance heavy handed regulations and red tape. The paper provides evidence on this relation and discusses Africa's innovation prospects in its light.

5 Empirical Evidence

To provide evidence we rely on a cross-country panel-data set that includes both industrial, emerging, and developing countries. We use the rate of diffusion of mobile-telephone connections as an example of innovation and therefore as our dependent variable. On the RHS we use: (a) the market share of existing telephone land lines, as a measure of the incumbent production; (b) the percentage of population between 25 and 35 over the total as a measure of youth population; (c) and the portion of the work force with a secondary-level school degree as a proxy of human capital. The table in Appendix II summarizes our preliminary results. There are a number of issues with the proposed approach:

First, our three proposed variable can help explains the diffusion of mobile technology only after we control for the impact of per-capita GDP that of course

[5]See Philippe Aghion, Ufuk Akcigit and Peter Howitt, "What do we Learn From Schumpeterian Growth Theory?" (2013), and Aghion and Howitt, "The Economics of Growth," Chapter 9 (2008). See Annex A for a summary description of the model.

plays a major role to explain changes in mobile telephony diffusion both over time and across countries. Therefore, we need to control for this income effect.

Second, we should adjust the impact of the age profile of the population to the income effect. In fact, the young tend to be poorer than the old are, particularly in developing and emerging countries. For this reason, we introduce an interaction effect between age structure and per-capita GDP that allows for non-linearity in the relation.

Third, we need to introduce an appropriate measure of the incumbent sector. We use the market share of land-lines, which corrects for different sizes of countries and markets. Moreover, we cannot assume a contemporary relation between incumbent size and innovation, as diffusion takes time. We use therefore a 5-year moving average of market shares.

The table below provides our econometric results, which, largely, confirm our hypotheses. In particular, **the parameter estimates for Africa are significant and all with signs consistent with our expectations,** with the population's age structure positive when interacted with that per-capita income. The parameter estimates for the whole cross-country panel are significant but go in the expected direction only for the land-line market share and per-capita GDP. Instead, they go contrary to our expectations for: (a) our measure of human capital (secondary education); and (b) population's age structure.

However, if one looks at the results for the sub-sets of the panel it becomes clear that the estimates for OECD countries drive the whole panel results for these two variables:

- As regards human capital, OECD countries have all high levels of secondary education that vary little both across countries and over time. Thus, no surprise, that secondary education has no impact on mobile phone diffusion.
- As regards the population's age structure, OECD countries have generally experienced a decline in the portion of young people over total population. Whereas, mobile-telephone subscription have continued to increase, which is what the negative parameter estimate picks up (Table 1).

6 A Look at the Future

Based on our econometric evidence, we have argued that Africa is in good position to take advantage of the new wave of technological innovation and the FIR. Opposition to the diffusion of innovation is likely to be weaker than elsewhere in the global economy, because: (a) the threatened sectors, such as traditional

Table 1 Coefficient estimates and t. statistics

Mobile penetration	Africa	East_Asia	Latin America	South Asia	OECD	All
Secondary education	0.924***	−0.268	0.0722	1.087***	−0.244***	−0.0539
	(0.118)	(0.179)	(0.210)	(0.275)	(0.0548)	(0.0615)
Fixed phone weight 5 yrs avg	−0.198***	−0.912***	−0.786***	−0.172**	−1.167***	−0.847***
	(0.0371)	(0.0724)	(0.0933)	(0.0698)	(0.0419)	(0.0266)
log pc gdp	1.902	59.08***	145.2***	−56.11	107.7***	59.69***
	(11.15)	(17.47)	(39.88)	(37.48)	(14.29)	(5.844)
young2035	−17.65***	6.703	30.97**	−27.09**	24.97***	2.112
	(3.016)	(5.656)	(13.01)	(11.52)	(5.749)	(1.710)
log pc gdp ## young2035	2.459***	−1.234**	−3.678**	4.079**	−2.803***	−0.508***
	(0.405)	(0.608)	(1.549)	(1.626)	(0.555)	(0.181)
Const	−30.31	−308.6*	−1155.6***	336.4	−877.2***	−378.8***
	(81.16)	(160.8)	(343.0)	(267.4)	(149.4)	(54.58)
R-sq	0.679	0.678	0.656	0.804	0.929	0.712
N	549	346	353	80	704	2382

manufacturing, are substantially smaller than, for instance, in Europe[6]; and (b) the demographic profile of the continent is such that its work force, already the youngest in the world, is going to grow even younger.

We illustrate the implications of these results for the future of innovation in Africa vis-à-vis the OECD countries, through a simple simulation. Based on our full-sample parameter estimates and assumptions on the future path of our independent variables, we build a path for the diffusion rate of innovation during the next (20) years.[7] The simulation reflects a strong assumption. We assume that we can use the inference we have drawn from the diffusion of mobile technology to predict the future path of other innovations. The results are striking. We acknowledge they need to be taken with extreme caution. However, if the experience for diffusion of mobile technology can tell us something on the pace of diffusion of innovation over the next 20 years, our simulations suggest that Africa is better placed than the OECD countries! (Figs. 2 and 3)

[6]Fox and Thomas estimate that formal employment constitutes on average in SSA only 15% of total employment. Employment in manufacturing is likely to be even smaller because their figure includes also government employment.

[7]We call the dependent variable the rate of diffusion of a generic innovation and we compute it for the next 25 years as a function of our variables and estimated parameters.

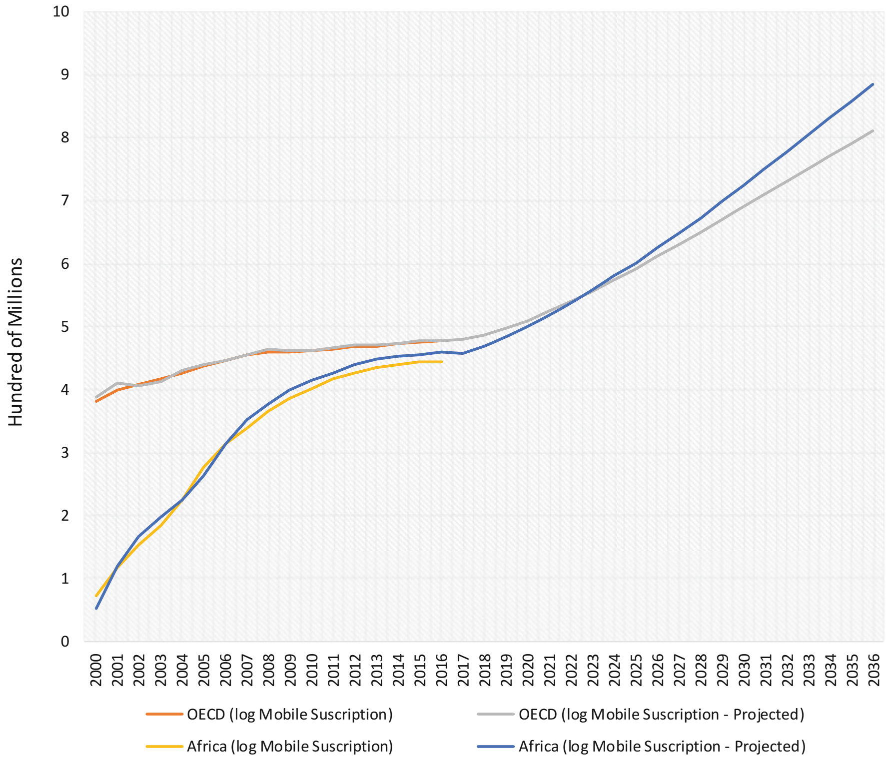

Fig. 2 Projection of mobile suscription (from 2017 onward)

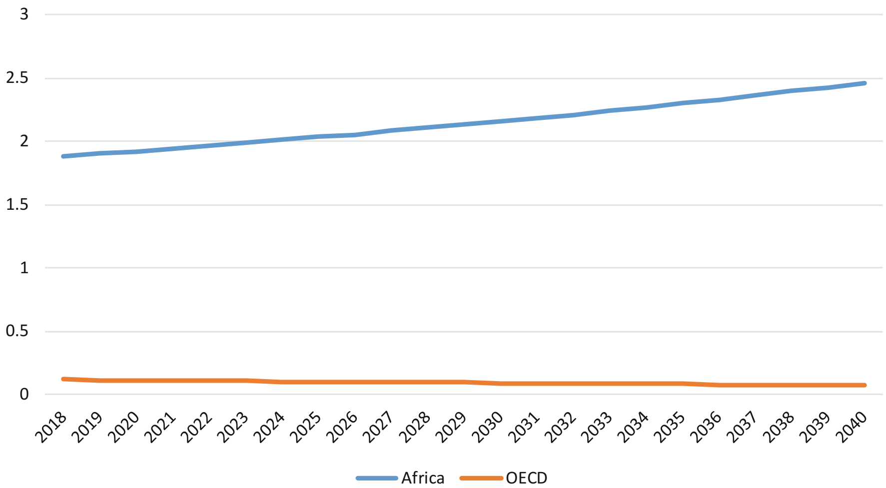

Fig. 3 Change in penetration rate

7 Can Africa Rely on Traditional Industry?

To illustrate how the "traditional" pattern of structural change would not succeed to address Africa's employment demand we use a simple simulation. We call "traditional" the pattern that sees economic development driven by productivity gains in industry. These gains attract labor supply from agriculture boosting industry employment, which in turn generates productivity improvements in agriculture, which then allow further shifts in the work force from agriculture to industry. The presence of, however, a productivity gap in favor of industry vis-a-vis agriculture (or services, for that matter) would allow sustaining a virtuous circle that provides labor supply to industry as needed, forcing productivity improvements in agriculture as a by-product. This mechanism would allow transforming developing economies along the lines experienced by Europe and South East Asia. This is the old basic Lewis model,[8] which has been proposed as a viable path for Africa by both J. Lin and D. Rodrick.[9]

We have built two scenarios based on the China's experience. The first assumes a 6% annual growth in industrial employment, which is what China experienced during the last 15 years. The second assumes twice as much, 12% per year.

Under the first scenario, it is clear the gap between overall labor supply would actually broaden over time. However, even under the quite optimistic second scenario, growth in industrial employment would not keep the pace of labor supply, still raising the gap between 2040 and 2016. These dynamics would reflect the base effect, because industrial employment levels in Africa are in fact quite low, whereas working-age population grows not only quickly, but also from a high initial level.

The message from this simulation is that the continent cannot make it if it follows the Lewis-type bluebook for industry-led development. Of course, productivity improvements in industry are to be more than welcome, but the point is that the continent cannot deal with its employment challenge without expanding employment in services and agriculture. Economy-wide productivity improvements are key! These need to happen in services, agriculture, and industry as well. Innovation provides an opportunity to achieve the needed economy-wide productivity improvements (Fig. 4).

8 Conclusions

This paper has provided evidence that make us believe that the current wave of technological innovation provides major opportunities for transforming the continent's economy. The absence of strong incumbents and an increasingly young and

[8]Lewis, W. A. (1954).

[9]See for instance J. Lin and A. Goldstein, "Achieving an African Industrial Revolution" (2017); and D. Rodrick, "Growth without Industrialization?" (2017).

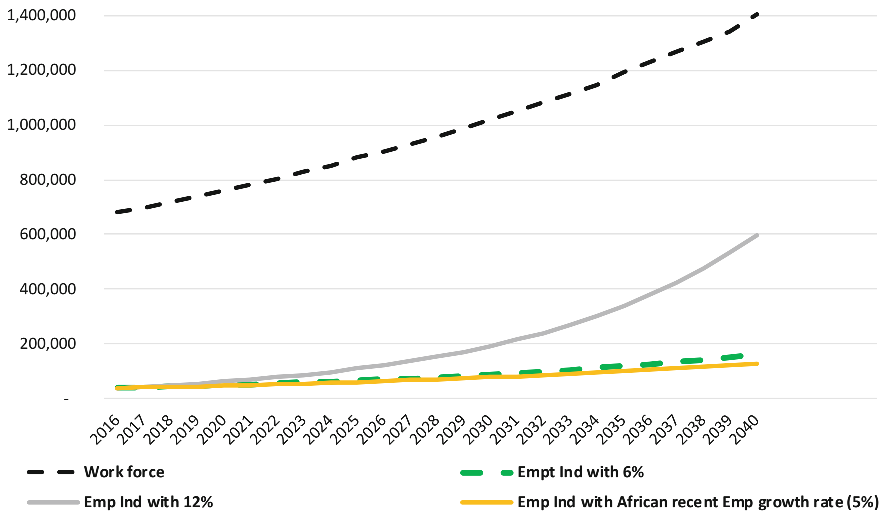

Fig. 4 Work force and employment

technology-prone population seem factors that can facilitate the diffusion of innovation, based on the experience of mobile telephony, one of the few innovations for which we dispose data that can used for building a cross-country panel. Of course, we need to provide caveats. The ongoing wave of innovation may differ from mobile telephony, but unfortunately, by definition data on new technologies are not readily available. Perhaps, microeconomic studies could provide additional insights.

We have also argued that Africa has virtually no alternative to embrace the new wave of technological innovations enthusiastically. Business as usual, even under the most optimistic assumptions would not help to reduce the expected yawning gap between labor supply and demand in the continent. Our simulations suggest industry cannot create the necessary jobs by itself, agriculture and services need to play both major roles. This conclusion has implications for policy. First, governments should refrain from protecting economic activities that come under threat from innovation. Second, policies should aim at creating an enabling environment for technological innovation, and avoiding channeling resources toward the pursuit of industrial dreams. The fact that advanced countries have gone through years of heavy industrialization does not imply Africa should go through the same experience. There is no bluebook for economic development! In fact, the continent could use new technologies to avoid both the social and environmental costs industrial based growth.

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Annex 1

The Basic Model

Aghion and Howitt assume that the economy is populated by a continuous mass, L, of infinitely lived individuals with linear preferences, who discount the future at rate ρ. Each individual is endowed with one unit of labor per unit of time, which she can allocate between production and research: in equilibrium, individuals are indifferent between these two activities.

There is a final good, which is also the numeraire. The final good at time t is produced competitively using an intermediate input, namely:

$$Y_t = A_t {y_t}^{\alpha}$$

where α is between zero and one, y_t is the amount of intermediate good currently used in the production of the final good, and A_t is the productivity (or quality) of the currently used intermediate input. The intermediate good y_t is in turn produced one for one with labor: that is, one unit flow of labor currently used in manufacturing the intermediate input, produces one unit of intermediate input of frontier quality. Thus, y_t denotes both, the current production of intermediate input and the flow amount of labor currently employed in producing the intermediate good. Growth in this model results from innovations that improve the quality of the intermediate input used in the production of the final good. More formally, if the previous state-of-the-arte intermediate good was of quality A_t; then a new innovation will introduce a new intermediate input of quality γA_t; where $\gamma > 1$. This immediately implies that growth will involve creative disruption, in the sense that Bertrand competition will allow the new innovator to drive the firm producing intermediate good of quality A out of the market, since at the same labor cost the innovator produces a better good than that of incumbent firm.

If z_t units of labor are currently used in R&D, then a new innovation arrives during the current unit of time at the Poisson rate λz_t. Henceforth we will drop the time index t, when it causes no confusion.

Two basic equations describe the growth process. The first is the labor market clearing equation:

$$L = y + z$$

reflecting the fact that the total of labor supply during any unit of time is fully absorbed between production and R&D activities (i.e. by the demands for manufacturing and R&D labor).

The second equation reflects individuals' indifference in equilibrium between engaging in R&D or working in the intermediate good sector. We call it the research arbitrage equation:

$$w_k = \lambda V_{k+1}$$

Where w_k denotes the current wage rate conditional on their having already been k innovations from time 0 until current time t. And V_{k+1} denotes the net present value of innovating the next period (k+1) innovator, in other words the value function:

$$\rho V_{k+1} = \lambda \pi_{k+1} - \lambda\, z V_{k+1}$$

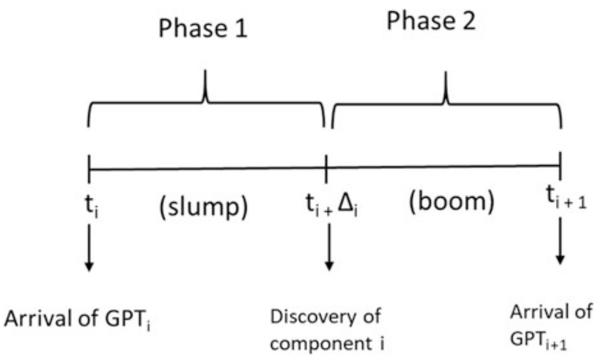
This equation states the annuity value of a new innovation (i.e. its flow value during a unit of time) is equal to the current profit flow k+1 minus the expected capital loss $\lambda z V_{k+1}$ due to creative destruction, i.e. to the possible replacement by a subsequent innovator.

General Purpose Technology (GPT)

We assume now that the discovery of a new generation of intermediate goods comes in two stages. Firs, at time t a new GPT must come, and then an intermediate good must be invented that uses that GPT. Neither can come before the other. One needs to see the GPT before knowing what sort of good will use it, and people need to see the previous GPT in action before anyone can think of a new one. For simplicity, we assume that no one directs R&D toward the discovery of a new GPT. Instead, the discovery arrives as a serendipitous by-product of learning by doing with the previous one (Fig. 5).

The economy will pass through a sequence of cycles, each having two phases, as indicated in Fig. 5. GPT_i arrives at time Ti. At that time, the economy enters phase 1 of the ith cycle. During phase 1, the amount z of labor is devoted to research. Phase 2 begins at time $T_{i+\Delta i}$ when this research discovers an intermediate good to implement GPT_i. During phase 2 all labor goes to direct production until GPT_{i+1} arrives, at which time the next cycle begins. Over the cycle, output is equal to A_{i-1} F(L − z)

Fig. 5 Phases of GPT cycles



during phase 1 and to A_i F(L) during phase 2. Thus, the drawing of labor out of manufacturing and into research causes output to fall each time a GPT is discovered, by an amount equal to A_{i-1}[F (L) − F (L z)]. A steady-state equilibrium is one in which people choose to do the same amount of research each time the economy is in phase 1; that is, z is constant from one GPT to the next.

We can solve for the equilibrium value of z using a research-arbitrage equation and a labor-market-equilibrium condition. Let ωj be the (productivity-adjusted) wage, and vj the expected (productivity-adjusted) present value of the incumbent (intermediate good) producer when the economy is in phase j ϵ {1; 2}. In a steady state these productivity-adjusted variables will all be independent of which GPT is currently in use.

Because research is conducted in phase 1, but pays off when the economy enters into phase 2, with a productivity parameter raised by the factor, γ, the following research-arbitrage condition must hold in order for there to be a positive level of research in the economy:

$$\omega_1 = \lambda\, \gamma\, v_2$$

Suppose that once we are in phase 2, the new GPT is delivered by a Poisson process with constant arrival rate μ. Then the value v_2 is determined by the Bellman equation:

$$\rho v_2 = \pi(\omega_2) + \mu\, z\, [v_1 - v_2]:$$

By analogous reasoning, we have:

$$\rho v_1 = \pi(\omega_1) - \lambda\, z\, v_1:$$

Combining the above three equations, yields the research arbitrage equation:

$$\omega 1 = \frac{\lambda\gamma}{\rho + \mu} \left\{ \pi(\omega 2) + \frac{\mu\, \pi(\omega 1)}{\rho + \lambda Z} \right\}$$

Because no one does research in phase 2, we know that the value of ω2 is determined independently of research, by the market-clearing condition:

$$L = y(\omega_2):$$

Thus we can take this value as given and regard the preceding research-arbitrage condition as determining ω1 as a function of z. The value of z is then determined by the labor-market equation:

$$L - z = y(\omega_1)$$

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