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Closing Technological Gaps to Alleviate Poverty: Evidence from 17 Sub-Saharan African Countries

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Abstract

This paper examines the dynamics of 'technological catch-up' and its effects in contributing to poverty alleviation, a crucial pillar of the United Nations' Sustainable Development Goals (SDGs). Using data of 17 sub-Sahara African (SSA) countries and employing the superlative-index number methodology, we first estimate the Total Factor Productivity (TFP) gap between these African nations and both the USA (leader of advanced countries) and China (leader of developing countries) to provide a measure for technological catch-up that is comparable across African countries. We then investigate the contribution of technological dynamics in SSA to poverty alleviation using the System Generalised Method of Moments (GMM) method. Our results show that during 1987-2014, many African nations have to some degree reduced technological gap to the USA, whilst only a few of them managed to briefly catch-up with China until the early 2000s and no such catching-up is observed thereafter, due to the exceptional technological advance achieved by China in the past fifteen years. We find that closing technological gap has had significant poverty alleviation effect for African nations, although such effect is weaker vis-à-vis China. Our paper therefore highlights the important role played by technological progress in alleviating poverty.

Keywords: technological progress; technological gap; poverty; Africa; Sustainable Development Goals.

1 Introduction

Superseding the 2000-2015 Millennium Development Goals (MDGs), the United Nations' Sustainable Development Goals (SDGs) for 2016-2030 have ushered in a new era, with greater precision and focus on harnessing and mobilising human resources and technology for economic development and for the eradication of global poverty (Griggs et al., 2013; United Nations, 2015). The pivotal features of the United Nations' 2030 Agenda for Sustainable Development within the SDGs include reducing inequality within and between nations, halting poverty and improving well-being through access to technology, education and jobs (Economist Intelligence Unit, 2016; Griggs et al., 2013; Sachs, 2012; United Nations, 2018). As Jeffrey Sachs (2012) observed, almost all the world's civilisations have recognised the need to combine environmental sustainability, economic development and social inclusion. Coupled with this growing recognition of the importance of inclusive growth and development, the launch of the 2030 Agenda for Sustainable Development has prompted many nations to devote policy attention, resources and manpower to improving living standards and fostering sustainable development (United Nations, 2018). Although adopting new technology is one of the most effective mechanisms for achieving these goals, technological gaps persist between advanced and developing economies. Accordingly, it has become a matter of urgency for policymakers to seek a better understanding of the core issues.

Although these developments have culminated in renewed scholarly attention to technological gaps and technology 'catch-up' (see Amankwah-Amoah, 2015, 2019; Lee and Lim, 2001; You et al., 2019), some key areas remain unexplored in the current literature. First, despite the importance of technology usage in this new century, limited research attention has been devoted to exploring technological gaps between leading and lagging nations, or to how bridging these gaps could help achieve SDGs. The third-generation mobile broadband network is a good case in point: by 2016, only 61% of people in the least developed countries were covered, compared with 84% worldwide (United Nations, 2018). In addition, despite progress in terms of technology adoption to improve access to internet and power, around 41% of the world's population in 2016 were still cooking with polluting fuel and stoves due to limited or no access to energy-efficient and environmentally friendly sources of power (United Nations, 2018; see also Schwerhoff and Sy, 2017). At present, we lack a deeper level of analysis and understanding of the economic effects of such technology gaps, yet such an understanding is needed to inform national and regional policies on how best to bridge the gaps.

Against this backdrop, the main purpose of this study is to examine technological gap reduction, or 'catch-up', between leading and lagging nations as a pathway to poverty alleviation. To accomplish this objective, we utilize data on 17 sub-Saharan African countries and examine this pivotal issue, this cornerstone for attaining the UN's SDGs.

Following from the literature on technological diffusion (Amankwah-Amoah & Sarpong, 2016; Nelson and Phelps, 1966; Bernard and Jones, 1996a, 1996b; Dal Bianco, 2010; Dowrick and Nguyen; 1989; Verspagen, 1991; Griffith et al., 2004; Hansson and Herkson; 1994; Harrigan, 1999; Dowrick and Rogers, 2002; Scarpetta and Tressel, 2004), we model technological change in SSA countries as a positive function of the so-called technological gap. The technological gap represents the distance of each follower (each SSA country in this study) from the technological leader. Thus, it proxies follower economies' potential for catching up with the leader.

In particular, we identified the USA and China as the relevant technological leaders among, respectively, developed and developing economies. Our choice in terms of technological leaders is justified by the following observations. The US is widely recognised as the "world's technological frontier" (Feenstra et al., 2015). Moreover, previous studies have compared African countries' TFPs with the USA's (e.g. Van Dijk, 2003; Edwards and Golub, 2003). By doing the same, our results will then be comparable with those of the (scant) established literature. Finally, and most importantly, recent evidence shows that technology spillovers from the USA have a stronger impact on labour productivity in African countries than in any other developed countries (Tiruneh et al., 2017). Hence, the USA is to be considered the developed technological leader of reference for sub-Saharan Africa.

As for China, it is the fourth largest foreign investor in Africa and the largest among developing nations (UNCTAD, 2018). China has also been Africa's largest trading partner since 2009 when it surpassed the United States (Comtrade, 2018). Moreover, the Chinese government recently announced that it wants to train Africa's next generation of scientists, devolving conspicuous amount of money in this endeavour (Cyranowski, 2018). These three features are key in the present context because foreign direct investment, trade and human capital have all been identified as fundamental determinants of technological transfer by the established literature (see, for example, Borensztein et al., 1998; Caselli and Wilson, 2004; and Benhabib and Spiegel, 2005). In addition, in the recent Sustainable Development Goals Report (2018), it was observed that the proportion of the world's workers living on less than $1.90 per person per day shrank from 26.9% in 2000 to 9.2% in 2017, much of it attributed to a sharp increase in economic development in China and other emerging economies (United Nations, 2018). Taken together, it is clear that developing African nations are in a position to acquire technological knowledge from China, the technological leader among developing countries.

Operatively, we employ an innovative two-stage analysis. Adopting the superlative-index number methodology, we first estimate the total factor productivity (TFP) of both the USA and China to provide a measure of technological progress to which each African country can be compared. We then calculate the technological gap of each country with respect to both the USA and China. In the second stage, we employ the System GMM estimator to assess the contribution of technological catch-up (along with a number of other influential factors) to poverty alleviation in each SSA country. We furthermore examine whether structural change is an important engine of productivity growth and explore the contribution of each sector to poverty reduction in Africa.

Despite the noble objectives of the SDGs, limited research attention has been devoted to how the SDGs can be effectively operationalized to deliver meaningful outcomes for wider society. Our study constitutes an extension from prior research on SDGs (Fullman et al., 2017; Sachs, 2012; United Nations, 2018) and technology catch-up (Landini and Malerba, 2017; Lee, 2013; You et al., 2019). Adopting an innovative two-stage analysis as described above for our empirical investigation, we contend that closing technological gaps can be an effective mechanism for achieving one of the SDGs' core objectives: zero poverty.

The rest of this article is structured as follows. We begin by presenting a brief review of the literature on sustainable development, technology catch-up and poverty alleviation, followed by an examination of relevant methods and data sources. We then present the findings of the study. The last section concludes the study by outlining some implications and opportunities for further research.

2 Sustainable Development, Technology Catch-Up and Poverty Alleviation

2.1. A brief review

Recent years have witnessed increased efforts by governments, non-governmental organisations and policymakers to address first the MDGs (from 2000 to 2015) and now the SDGs. The ultimate aim of the transition from MDGs to SDGs is to deliver sustainable economic development and to eradicate poverty whilst concurrently protecting the environment and achieving gender equality and sustainable consumption. The first SDG is to achieve zero poverty: this is a complex issue and many recent studies have analysed the influence of a number of factors on poverty reduction. These factors include government expenditure (Anderson et al., 2018; Kazungu and Cheyo, 2014), financial development (e.g.

Rewilak, 2017; Donou-Adonsoua and Sylwester, 2016), trade openness and liberalisation (e.g. Goff and Singh, 2014; Liyanaarachchi et al., 2016), inflows of foreign direction investment (e.g. Magombeyi and Odhiambo, 2018; Soumaré, 2015; Fowowe and Shuaibu, 2014), infrastructure investment (e.g. Marinho et al., 2017; Parikh et al., 2015), economic growth (e.g. Chen et al., 2016; Moore and Donaldson, 2016; Amini and Dal Bianco, 2016) and the inflation rate (e.g. Inoue, 2018; Rewilak, 2017). The UN itself recognises the connection between economic development and eliminating poverty, as its SDG number 8 is to "promote sustained, inclusive and sustainable economic growth" and Goal 7 is to "ensure access to affordable, reliable, sustainable and modern energy for all" (United Nations, 2018, p. 3-8).

Now, it has been shown that achieving such inclusive development, which is synonymous with poverty-reducing economic growth (sometimes dubbed 'pro-poor growth'), depends in part on technological choices and technological development trajectories (Mackintosh et al., 2007). This implies that Goals 7 and 8 are predicated in part on countries' ability to bridge the technological gap between themselves and other nations. The technological gap is a metric that broadly captures the difference in overall technological capabilities between two countries, i.e., in the stages of adopting various technologies (see Geronikolaou and Mourmouris, 2015; Jayaraman et al., 1997). In many instances, it may reflect the use of the recommended and the latest technologies in a particular sector. Recent lines of research suggest that in order for lagging nations to narrow this technological gap to advanced nations, capability building in tandem with organisational learning play a key role (Amankwah-Amoah, 2019; Landini and Malerba, 2017; Lee and Ki, 2017). A number of studies have demonstrated that in order for lagging nations to catch up with the leading nations, learning advances must take place at both organisational and national levels to create new paths or follow existing ones (Lee and Lim, 2001; You et al., 2019). In addition, specialising in short-cycle technology sectors has proven successful for several countries such as China in upgrading technology and in fuelling this catch-up process (Lee, 2013).

As urged by UNCTAD (2007), reducing poverty by narrowing technological gap represents an important development strategy for the least developed nations. The World Bank (2018) argues that new technologies provide pathways to poverty reduction and can bring prosperity into poor regions such as Latin America and the Caribbean. While a number of researchers have suggested that economic growth (measured through GDP) can benefit the poor through the trickle-down mechanism where wealth radiates out from the rich to the poor (e.g. Bhagwati, 1985; Dollar and Kraay, 2002; Lal and Myint, 1996; Spence, 2008), poverty reduction through technology adaptation works along numerous different pathways. One powerful pathway is described as the *price effects* of technology gains in Irz et al. (2001) and Schneider and Gugerty (2011), who argue that increased agricultural production reduces food prices and hence raises the real wages of the poor. Such technology-driven price effects can occur in an array of activities in which technological advances can benefit the poor above all – for instance, in energy generation, fighting diseases and providing clean drinking water more cheaply and effectively (POST, IOP and EPSRC 2010). Technology also constitutes promising solutions for providing better education in poor, rural and isolated communities around the world (Aftab and Ismail, 2015; *The Economist*, 2018). Technology has weakened market entry barriers for small businesses as it has led to an exponential decline in the cost of capturing, analysing and sharing information, while also facilitating fundraising (Moules, 2014): both of these factors have dramatically lowered the cost of starting a business, which in turn has helped alleviate extreme poverty (Agupusi, 2007; Ali et al., 2014).

2.2. The theoretical link between technology catch-up and poverty alleviation

As noted earlier in our objectives, our testable hypothesis explicitly links poverty reduction with technological catch-up. This hypothesis hinges upon two premises: first, in keeping with the findings of Dollar and Kraay (2002), that economic growth is good for the poor. Second, in line with Pack and Westphal (1986), that the process of assimilating existing technologies in less developed countries is not unlike that of creating entirely new technologies in more developed ones and, consequently, that technological diffusion is an ultimate driver of economic growth in underdeveloped economies.

Both exogenous and endogenous growth models can encompass our testable hypothesis in which the faster the technological change, the higher the economic growth rate and thus the progressively lower poverty numbers over time. The empirical strategy adopted here is also compatible with the "big push" theoretical framework that inspired the MDGs (see Easterly and Easterly, 2006). Hence, it is particularly well-suited to analyse sub-Saharan African countries that have experienced negligible real growth in per-capita income over the past half-century. Taking for example Burundi, one of the countries in our sample, in 1960 its GDP per capita was $347 (in 2005 purchasing power parity, or PPP adjusted US dollars as reported in the Penn World Tables). In 2010, that figure had only risen to $396.

The presence of persistently poor countries could be explained by the theory of poverty traps, which refers to a situation where poor countries are locked in a protracted poverty cycle, unable to push themselves above a certain per-capita income threshold (see Azariadis and Stachurski 2005). Of the many explanations for how such poverty traps take hold (for more detailed analysis and an exhaustive review, see Kraay and McKenzie (2014)), in the present work we explicitly refer to two that are particularly relevant for SSA countries. The first one is the so-called 'savings trap': this is a situation where the savings rate is close to zero in a poor country for subsistence reasons, which stifles investment and this in turn limits increases in income. However, if a country manages to accumulate capital above a certain threshold, it can move to a high saving rate and, thus, the country will enjoy a higher long-run income per capita. The case of Burundi exemplifies such a situation. The second one is related to non-convex production technology. In this situation, there is a range where investing a little has low returns and investing substantially more has a much higher returns. With regard to SSA, ‘aggregate’ non-convexities can contain variations in returns on activities in different economic sectors. Typically, the traditional agriculture sector is characterised by constant returns and the ‘modern’ sectors by increasing returns.

More formally, consider the fundamental equation of the Solow-Swan growth model:

$$\Delta k/k = sf(k)/k \; - \; (\delta + n),$$

where k indicates the capital stock (physical, or human or both) per capita; $f(k)$ is the production function in per capita terms that is generally specified as Ak^{α} where A represents the TFP and α the capital share; s, δ and n are savings, depreciation and population growth rates, respectively. Thus, the left side of the equation represents capital accumulation per capita; the first and second terms on the right side identify the savings function and the depreciation line, respectively. We refer to Barro and Sala-i-Martin (1995) for full derivation of the above equation.

If s and n are constant, and $f(.)$ is neoclassical (concave with Inada conditions), then there is a unique and stable steady state. If instead s is non-constant, as encompassed by the ‘savings trap’, or the production function is not neoclassical, as per the non-convexities trap, there will be three steady states, where the lower and upper steady states are stable, while the middle one is unstable. See Figure 1 for a graphical illustration of this equation.

It is apparent that the poverty trap will disappear if there is “enough” technological change or, in the terms of the present work, enough technological diffusion. In graphical terms, technological diffusion from leaders to followers (to the SSA countries in our case) implies that the SSA production function will move upwards. Subsequently, the savings function will no longer cross the depreciation line in correspondence with the lower equilibrium (which will in turn disappear). The final result will be massive poverty reduction in the long run.

The theory of poverty traps has received mixed support from empirical studies. Jalan and Ravallion (2004) and Naschold (2013) find no evidence of savings or convexity traps in China (the former study) and Pakistan and Ethiopia (the latter). By contrast, Kraay and Raddatz (2007) found that when countries are very close to subsistence levels, savings and investment would be so low that growth would stagnate for long periods of time. Their findings help explain Burundi's situation. Furthermore, Barrett et al. (2006) find supportive evidence for the existence of multiple equilibria in Kenya and Madagascar, as do Adato et al. (2006) in the case of South Africa. On a more general note, Barrett and Carter (2013) underline that direct testing of income or asset dynamics may struggle to find poverty traps even if they exist. Proving the existence or non-existence of poverty traps goes beyond the scope of the present work. In this review, we simply wish to highlight that our empirical strategy is consistent with a large spectrum of theoretical frameworks (including poverty traps) that some scholars have argued are extremely well-suited for analysing the situation of SSA countries.

A number of studies have examined the impact of technology investment and adaptation on the important issue of poverty reduction (e.g. Mendola, 2007; Minten and Barrett 2008; Burney and Naylor, 2012; Ainembabazi et al., 2018). However, these studies focus mainly on the agricultural sector; our searches indicate that country-level studies investigating the impact of technology on poverty alleviation for less developed countries are very rare. Therefore, our paper intends to add to the literature by examining the impact of technological catch-up on poverty alleviation for a group of 17 African countries. We conduct an innovative two-stage analysis. First, to provide a measure of technological catch-up progress that is comparable across countries, we apply a superlative-index number methodology to estimate the total factor productivity (TFP) of these African nations relative to both the USA and China, the respective leaders among advanced and developing economies. We then employ the System Generalised Method of Moments (GMM) to investigate whether the narrowing of the technology gap between Africa and the two leaders has contributed to reducing poverty in these African nations.

3 The Model

3.1. TFP estimation and TFP gap calculation

Following the seminal contributions of Diewert (1976) and Caves et al. (1982), we obtain our TFP estimates employing the superlative index number methodology. This methodology allows one to accurately isolate the productivity differences between two (or more) countries that cannot be explained by differences in productive inputs, thus providing a measure for technological progress that is comparable across countries. This is because such a TFP index is superlative and transitive. The former property implies that it provides a TFP measure that is as precise as possible (i.e. not an approximation), and the latter ensures that the choice of the term of reference, whether a country or a year, is inconsequential. The transitivity property can be proved for the multilateral version of the index (see for details Mas and Stehrer, 2012) as well as for the generic base country *b*, as done by Feenstra et al. (2015).

It is important to stress that, by construction, the Törnqvist index, which is employed here, measures the distance between observed and efficient output. Hence, it enables researchers to obtain information on differences in TFP levels, rather than on growth rates. This is extremely relevant because, as originally noted by Hall and Jones (1999), cross-country differences in TFP growth rates have been shown to be mostly transitory.

As for the formal derivation of TFP estimates using the superlative index number methodology, this has already been widely presented in the literature (see, for example, Feenstra et al., 2015; Dal Bianco, 2016; You et al., 2019); the interested reader may refer to Appendix A for details.

It should be noted here that, as explained in the introduction, we consider two production possibility frontiers deemed most relevant for African nations: the USA, leader of advanced economies, and China, leader of developing ones. Applying the superlative index methodology, we obtain two TFP series that represent the productive efficiency of each sub-Saharan African country relative to the USA and to China (TFP_USA and TFP_CHINA, respectively). As by its very construction the corresponding TFP index for both technological leaders is equal to 1, we calculate the technological gap by subtracting each SSA TFP indexes from 1, obtaining TFPgap_USA and TFPgap_CHINA, which signify the technological distance between any SSA country and, respectively, the USA and China. Intuitively, the closer the TFP gap is to zero (one), the closer (further) the follower country is to (from) the leader and hence the more (less) prominent the process of technological catch-up.

3.2.Technological gap and poverty alleviation

Having explained how we obtain the technological gaps to the USA and China (*TFPgap_USA* and *TFPgap_CHINA*), we next specify in detail the empirical model employed in our second stage of estimation (in Section 4.3). Specifically, we assume that the level of poverty (*POV*) depends on the technological gap (*TFPgap*), poverty in the previous period, and a list of control variables that capture the economic conditions in SSA (Equation (1)):

$$POV_{i,t} = POV_{i,t-1} + \alpha TFPgap_{i,t} + x'_{i,t}\beta + \varepsilon_{i,t} \tag{1}$$

$$\varepsilon_{i,t} = \eta_i + v_{i,t} \tag{2}$$

In Equation (1), the SSA countries and time are denoted by $i = 1,2, \dots N$ and $t = 1,2, \dots T$, respectively, α is the coefficient of the technological gap, x is a column vector of control variables, and β is a row vector of corresponding parameters. Furthermore, $\varepsilon_{i,t}$ is the disturbance term which consists of the unobserved individual specific effects (η_i) and the remainder of the disturbances $v_{i,t}$ as shown in (2).

We expect a closing of the technological gap between SSA and the USA and China (that is, movement towards zero or below in *TFPgap_USA* and *TFPgap_CHINA*), which would result in a reduction in the level of poverty (POV). The control variables are GDP growth per capita ($GDPG$), trade openness ($OPEN$), inflation rate ($INFL$), inward FDI ($IFDI$), financial development ($FDEV$), government spending ($GSPEN$) and infrastructure ($INFR$). The seminal study by Bane and Ellwood (1986) demonstrates that poverty is persistent, and hence past levels of poverty can explain current and future poverty levels. A number of recent studies have confirmed such persistence in their analysis (e.g., Alem, 2014; Thelle at al., 2015; Marinho et al., 2017; Inoue, 2018), and thus we also introduce the lagged value of poverty in our model. The expected signs of the control variables are discussed in Section 4.1 and further summarised in Appendix B.

Since Equation (1) includes as one of its regressors the lagged dependent variable, as demonstrated by Caselli et al. (1996), using a conventional ordinary least squares (OLS) would yield biased and inconsistent estimates due to the correlation between individual specific effects (η_i) and the right-side variables. Furthermore, inclusion of the technological gap would also raise endogeneity issues due to potential bidirectional causality between the TFP gap and poverty. Such endogeneity may also exist between poverty and a number of the other control variables. To overcome this, we employ the system Generalised Method of Moments (GMM) (two-step) estimator developed by Arellano and Bover (1995) and by Blundell and Bond (1988) for our estimations. The Arellano-Bover/Blundell-Bond estimator is also referred to as the A-B-B estimator. GMM is generally used to study the dynamics of adjustment using samples with a short time period and a relatively large cross-section. In addition, system GMM also increases the efficiency of the estimation as it takes into account country-specific effects and possible issues of endogeneity, measurement errors, and omitted variables. By using the A-B-B estimator, the endogenous regressors can be instrumented using its lagged levels. Additionally, by taking the first differences of Equation (1) it eliminates the individual specific effects. In the framework of the two-step system GMM, the Sargan-Hansen test for over-identifying restrictions is used to assess the validity of the instruments. The null hypothesis is that the instruments as a group are exogenous. The second order serial correlation in the difference error term is also tested where the null hypothesis is that there is no serial correlation.

Despite its advantages, the system GMM is not free from some caveats. In system GMM, the number of instruments tends to increase rapidly with the endogenous variables, leading to a weakened Hansen test for over-identification restrictions and increased finite-sample bias. To tackle this issue, we adopt the recommendation by Roodman (2006), limiting the number of lags employed and collapsing the instrument matrix. Specifically, the 'collapse' option (available in Stata) was employed so that one instrument is created for each variable and lag distance, instead of for each time period.

4 Empirical Results

4.1 Variable measurement and data source

Our study covers 17 sub-Saharan African countries: Benin, Botswana, Burkina Faso, Burundi, Cameroon, Côte d'Ivoire, Kenya, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania and Togo. Although it would be ideal to include all SSA nations, our sample choice is restricted by the overall data availability, so we have settled for the 17 countries above in our analysis.

The dataset employed here for estimating our TFP indexes is the Penn World Table (PWT). For the last forty years, the PWT has been a canonical source for comparable real GDP data across countries. Unfortunately, we could not use the long-awaited PWT 9.1, as its release, due in Summer 2018, was postponed to Spring 2019 (GGDC, 2019). Hence, we relied on the

PWT 9.0, which as explained by Feenstra et al. (2015) still possesses three main advantages over its predecessors.

First, it provides measures of real GDP from both the expenditure and the production sides. Therefore, by taking the latter indicator it is possible to evaluate and compare countries' productive capacities. Second, PWT 9.0 encompasses capital stock series. This information, combined with new data on real inputs (i.e. labour income in real terms), enables researchers to construct and compare TFP across countries. The third advantage of PWT 9.0 is that it employs interpolated price indexes. Hence, PWT 9.0 provides measures of real GDP that correct for changing prices over time; it also employs International Comparison Programme benchmarks from multiple years. In this way, all series calculated in "real terms" become less sensitive to the choice of the base year, which minimises the problem of using real GDP estimates in non-benchmark years noted by Johnson et al. (2013). All of the above features make such a dataset an extremely appealing choice for the calculation of technological efficiency in production as well as for evaluating its dynamics across countries and over time.

At this point, it must be noted that in order to make TFP estimates comparable across countries and over time, we need to work with series where figures are expressed at chained PPP rates. This is problematic when the capital stock series is considered, as PWT 9.0 reports it at current and not chained PPPs. To overcome this difficulty, we combined the information on capital stock and GDP at current PPPs with the GDP figures at chained PPPs. In particular, we calculated the capital share, or the ratio of capital stock to output-side real GDP, both expressed at current PPPs ($K\_share= CK/ CGDP^{O}$, see Appendix B for a description of the variables). We then multiplied this ratio by output-side real GDP at chained PPPs ($RK=K\_share* RGDP^{O}$). Having thus obtained capital stock data expressed at chained PPPs, we were able to calculate TFP series that are comparable across countries and over time. Details on TFP calculations are reported in Appendix A.

Let us now turn to the data used in the second stage, the System GMM analysis. Our dependant variable, poverty, is measured using the widely employed headcount ratio of the World Bank (e.g. Ainembabazi et al., 2018; Inoue, 2018; Donou-Adonsoua and Sylwester, 2016). Specifically, the percentage of individuals living below the poverty line of $1.90 a day (in 2011 PPP-adjusted dollars) is employed as the indicator of poverty. This data is available at three-year time intervals. Our key variable of interest, technological gap, is estimated as outlined in Section 3.1 and the estimates are further discussed in Section 4.2. We expect that technological catch-up (i.e. a reduction in the technology gap between African nations and the USA and China) will reduce the poverty headcount ratio.

Based on relevant studies reviewed in Section 2, we introduce a number of control variables in our analysis in Section 4.3. These variables include government expenditure, trade openness, inward FDI, financial development, inflation, real per-capita GDP growth and infrastructure. Government spending on transfers and subsidies can reduce poverty directly by raising the real disposable income of poor households. Because it tends to lead to better nutrition, improved health and better education for the poor, government spending can also bring about higher market income for the poor (Anderson et al., 2018). There can be welfare gains from trade openness at the country level through specialisation, investment in innovation, productivity improvements and better resource allocation, all of which may have a downward impact on poverty levels (Goff and Singh, 2014). Increased FDI has been touted as an important stimulant for improving economic conditions and reducing high poverty rates (Fowowe and Shuaibu, 2014). Rewilak (2017) finds that fragile financial sectors may impair financial actors' ability to extend credit to individuals or to innovative small enterprises, which may block a poverty-reducing pathway. The poor population are likely to have a greater share of cash in small portfolios and relatively limited scope for hedging against inflation: therefore, high and unpredictable price volatility is considered to have a strong negative impact on the poor

(Easterly and Fischer, 2001; Holden and Prokopenko, 2001). Infrastructure improves the poor's access to local markets, other regions, information and health services, and thus increases the productivity and wellbeing among poor people (Marinho et al., 2017). Economic growth can generally be presumed to improve the living conditions of the poor through the trickle-down mechanism (Spence, 2008), whereby when economic output expands, members in all income bands will generally benefit. As such, we expect that higher levels in government spending, trade openness, inward FDI, financial development, economic growth and infrastructure would reduce poverty, while the opposite is true for inflation.

Taking into account the overall availability of data, our sample period runs from 1987 to 2014. To be consistent with the poverty measurements provided by the World Bank, which are available every three years (i.e., for 1987, 1990, 1993, etc.)[1], we apply the same three-year time intervals to our data used in Section 4.3 (i.e., we also use data for the years 1987, 1990, 1993, …, 2014). Details of variable measurements and data sources are illustrated in Appendix B.

4.2. TFP

Figures 2 to 4 report our *TFPgap* estimates for each SSA country. In particular, Figure 2 shows the *TFPgap* relative to the USA (*TFPgap_USA*), Figure 3 the *TFPgap* to China (*TFPgap_CHINA*), and Figure 4 compares these two series. The corresponding descriptive statistics are reported in Table 1. Figure 5 reports the technological gap between China and the USA.

A number of facts emerge from our observation of these estimates. To begin with, looking at the descriptive statistics in Table 1, the technological dynamics of the majority of

[1] For 2014, the World Bank provides headcount ratios for 2013 and 2015 instead of 2014, so we take the average of the values for 2013 and 2015 as the ratio for 2014.

the countries with respect to the USA have been quite stagnant over most of the period considered. From Figure 2, it can be seen that only Nigeria exhibits clear signs of catching up. In addition, towards the end of sample period there are some signs of catching up for Burkina Faso, Côte d'Ivoire, Kenya, Mozambique, Niger, Rwanda and Tanzania. Meanwhile, Botswana, Mauritius and South Africa are interesting exceptions: these countries seem to have lost ground to the USA; a process of technological divergence seems to be at work. A widening technological gap is even more apparent between African countries and China. Table 1 shows huge differences between minimum and maximum *TFPgap_CHINA* levels as well as a symmetrical distribution of this variable: the mean value is very similar to the median. This observation applies to all countries but Sierra Leone, an exception probably due to the country's civil war that lasted from 1991 to 2002. Figure 3 also shows that, at the beginning of the period of observation, the vast majority of SSA economies were technologically ahead of China (14 countries had a *TFPgap_CHINA* around zero or below). Since the early 1990s, SSA countries have started lagging behind China, although a short burst of catching up is observed from the mid-1990s till the early 2000s. After 2000, an upward *TFPgap_CHINA* trend became a common feature across all of the SSA countries sampled. This means that even the historically most dynamic economies of Nigeria, Botswana, Mauritius and South Africa are close to becoming technological laggards compared to China.

Figure 4 compares SSA technological catch-up to both the advanced leader (the USA) and the developing leader (China). Not surprisingly, most African countries are further behind the USA than China, although the remarkable fact is that their technological gap to China has grown bigger.

Figure 5 shows that the process of technological divergence relative to China has been driven mainly by China's exceptional performance. Since the 2000s, China has been closing its own technological gap to the USA at an astonishing pace, despite a very short-lived slowdown in 2009, when the great financial crisis hit emerging economies hardest (Didier et al., 2011).

In conclusion, the descriptive evidence shows that African countries are lagging behind both the advanced and developing countries' leaders. Moreover, a process of divergence seems to be in place for many African nations, especially with respect to China. Correspondingly, based on the figures presented here, we expect that the effect of technological catch-up on poverty reduction might be milder when compared with China than with the USA. This is not only because there is more room to catch up with the USA (which is still technologically ahead of China), but also because the technological gap between SSA economies and China is in fact increasing rather than decreasing.

Structural change is one of the earliest and most central insights of the literature on economic development (see Lewis (1954) for seminal contribution). It describes the rise of overall productivity and incomes generated by labour and other resources as a consequence of a shift from less efficient productive activities, such as traditional agriculture, to more productive modern economic activities (McMillan and Rodrik, 2011). In the following section, we examine whether structural change is an important engine of productivity growth in Africa. Following McMillan et al. (2014) and Diao et al. (2019), we break down productivity growth into two components: 1) productivity growth originating from pure technological progress within sectors; 2) productivity growth resulting from the reallocation of labour between economic sectors – the structural change component. More details on this method can be found in Appendix C.

Given that PWT 9.0 contains limited sector-level data, in this part of the analysis we employ annual value added and employment data (for 1990-2014, in 2011 PPP-adjusted dollars) from the World Bank for the following macro-sectors: 1) agriculture, forestry, and fishing (hereafter shortened to 'agriculture'), 2) industry, and 3) services (as in Sampath

(2014)). We compute sector-specific productivity by dividing each sector's value added by its corresponding employment figure, in accordance with the method proposed by McMillan et al. (2014). To be consistent, we construct economy-wide productivity in the same way[2]. In line with Diao et al. (2019), we then calculate average annual growth rates for the within-sector and structural change components for the 1990-2014 time series. The results are presented in Table 3, where the contribution of within-sector productivity growth and structural change to total productivity growth are illustrated in the second and third columns, respectively.

Data in Table 3 shows that structural change has boosted productivity in a handful of African countries, namely Burkina Faso, Cameroon, Rwanda and Tanzania. However, for the majority of the countries, the prime contributor to economy-wide productivity growth has been the within-sector component: this is true for Benin, Botswana, Cote d'Ivoire, Kenya, Mauritius, Mozambique, Nigeria, Senegal, Sierra Leone, South Africa, Togo. Of these countries, Botswana, Cote d'Ivoire, Kenya and Sierra Leone experienced structural change that was actually growth-reducing instead of growth-inducing. Productivity levels are much higher in industry and services than in agriculture in these four countries, yet the labour share in the industrial sector has been shrinking, by 1.6%, 1.1%, 2.4% and 0.9% per year, respectively, while the labour share in the agricultural sector has either been growing (by 1.7% per year in Botswana and by 1.0% in Kenya) or remained largely unchanged (in Cote d'Ivoire and Sierra Leone).

Our finding indicates that not enough labour has been moving to sectors with relatively high productivity in Africa. Though discouraging, it is consistent with McMillan et al. (2014) and Diao et al. (2019)[3]. McCullough (2017) points out that despite cross-sector productivity

[2] We have also used PWT 9.0 data to calculate economy-wide productivity using McMillan's method. The results are very similar to those obtained using the World Bank data. For consistency with the sectoral level results, we adopt the World Bank data in this part of analysis.

[3] Note that our sample includes a much larger number of African nations and a longer data time series than in Mamillan et al. (2014) and Diao et al. (2019).

gaps, households in Africa are not able to move across sectors because of limited human capital, experience, or financial capital. Africa is also influenced by globalisation in a way that does not promote cross-sector labour movement. There is a dearth of technological capabilities to start with, and trade opportunities for many nations are dictated by export opportunities (which are currently present only in some sectors, particularly natural resource-based industries and agriculture) (Sampath, 2014). This situation may lead to some primary sectors (e.g. minerals) operating at high productivity levels, but with very limited capacity to generate substantial employment and hence an inability to bring about strong structural change (McMillan et al., 2014).

4.3. Technology gap and poverty alleviation

In this section we examine the direction and magnitude of influence that technological catch-up has on poverty alleviation. We estimate Equation (1) using the system GMM method; the results are shown in Table 2. Models (1) and (3) are for the case of Africa's technological catch-up with the US and Models (2) and (4) are in comparison with China. Models (5) to (8) correspond to Models (1) to (4), but where we exclude South Africa from the sample. Sargen-Hansen tests and serial correlation tests are reported at the bottom of the table. In all cases, both Sargan and Hansen tests indicate rejecting the overidentifying of restrictions, thus supporting the validity of the chosen instruments. The serial correlation tests show there are first order serial correlations, which is often expected, but no evidence of second-order serial correlation in the differenced error terms, implying that the GMM estimators are consistent in all models.

In Model (1) of Table 2, African nations' TFP relative to the leading developed country, the USA (*TFPgap_US*), has a positive sign and is statistically significant, implying that a narrowing technological gap has a strong poverty-reducing effect for SSA. The size of the coefficient is 0.2176, suggesting that a one percentage decrease (or increase) in the TFP gap would reduce (or raise) the poverty headcount by 0.22%. It supports the view noted by Fofack (2008) that the widening income and welfare gap between SSA and the rest of world is largely accounted for by a technology trap, which is in turn responsible for the poverty trap. It also echoes evidence found by Dutz et al. (2018) that adopting new technology has a positive impact on inclusive growth – growth that improves the job prospects of less-skilled workers in the context of Latin America and the Caribbean.

The lag of poverty is positive and highly significant. It confirms previous studies that at least in the short term, poverty rates are highly persistent (e.g. Alem, 2014; Thelle et al., 2015; Marinho et al., 2017; Inoue, 2018). Other variables that are significant include GDP growth (*GDPG*), inflation (*INFL*), inward FDI (*IFDI*) and infrastructure (*INFR*). The negative signs of *GDPG*, *IFDI* and *INFR* suggest that these factors contribute to poverty alleviation in SSA, while the positive *INFL* coefficient reflects the adverse impact of inflation on poverty.

On the other hand, openness (*OPEN*), government spending (*GSPEN*) and financial development (*FDEV*) turn out to be insignificant. While engagement in international trade may raise the real wages of labour and thus help alleviate poverty, competition in export markets may drive production away from labour-intensive sectors toward capital-intensive sectors, lowering demand for unskilled labour. Consequently, the real wages of unskilled labour would drop (Davis and Prachi, 2007; Kelbore, 2015), meaning that the poverty reduction effect of trade openness is limited. In terms of *GSPEN*, Anderson et al. (2018) find no evidence that higher government spending has played a significant role in reducing income poverty in low- and middle-income countries, and they attribute this finding to the theory that fiscal policy plays a much more limited redistributive role in developing countries than it does in OECD economies. Focusing on Tanzania, Kazungu and Cheyo (2014) suggest that government expenditures to finance poverty reduction strategies may take substantial time to generate its intended effect. Furthermore, Asghar et al. (2012) discover that government spending on budget deficits as well as on economic and community services appeared to be responsible for poverty *increases* in Pakistan, as that government spending has had unintended inflationary effects, while poorer areas of the country either did not have access to the services or were neglected altogether. Wilhelm and Fiestas (2005) find that government spending in sectors that are generally seen as poverty-reducing actually tended to benefit the richer quintiles of the population most, and thus such government spending has reduced poverty only minimally and could actually widen inequality between rich and poor. With regard to financial development, although it may broaden the financial service sector's access to the poor and thus raise their income and reduce poverty (Jalilian and Kirkpatrick, 2002), it may also have the unintended negative consequence of financial instability (Akhter and Daly, 2009). A further study by Jeanneney and Kpodar (2011) confirms that despite the benefits of financial development, the financial instability arising from it hurts the poor, and this seems to be the case for our sample of African countries: the positive effect of financial development on poverty reduction is insignificant.

Overall, the results based on African nations' TFP vis-à-vis the USA suggest that closing the technological gap between SSA and the world leader does represent a powerful means of alleviating poverty. Other contributing factors include overall economic growth per capita, low inflation, inward FDI and infrastructure expansion. There is also strong evidence of poverty persistence in Africa.

We then examine TFP vis-à-vis the leader of developing countries, China (Model (2)). Here again, we found that the TFP gap between African nations and the leader (*TFPgap_CHINA*) has the expected positive sign and is statistically significant, confirming the poverty-reducing impact of technological catch-up. Specifically, every percentage decrease (or increase) in the TFP gap would reduce (or raise) the poverty headcount by 0.04%. The log of poverty (POV*(t-1)*), GDP growth (*GDPG*), inflation (*INFL*) and infrastructure (*INFR*) remain significant, while openness (*OPEN*) also becomes significant. In contrast, government spending (*GSPEN*) and financial development (*FDEV*) remain insignificant, as in Model (1). Interestingly, inward foreign direct investment (*IFDI*) is no longer significant. Due to a lack of labour market mobility in Africa, inward FDI may favour those that already have high incomes and are highly skilled, while bypassing the low-skilled, low-income workers (Feenstra and Hanson, 1997), restricting the positive influence IFDI could have on poverty reduction.

Comparing the two sets of results described above, we highlight one important difference: the poverty alleviation effect seems to be stronger for Africa in catching up with the USA than in catching up with China. As shown in Figure 4, the SSA nations' TFP gap to the USA is higher than their gap to China; in other words, there is a wider technological gap between SSA and the USA than between SSA and China. Therefore, technological catch-up to the USA can be seen as an earlier stage of catching up than in the case of the SSA-China pairing. Analogous with capital accumulation, our findings suggest that the concept of diminishing returns can also be applied to the effect of technological catch-up on poverty alleviation, as the early steps of technological catch-up are relatively more effective in reducing poverty and less costly to achieve. Using data on 89 developing economies from 1990 to 2013, Asadullah and Savoia (2018) find that poverty headcount tends to decrease faster in countries with initially more severe income poverty (see similar argument in Noorbakhsh, 2007), and such severe initial poverty is often linked to a low starting level of technology. Although poverty is much more acute and the level of technology is much lower in most SSA nations than in either the USA or China, the gaps are much more profound relative to the USA, so any narrowing of these gaps would have a greater poverty reduction effect. Another explanation is the exceptional growth in technology China has experienced in the past decade (Figure 5), making the recent actual technological catch-up of African nations towards China much smaller than compared to the US.

Although we have employed the sum of landlines and mobile phones per 100 people as our indicator of infrastructure development (as in Andrés et al. (2013)) in SSA, a recent study by Arimah (2017) finds that the spectacular growth in mobile phone users in Africa over the last decade and a half has contributed greatly to poverty reduction and prosperity in African cities. Mobile technology is found to be the infrastructure with the highest impact on poverty reduction, followed by electricity, roads and irrigation for developing countries (Runsinarith, 2009). Therefore, in Models (3) and (4) we employ as an alternative measurement of infrastructure the number of mobile phones per 100 people (as in Arimah, 2017) (*MOBILE*). We obtained very similar results to those in Models (1) and (2), respectively, for all coefficients (in terms of size, sign and level of significance)[4]. It is worth mentioning that the technological gap variable remains correctly signed and significant in both Models (3) and (4)[5].

One of the largest economies in Africa (second only to Nigeria), South Africa, has had the highest living standard in the region since 1997 (based on GDP per capita at constant 2010 US dollars, according to the World Development Indicators 1997-2016). Over the past three decades, South Africa has also experienced a more stable economic growth rate than most other African countries have, especially since the 2008 global financial crisis. In spite of a recent mild slowdown in productivity growth relative to other African countries, South Africa remains the regional technological leader (Dessus et al., 2017; You et al., 2019). Our estimates

[4] We have also employed the statistic of fixed landlines per 100 people (as in Magombeyi and Odhiambo, 2018) as an alternative proxy for infrastructure. However, it was insignificant in all Models (1) to (4). It may reflect that the number of landlines in Africa has stagnated, especially in the past ten years. The technological gap variable again remains correctly signed and significant. Results are not presented here to save space but are available upon request.

[5] A number of studies have examined whether good governance reduces poverty (see a recent review by Jindra and Vaz (2019)). We employ the widely used World Bank Worldwide Governance Indicators (WGI), which account for six components of governance since 1996: voice and accountability; political stability and absence of violence/terrorism; government effectiveness; regulatory quality; rule of law; and control of corruption. We construct an average of these six indicators and included this overall governance index as an additional variable in Models (1)-(4). However, the index was not significant in any of the models. The relationship between quality of governance and poverty may be development stage-dependent (e.g., Grindle, 2004; Khan, 2007, 2009; Sachs et al., 2004). In the case of African nations, good governance may have a limited impact, as the general resources available may be insufficient to effectively translate government capabilities into positive outcomes in terms of poverty.

also confirm South Africa's leading position in Africa with the smallest technological gaps vis-à-vis both the US and China (Figure 4). In light of its unique economic position, we opted to exclude South Africa from our sample and re-estimate Models (1) to (4). The results are presented as Models (5) to (8) in Table 2.

Nevertheless, we obtain similar findings in Models (5)-(8) as in Models (1)-(4). The lag of poverty, *TFPgap_USA*, *TFPgap_China*, *GDPG*, *INFL*, *INFR* and *MOBILE* continue to have the correct signs and remain significant, although openness is no longer significant in the case of *TFPgap_China* (Models (6) and (8)) whilst inward FDI *is* significant in the case of *TFPgap_USA* (Models (5) and (7)). However, one interesting difference emerges: the technological gap coefficients (*TFPgap_USA* and *TFPgap_China*) are higher in Models (5)-(8). This corroborates the claim that technological catch-up is more effective in alleviating poverty in countries where poverty is initially more severe (since the omitted nation, South Africa, is a large economy with the highest living standard in Africa).

We are also interested in evaluating the contribution of technological catch-up at the sectoral level to overall poverty alleviation in Africa. To do so, we divide sector-specific productivity levels (constructed in Section 4.2) of each African nation by the corresponding values for the US and China, to obtain relative sector productivity figures. We then multiply each ratio by the respective labour share, and the sum of these three sector values represents the overall productivity of this African nation relative to the US or to China.

To make this relative productivity comparable to the relative TFP index estimated using the superlative index number methodology (Section 4.2), we divide the latter by the former to provide a scaling factor. Then, adjusting the relative sectoral productivity by this scaling factor and then subtracting the scaled outcome by 1, we obtain proxies of the technological gap between each African country and both the USA and China in agriculture (*TFPgap_USA_A*, *TFPgap_China_A*), industry (*TFPgap_USA_I*, *TFPgap_China_I*) and services

(*TFPgap_USA_S*, *TFPgap_China_S*). The economy-wide technological gaps (*TFPgap_USA*, *TFPgap_China*) in Models (1) to (4) are each replaced by three sectoral gaps; the results are summarised in Models (9) to (12) in Table 4. In Models (13) to (16) in Table 4, we account for the distribution of labour across sectors by multiplying sectoral gaps by their corresponding labour shares, generating the weighted sectoral technological gaps for agriculture (*TFPgap_USA_AW*, *TFPgap_China_AW*), industry (*TFPgap_USA_IW*, *TFPgap_China_IW*) and services (*TFPgap_USA_SW*, *TFPgap_China_SW*). Note that the three-year interval applied to the data in Table 2 is also applied to the sectoral gaps.

For all models in Table 4, the Sargan and Hansen tests both support the choice of the instruments and, implying that our estimates are reliable. The serial correlation tests show the expected first order serial correlations and reject second-order serial correlation in the differenced error terms, indicating that the GMM estimators are consistent.

In Models (9)-(12), the only sectoral technological gap that has a significant poverty reduction effect is agriculture. It reflects an interesting fact that despite having the lowest level of productivity, the agriculture sector in the 17 African countries has actually experienced the fastest growth of the three macro-sectors from 1990 to 2014, averaging 2.2% annually compared with 1.4% in industry and 1.3% services, according to World Bank data). The lag of poverty, *GDPG*, *OPEN* (in the case of TFP gaps vis-à-vis the USA), *INFL* (in the case of TFP gaps vis-à-vis China), *INFR* and *MOBILE* remain significant and correctly signed, whilst *IFDI*, *FDEV* and *GSPEN* continue to have no impact.

In Models (13)-(16), two important findings emerge. First, the weighted technological gap for agriculture in these four models has higher coefficients than in Models (9)-(12). Whilst Models (9)-(12) highlight the poverty reduction power of technological progress in agriculture, Models (13)-(16) show furthermore that labour allocation in the agricultural sector has reinforced this poverty reduction power. Indeed, in contrast to countries like China where labour has been moving out of agriculture and into the industrial and service sectors over the past three decades (You and Sarantis, 2013), such structural change has not become a strong occurrence in Africa (as discussed in Section 4.2). Second, the weighted technological gap in the services sector becomes significant in the case of TFP gaps vis-à-vis the USA. It probably captures the combined growth effect of service sector productivity as well as the labour share in this sector (with average annual rates of 1.3% and 1.5%, respectively) in Africa. This variable is not significant in the case of TFP gaps vis-à-vis China, as China's service sector productivity is growing at a much higher average annual rate of 8.0%.

The sector-level investigation highlights that the agricultural sector (and to some extent the services sector) is the prime contributor to poverty reduction in Africa, and that the lack of sizeable structural change in Africa as a whole seems to have strengthened this contribution.

5. Conclusions and Implications

The main purpose of this study was to assess the impact on poverty levels of technological diffusion, i.e. of narrowing the technological gap, for a selected group of sub-Saharan African (SSA) countries. We adopted a two-stage analytical framework. First, we estimated the total factor productivity gap between African nations and the USA (the productivity leader among advanced countries) and China (the leader among developing countries). We employed the superlative index number methodology to provide a measure for technological progress that is comparable across the African countries. Our estimates show that although some African countries (namely Nigeria, Burkina Faso, Côte d'Ivoire, Kenya, Mozambique, Niger, Rwanda, and Tanzania) appear to be in the process of catching up technologically with the US, especially towards the end of the sample period, such a process is not occurring between African nations and China, with the exception of some countries for brief spells around the year 2000 (Benin, Burkina Faso, Botswana, Cameroon, Côte d'Ivoire, Mauritius, Nigeria and Zimbabwe). This contrast can be attributed to the exceptional pace at which China has been closing its own technological gap to the USA since 2000. Using sector-level data, we also found evidence that the main engine of productivity growth in Africa comes from the 'within- sector' component rather than from structural change.

In the second stage, we examined whether technological catch-up can actually alleviate poverty. Such an effect was expected through a number of pathways including reducing prices and raising real wages, providing more accessible education and lowering the cost of starting a business for the poor. Based on GMM estimates, we found that closing the technological gap between African nations and both the USA and China has had a strong poverty reduction effect. There is also, however, strong evidence of poverty persistence in sub-Saharan Africa. Other poverty alleviation factors include GDP growth and infrastructure, whilst inflation deteriorates the poverty headcount ratio. Government spending and financial development appear to have little or no influence on poverty in Africa. This is true for both the technological gap to the USA and for the gap relative to China. In addition, inward FDI and trade openness were found to alleviate poverty headcount ratio in the former and latter case, respectively. The results are robust regardless of whether South Africa, the strongest economy in the sample set, is included. Our sector-level analysis shows that the agricultural sector, rather than industry or services, is the prime contributor to poverty reduction in Africa.

5.1. Implications for theory and practice

Our results suggest that closing the technological gap is a crucial ingredient of poverty alleviation in the context of sub-Saharan Africa from 1987 to 2014. However, our estimates also show that, in actuality, such technological catching-up was largely absent in Africa, whether we measure the gap against the most advanced developed country (the US) or against the most advanced developing country (China). A recent study by the World Bank (Cirera and Maloney, 2017) establishes that countries farther from the production frontier are more likely to lack complementary critical innovation factors across many markets and, in particular, firm-level capabilities. Government policy and support can create conditions for citizens to adopt new technologies and for firms to embrace technology as a means of improving their competitiveness. Some prior research has demonstrated that governments can also create incentives via subsidies for firms to upgrade production facilities and materials, and can implement industry-wide training programmes aimed at fostering the adoption of new processes, technologies and energy efficiency (Debrah and Ofori, 2005, 2006). When governments establish and raise production, safety and technical standards through regulations, firms can be forced to adopt new technologies. Without such pressure, firms might be reluctant to adopt new technology. In addition, bureaucratic bottlenecks can stifle the development of new businesses and their ability to adopt technology (Amankwah-Amoah, 2016). By eliminating such red tape, firms would be better placed to innovate via process improvements (Amankwah-Amoah et al., 2019; Amankwah-Amoah & Syllias, 2020; Zhang et al., 2018).

For Africa, technological transfer from China constitutes a great opportunity for enhanced productivity and competitiveness (United Nations and African Union, 2014). However, our results highlight that this phenomenon is generally absent; instead, a process of technological divergence seems to be in place for most African countries relative to China. Even though technology transfer between China and Africa has existed and developed since the Eight Principles for Economic Aid and Technical Assistance to Other Countries were issued in 1964, there is ample room for improvement in scale and depth to strengthen cooperation between Chinese companies and Africa (Li, 2016). In the Forum on China–Africa Cooperation Johannesburg Action Plan 2016–2018 that was recently issued at the China–Africa Summit, 'technology transfer' is greatly emphasised. To tackle poverty in Africa, more intense technological collaboration between China and Africa is needed. As suggested by the African Union during the 2018 FOCAC-Africa-China Poverty Reduction and Development

Conference, technological collaboration aiming to reduced poverty in Africa includes not only activities such as visits by Chinese experts and their assistance in crop planting, pest disease prevention and control, product processing, livestock breeding, and fish farming, but also activities that entail more comprehensive partnerships, such as learning from China in areas like natural resource management, agriculture transformation, policy research, evidence-based planning, as well as the promotion of competitive value chains and agri-business development.

Furthermore, in light of our finding that structural change has played a minimal role in raising productivity in Africa, there would appear to be major regional growth potential embedded in structural change. Yet it is not an automatic process. Therefore, policy guidance with appropriate direction to promote growth-inducing structural change is urgently needed for African nations, especially for those that have a strong comparative advantage in natural resources (McMillan and Rodrik, 2011).

Finally, in addition to emphasising the critical role played by technological catch-up in poverty reduction, our study also confirms that there are a number of other important contributing factors, including economic growth, trade openness, infrastructure and financial development. However, it also indicates that government spending and inward FDI may not necessarily alleviate poverty, suggesting that policymakers need to make sure that at least a portion of their spending and capital inflows are specifically targeted to benefit the poor.

5.2. Limitations and indications for future research

Our paper identifies that a process of technology divergence seems to be in place for most African nations with respect to the USA and China, especially the latter. Investigating the reasons behind the lack of technological transfer from China to SSA countries is beyond the scope of this paper but stands out as an important area for future research. A related area of research extension is to link technological catch-up (or lack thereof) to technology absorption capability. To exploit the full economic potential of closing technological gaps, technological laggards have to possess the necessary absorptive capacity, which is the ability to identify, assimilate and exploit outside knowledge (Cohen and Levinthal, 1989). Hence, it would be very informative to re-model the process of technological diffusion, and thus of technological catch-up, by making it conditional upon followers' absorptive capacities such as human capital, domestic R&D and patents. Operatively, this line of research could be implemented for instance along the lines of Bond et al. (2001), by including absorptive capability variables as extra instruments when employing the System GMM estimator. Finally, based on our findings, government spending and inward FDI seem to have an undesired adverse effect on poverty reduction in Africa. Although this corroborates a number of previous studies (e.g., Anderson et al., 2018; Huang et al., 2010) where several theoretical explanations have been presented, a future research direction could be to construct full-fledged models and conduct empirical examinations in order to gain a better understanding of the fundamental causes of such an unexpected relationship.

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Table 1. TFP_gap: Descriptive Statistics (1987-2014)

Country	TFPgap_USA	TFPgap_CHINA
Burundi (BDI)		
Mean	0.92	0.53
Median	0.93	0.54
Maximum	0.94	0.74
Minimum	0.88	0.21
Number of observations	28	28
Benin (BEN)		
Mean	0.83	0.24
Median	0.84	0.25
Maximum	0.86	0.49
Minimum	0.78	-0.06
Number of observations	28	28
Burkina Faso (BFA)		
Mean	0.83	0.14
Median	0.83	0.11
Maximum	0.85	0.39
Minimum	0.81	-0.04
Number of observations	28	28
Botswana (BWA)		
Mean	0.34	-0.52
Median	0.33	-0.57
Maximum	0.50	-0.03
Minimum	0.20	-1.05
Number of observations	28	28
Côte d'Ivoire (CIV)		
Mean	0.71	-0.19
Median	0.71	-0.17
Maximum	0.77	0.22
Minimum	0.60	-0.61
Number of observations	28	28
Cameroon (CMR)		
Mean	0.77	-0.05
Median	0.78	-0.04
Maximum	0.82	0.40
Minimum	0.62	-0.66
Number of observations	28	28
Kenya (KEN)		
Mean	0.77	0.02
Median	0.79	-0.02
Maximum	0.84	0.33
Minimum	0.66	-0.41
Number of observations	28	28
Mozambique (MOZ)		
Mean	0.89	0.37

Median	0.90	0.36
Maximum	0.92	0.56
Minimum	0.85	0.21
Number of observations	28	28
Mauritius (MUS)		
Mean	0.23	-0.80
Median	0.24	-0.79
Maximum	0.36	-0.37
Minimum	0.09	-1.42
Number of observations	28	28
Niger (NER)		
Mean	0.87	0.51
Median	0.88	0.49
Maximum	0.91	0.62
Minimum	0.82	0.39
Number of observations	28	28
Nigeria (NGA)		
Mean	0.71	-0.21
Median	0.75	-0.25
Maximum	0.92	0.47
Minimum	0.44	-0.67
Number of observations	28	28
Rwanda (RWA)		
Mean	0.91	0.44
Median	0.92	0.53
Maximum	0.95	0.68
Minimum	0.87	-0.06
Number of observations	28	28
Senegal (SEN)		
Mean	0.68	0.00
Median	0.71	0.07
Maximum	0.74	0.24
Minimum	0.51	-0.54
Number of observations	28	28
Sierra Leone (SLE)		
Mean	0.81	-0.05
Median	0.84	0.26
Maximum	0.88	0.56
Minimum	0.70	-1.20
Number of observations	28	28
Togo (TGO)		
Mean	0.90	0.40
Median	0.91	0.37
Maximum	0.93	0.72
Minimum	0.84	0.00
Number of observations	28	28

Tanzania (TZA)		
Mean	0.85	0.39
Median	0.86	0.39
Maximum	0.89	0.65
Minimum	0.81	0.27
Number of observations	28	28
South Africa (ZAF)		
Mean	0.24	-0.81
Median	0.24	-0.76
Maximum	0.43	-0.39
Minimum	0.05	-1.16
Number of observations	28	28
Total		
Mean	0.72	0.02
Median	0.82	0.16
Maximum	0.95	0.74
Minimum	0.05	-1.42
Number of observations	476	476

Table 2: Technological Gap and Poverty: System GMM Results

Dependent Variable: Poverty Headcount Ratio (1987 – 2014 with 3-year interval)								
Independent Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
POV(-1)	0. 6929***	0.7140***	0.6674***	0.7265***	0.5067*	0.7400***	0.5304**	0.7346***
	(3.51)	(5.02)	(2.93)	(5.36)	(1.87)	(5.39)	(2.04)	(5.03)
TFPgap_USA	0. 2176**		0.2264**		0. 3345**		0.3251**	
	(1.97)		(2.09)		(2.22)		(2.26)	
TFPgap_CHINA		0.0440**		0.0422**		0.0651**		0.0649**
		(2.12)		(2.07)		(2.45)		(2.38)
GDPG	-0.0066***	-0.0125***	-0.0066**	-0.0126***	-0.0070**	-0.0075***	-0.0069**	-0.0080***
	(-2.71)	(-3.06)	(-2.57)	(-3.14)	(-2.42)	(-3.60)	(-2.37)	(-4.15)
OPEN	-0.0002	-0.0009*	-0.0003	-0.0009*	-0.0001	-0.0004	-0.0001	-0.0004
	(-0.28)	(-1.70)	(-0.40)	(-1.76)	(-0.09)	(-0.71)	(-0.07)	(-0.74)
INFL	0.0009***	0.0007*	0.0009***	0.0007*	0.0011***	0.0009**	0.0010***	0.0009***
	(2.64)	(1.96)	(2.89)	(1.83)	(2.77)	(2.49)	(2.83)	(2.66)
IFDI	-0.0037*	0.0020	-0.0031	0.0022	-0.0053***	-0.0046	-0.0049**	-0.0040
	(-1.77)	(0.39)	(-1.05)	(0.44)	(-2.81)	(-1.01)	(-2.50)	(-0.97)
FDEV	-0.0001	-0.0005	-0.0002	-0.0005	-0.0018	-0.0003	-0.0017	-0.0006
	(-0.33)	(-0.94)	(-0.42)	(-0.98)	(-1.22)	(-0.49)	(-1.30)	(-1.06)
GSPEN	0.0070	0.0015	0.0075	0.0011	0.0098	-0.0020	0.0096	-0.0000
	(1.03)	(0.77)	(1.04)	(0.75)	(1.23)	(-0.15)	(1.24)	(-0.02)
INFR	-0.0004***	-0.0004**			-0.0004***	-0.0005*		
	(-3.00)	(-2.10)			(-2.87)	(-1.86)		
MOBILE			-0.0008***	-0.0004**			-0.0004***	-0.0004*
			(-2.66)	(-2.14)			(-2.86)	(-1.89)
CONST	-0.0650	0.2317**	-0.0566	0.2250***	-0.0707	0.1942*	-0.0775	0.1999*
	(-0.46)	(2.03)	(-0.42)	(2.04)	(-0.50)	(1.90)	(-0.52)	(1.83)
N	153	153	153	153	144	144	144	144
No of groups	17	17	17	17	16	16	16	16
ar1(p-value)	0.015	0.024	0.022	0.022	0.006	0.034	0.007	0.034
ar2(p-value)	0.184	0.738	0.201	0.720	0.332	0.257	0.325	0.313
Sargan(p-value)	0.915	0.729	0.817	0.725	0.857	0.736	0.854	0.756
Difference in Hansen tests (p-value)	0.921	0.964	0.886	0.983	0.933	0.893	0.949	0.895

Note: t-stats are in brackets. ***, ** and * indicate the statistical significance at the 1%, 5% and 1% level respectively. ar1 and ar2 are tests for 1st order serial 2nd order serial correlation respectively. Models (1) – (4) include all 17 African nations in our sample. Models (5) – (8) exclude South Africa.

Table 3. Productivity growth within sector and due to structural change (average annual growth rates, 1990-2014)

	Productivity growth of the whole economy (%)	Within-sector (%)	Structural change (%)
Benin	1.04	1.02	0.02
Botswana	2.25	2.92	-0.67
Burkina Faso	3.66	0.47	3.19
Burundi	-0.57	-0.57	0.00
Cameroon	0.24	-1.17	1.41
Cote d'Ivoire	-0.13	0.05	-0.18
Kenya	0.95	1.52	-0.57
Mauritius	3.93	3.60	0.33
Mozambique	4.66	2.64	2.02
Niger	-0.22	-0.21	0.00
Nigeria	2.37	2.12	0.25
Rwanda	3.84	1.21	2.62
Senegal	1.57	0.98	0.59
Sierra Leone	2.37	2.53	-0.16
South Africa	0.81	0.73	0.09
Tanzania	2.27	0.48	1.79
Togo	0.63	0.58	0.05
China	9.95	8.25	1.70
United States	1.42	1.39	0.03

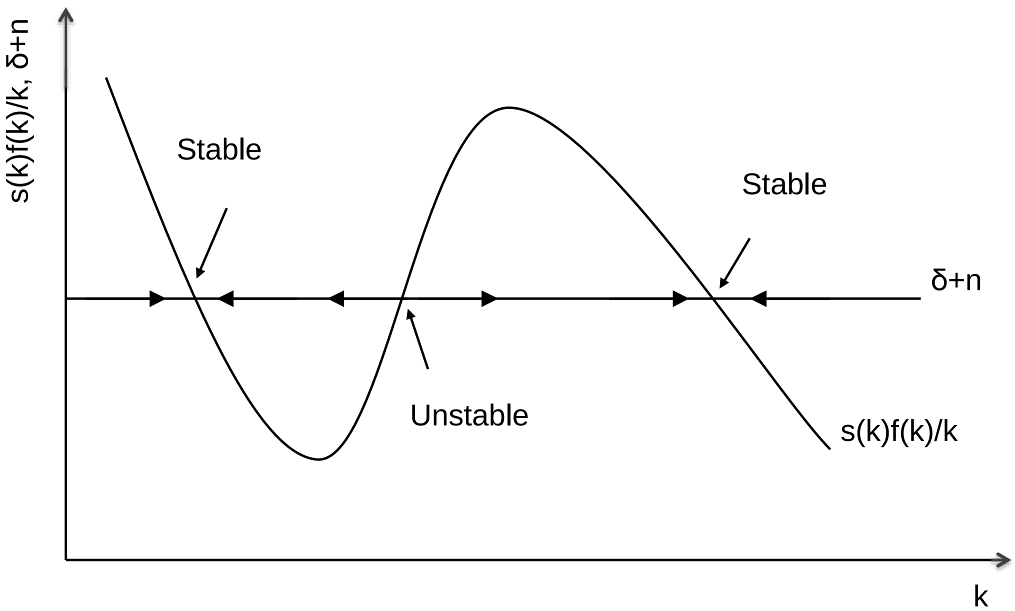
Note: Following McMillan et al. (2014) and Diao et al. (2019), the within-sector item captures the productivity growth originating from pure technological progress in each sector, while the structural change component captures productivity growth induced by labour reallocation between sectors. See Appendix C for more details of this method.

Table 4: Sectoral Level Technological Gap and Poverty: System GMM Results

Dependent Variable: Poverty Headcount Ratio (1990 – 2014 with 3-year interval)									
Independent Variables	(9)	(10)	(11)	(12)	Independent Variables	(13)	(14)	(15)	(16)
POV(-1)	0. 7437***	0.8153***	0.7406***	0.8271***	*POV(-1)*	0.6530***	0.7160***	0.6415***	0.7320***
	(9.36)	(7.94)	(9,36)	(8.55)		(5.18)	(3.70)	(4.76)	(4.15)
TFPgap_USA_A	0. 1057*		0.1048*		*TFPgap_USA_AW*	0. 2915***		0.3018***	
	(1.88)		(1.81)			(2.93)		(2.91)	
TFPgap_USA_I	0.0238		0.0231		*TFPgap_USA_IW*	0.0093		-0.0003	
	(1.48)		(1.47)			(0.14)		(-0.00)	
TFPgap_USA_S	-0.0001		0.0040		*TFPgap_USA_SW*	0.1659**		0.1778**	
	(-0.00)		(0.09)			(2.37)		(2.49)	
TFPgap_CHINA_A		0.0286***		0.0275***	*TFPgap_CHINA_AW*		0.1031**		0.0978***
		(3.13)		(2.96)			(2.59)		(2.68)
TFPgap_CHINA_I		0.0036		0.0032	*TFPgap_CHINA_IW*		0.0045		0.0021
		(0.52)		(0.11)			(0.11)		(0.05)
TFPgap_CHINA_S		-0.0086		-0.0076	*TFPgap_CHINA_SW*		0.0537		0.0510
		(-0.65)		(-0.55)			(1.11)		(1.29)
GDPG	-0.0073***	-0.0073***	-0.0075***	-0.0074***	*GDPG*	-0.0076***	-0.0069***	-0.0069**	-0.0073***
	(-2.78)	(-3.71)	(-2.67)	(-3.78)		(-2.96)	(-3.23)	(-2.78)	(-3.43)
OPEN	-0.0006**	-0.0002	-0.0007**	-0.0002	*OPEN*	0.0001	-0.0004	-0.0001	-0.0005
	(-2.25)	(-0.44)	(-2.40)	(-0.51)		(0.03)	(-0.57)	(-0.13)	(-0.64)
INFL	0.0008	0.0007***	0.0009	0.0007***	*INFL*	0.0007	0.0009**	0.0010	0.0009***
	(1.58)	(4.07)	(1.61)	(3.71)		(1.35)	(2.32)	(1.38)	(2.79)
IFDI	0.0001	-0.0020	0.0002	-0.0017	*IFDI*	-0.0005	-0.0058	0.0007	-0.0050
	(0.06)	(-0.83)	(0.14)	(-0.78)		(-0.32)	(-0.84)	(0.26)	(-1.36)
FDEV	-0.0002	0.0003	-0.0003	0.0002	*FDEV*	0.0004	-0.0001	-0.0004	-0.0002
	(-0.90)	(0.77)	(-1.03)	(0.67)		(1.34)	(-0.84)	(-1.19)	(0.27)
GSPEN	0.0007	-0.0008	0.0007	-0.0008	*GSPEN*	0.0003	-0.0013	0.0003	-0.0012
	(0.52)	(-0.69)	(0.57)	(-0.70)		(0.18)	(-0.84)	(0.19)	(-0.78)
INFR	-0.0004**	-0.0005***			*INFR*	-0.0004**	-0.0005**		
	(-2.11)	(-2.70)				(-2.38)	(-2.57)		
MOBILE			-0.0004**	-0.0004***	*MOBILE*			-0.0005**	-0.0005***
			(-2.08)	(-2.70)				(-2.41)	(-2.66)
CONST	0.0862	0.1502*	0.0894	0.1437*	*CONST*	0.0137	0.2189	0.0177	0.2121
	(1.57)	(1.71)	(1.54)	(1.73)		(0.20)	(1.45)	(0.24)	(1.48)
N	153	153	153	153	N	153	153	153	153
No of groups	17	17	17	17	No of groups	17	17	17	17
ar1(p-value)	0.052	0.047	0.051	0.048	ar1(p-value)	0.040	0.029	0.038	0.033
ar2(p-value)	0.568	0.326	0.545	0.348	ar2(p-value)	0.473	0.218	0.513	0.248
Sargan(p-value)	0.778	0.712	0.797	0.713	Sargan(p-value)	0.762	0.541	0.800	0.606
Difference in Hansen tests (p-value)	0.969	0.851	0.946	0.844	Difference in Hansen tests (p-value)	0.994	0.780	0.994	0.826

Note: t-stats are in brackets. ***, ** and * indicate the statistical significance at the 1%, 5% and 1% level respectively. ar1 and ar2 are tests for 1st order serial 2nd order serial correlation respectively. Although Table 4 uses data for 1990-2014 and Table 2 uses data for 1987-2014, both tables have the same number of observations (153) when all 17 countries are included. This was because data for 1987 did not enter the estimation due to the inclusion of the poverty lag in Table 2, so the estimation for both tables starts in 1990.

Figure 1: Savings and non-convexities traps



Source: Authors' elaboration

Figure 2. TFP gap of SSA nations to the USA (TFPgap_USA)

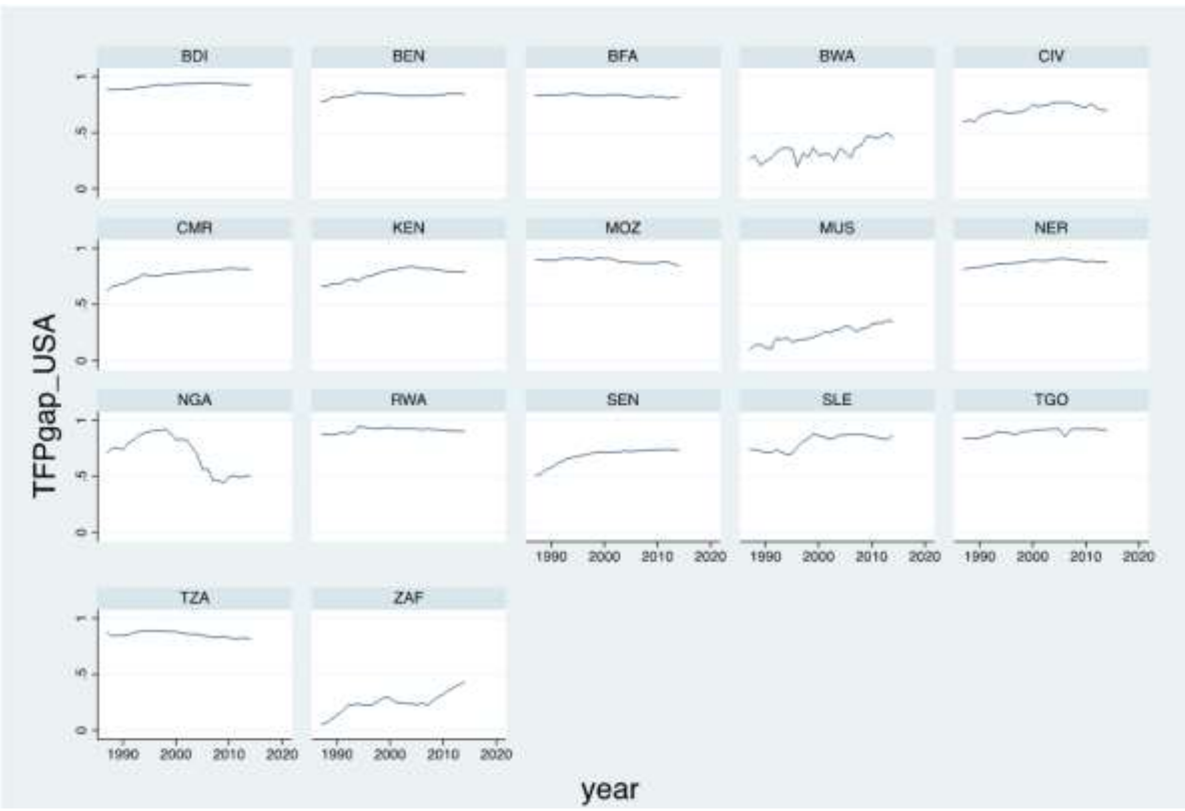


Figure 3. TFP gap of SSA nations to China (TFPgap_CHINA)

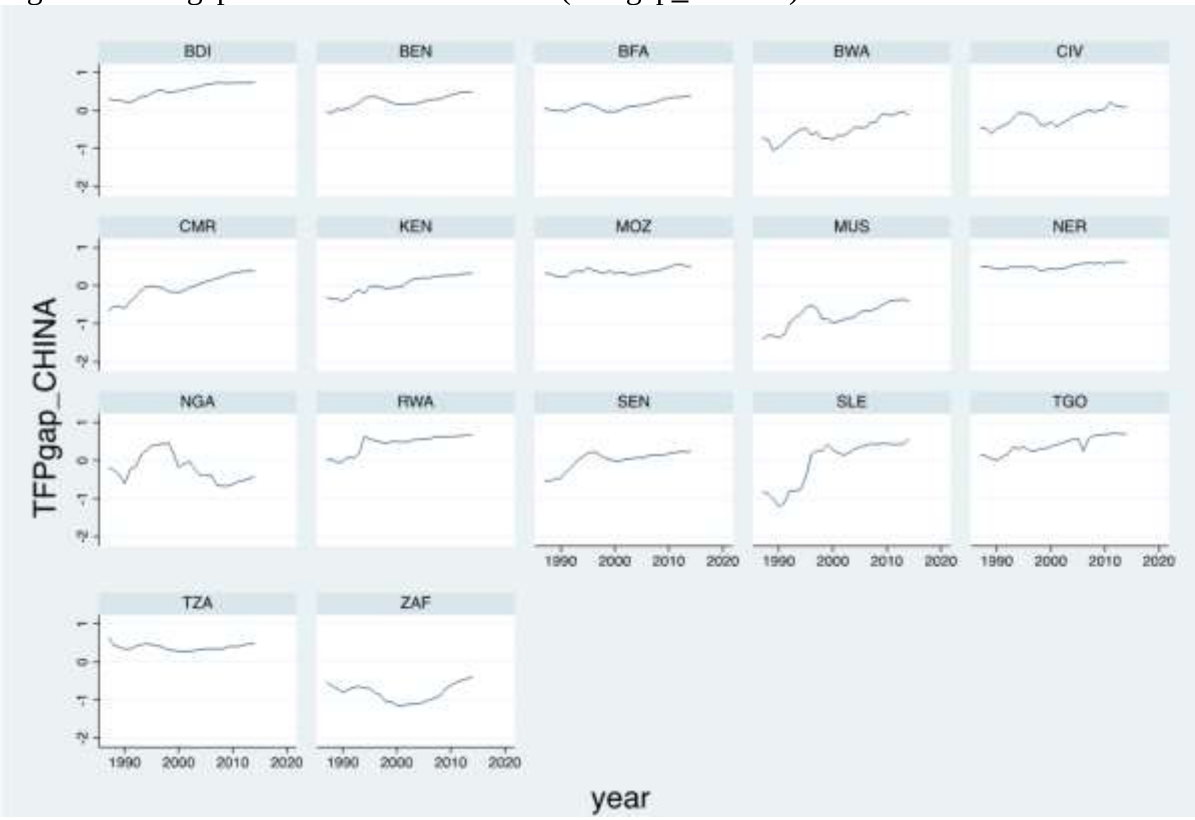


Figure 4. TFP gap of SSA nations to the USA and China: a comparison

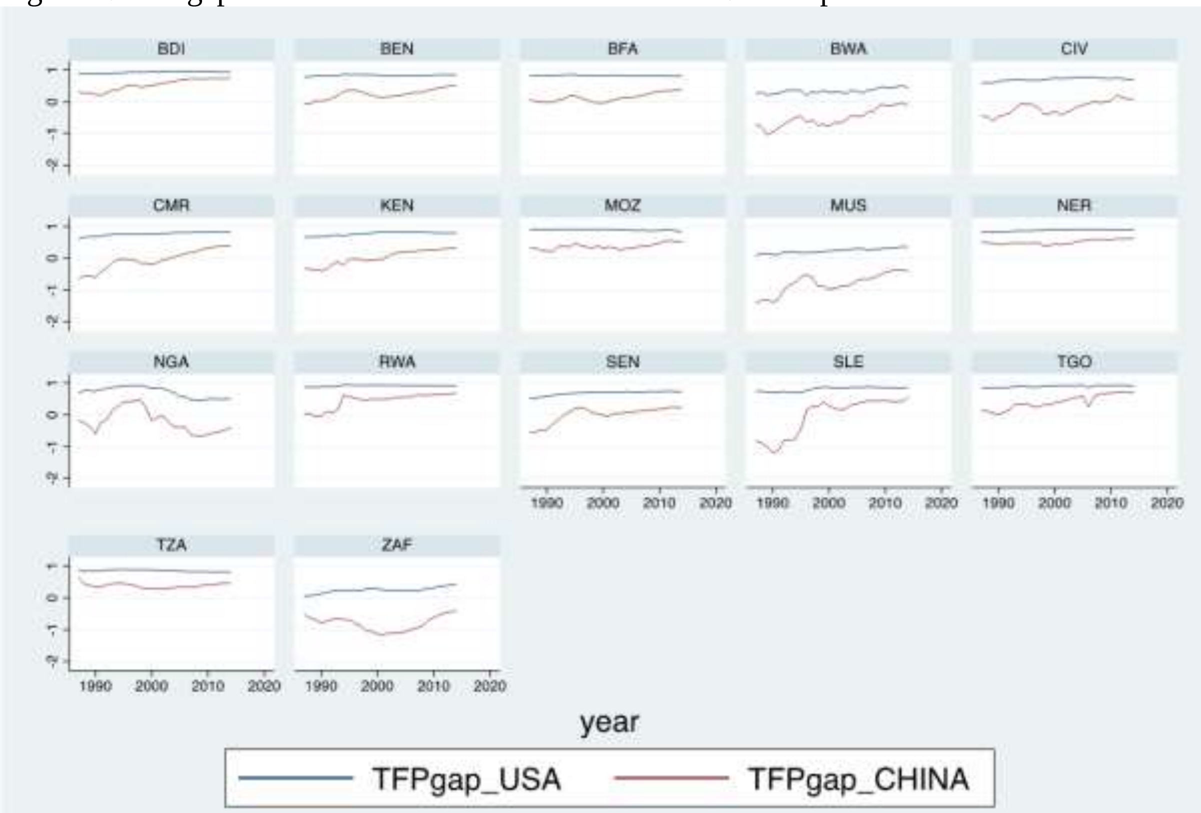
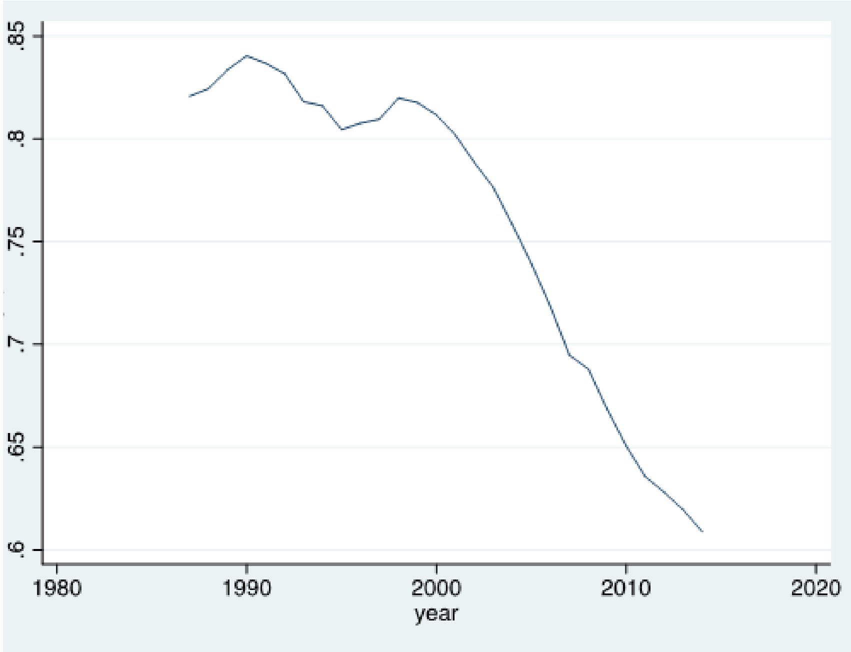


Figure 5. TFP gap between China and the USA



Appendix A: The superlative index number methodology and TFP estimation

This appendix explains how the superlative index number methodology has been employed to retrieve TFP indexes that are comparable across countries and over a long time series.

It is assumed that: a) production output of a generic country is a function of capital stock and employment; b) the production function is translog with identical second-order term; c) constant returns to scale apply; and d) inputs are measured perfectly and in the same units for each observation. In symbols:

$$lnY = \alpha_0 + \alpha_1 lnL + \alpha_2 lnK + \alpha_3 (lnL)^2 + \alpha_4 (lnK)^2 + \alpha_5 (lnL * lnK)$$

where constant returns to scale hypothesis requires $\alpha_1 + \alpha_2 = 1$ and $2\alpha_3 + \alpha_5 = 2\alpha_4 + \alpha_5 = 0$. Furthermore, perfect competition is assumed in both output and input markets. It is worth noting that all the stated assumptions are necessary to derive the TFP superlative index number. Nonetheless, some progress has been made recently in incorporating imperfect competition into the measurement of productivity, cfr. Burstein and Cravino (2015).

Relying on the concept of distance function, Caves et al. (1982) derive the TFP index number for bilateral as well as multilateral comparisons. As for the TFP index for bilateral comparisons, it is assumed that there are two countries, *b* and *c*, where country *b* is the basis of comparison. The distance function $D_c(Y_b, L_b, K_b)$ represents the minimum proportional decrease in Y_b such that the resulting output is producible with the inputs and productivity levels of *c*. Or, $D_c(Y_b, L_b, K_b)$ is the smallest input bundle capable of producing Y_b using the technology in country *c* (i.e. $D_c(Y_b, X_b) = \min\{d \in R_+ : f_c(dX_b) \geq Y_b\}$, where $X_b = (K_b, L_b)$ represents country *b*'s labour and capital input and Y_b is the previously described translog production function. Caves et al. (1982) show that the Mälmquist index (i.e. the geometric mean) of two distance functions for any two countries, *c* and *b*, provides a superlative and transitive index number for TFP. Superlative means that it is exact for the flexible aggregator function chosen (i.e. translog production function) and thus it is not an approximation (see for more details Diewert, 1976) and its result on the use of Törnqvist-Theil approximation to the Divisia index (Törnqvist, 1936). It is also worth noting that an aggregator function is flexible if it can provide a second-order approximation to an arbitrary twice differentiable linearly homogeneous function. Finally, thanks to transitivity, the choice of base country and year is inconsequential. Such desirable properties have made the superlative index number a well employed methodology for TFP calculation, see for example Harrigan (1997), Griffith et al. (2004) and Dal Bianco (2016).

Drawing on these results, Feenstra et al. (2015) show that the productivity level in country *c* relative to country *b* can be expressed as the ratio of output-side real GDP divided by the Törnqvist index of factor endowments for the country of reference. As we are interested in TFP measures that are comparable across countries and over time, we employ the output-side real GDP at chained PPPs (i.e. $RGDP^O$) rather than the output-side real GDP expressed at current PPPs (i.e. $CGDP^O$). The same applies to our measure for capital stock, which is expressed in at chained PPPs US$ (i.e. RK). In symbols:

$$\frac{TFP_{ct}}{TFP_{bt}} = \left(\frac{RGDP^O_{ct}}{RGDP^O_{bt}}\right) / Q_{cbt} \qquad \text{(A1)}$$

where Q_{cbt} is the Törnqvist index of factor endowments for the country of reference, which can be formally written as:

$$Q_{cbt} = \frac{1}{2}(LABSH_{ct} + LABSH_{bt})\left(\frac{EMP_{ct}}{EMP_{bt}}\frac{HC_{ct}}{HC_{bt}}\right) + \left[1 - \frac{1}{2}(LABSH_{ct} + LABSH_{bt})\left(\frac{RK_{ct}}{RK_{bt}}\right)\right]$$

where *b* indexes the country of comparison, which in our case is either the leader of advanced economies (i.e. USA) or the leader of developing economies (i.e. China); *c* represents the generic African country in the sample and *t* indexes any year between 1987 and 2014.

Appendix B. Variable measurements and data sources

TFP gap

Variable name	**Measurement**	**Data Source**	**Prices**
$RGDP^{O}$	Output-side real GDP at chained PPPs (in million 2011 USD)	PWT 9.0	Constant across countries and over time
$CGDP^{O}$	Output-side real GDP at current PPPs (in million 2011 USD)	PWT 9.0	Constant across countries in a given year
CK	Capital stock at current PPPs (in million 2011 USD);	PWT 9.0	Constant across countries in a given year
EMP	Number of persons engaged (in millions)	PWT 9.0	Not applicable
HC	Human capital index, based on average years of schooling	Barro and Lee (2012)	Not applicable
LABSH	Labour income of employees and self-employed workers as a share of nominal GDP	PWT 9.0	Not applicable

System GMM Analysis (dependent variable Poverty)

Variable name	**Measurement**	**Data Source**	**A-Priori Sign**
Poverty	*POV*: Percentage of headcount living below the poverty line of $1.9 a day in 2011 PPP	PovcalNet of the World Bank	
Lag of Poverty	$POV_{(t-1)}$: Percentage of headcount living below the poverty line of $1.9 a day in 2011 PPP	PovcalNet of the World Bank	+
TFPgap	*TFPgap_USA* (*TFPgap_CHINA*) measures the technological gap between the SSA nations and the USA (China)	Estimated in the first stage	+
Trade openness	*OPEN*: The sum of exports and imports divided by GDP	World Development Indicators (WDIs)	-
Inward FDI	*IFDI*: Inward FDI to GDP ratio	WDIs	-
Financial development	*FDEV*: domestic credit to GDP ratio	WDIs	-
Inflation	*INFL*: percentage change of the Consumer Price Index	WDIs	+
Economic growth	*GDPG*: Growth rate of real GDP (constant LCU)	WDIs	-
Infrastructure	Measured using two alternative indicators: mobile phones and landlines per 100 people (*INFR*) and mobile phones per 100 people (*MOBILE*)	WDIs	-
Government Spending	*GSPEN*: Government spending to GDP ratio	WDIs	-

Appendix C. The decomposition of productivity growth

McMillan et al. (2014) and Diao et al. (2019) propose to decompose productivity growth of an economy into two terms as follows:

$$g_y^t = \sum_i \theta_i^{t-1} \pi_i^{t-1} g_{y_i}^t + \sum_i \Delta\theta_i^t \, \pi_i^{t-1} \left(1 + g_{y_i}^t\right)$$

where $g_y^t = \frac{\Delta y^t}{y^{t-1}}$ and $g_{y_i}^t = \frac{\Delta y_i^t}{\Delta y_i^{t-1}}$ with y^t refers to economy wide productivity level at time t and y_i^t denotes the productivity level of sector i; $\pi_i^t = \frac{y_i^t}{y^t}$ refers to the relative labour productivity for sector i; θ_i^t denotes the share of employment in sector i at time t; and the Δ operator refers to the change in productivity or employment shares between $t-1$ and t. The first term is the weighted sum of productivity growth within individual sectors, where the weights are determined by the employment share and relative productivity for each sector at the beginning of the period. The second term is the inner product of the relative productivity for sector at t to the economy wide productivity at $t-1$, with the change in employment shares across sectors. Therefore, the first term captures the productivity growth originated from pure technological progress within sectors; the latter is the structural change term that captures productivity growth introduced by inter-sectoral labour reallocation (i.e., structural change).

McMillan et al. (2014) suggest that economy-wide productivity is computed by dividing the economy's value added by its total employment, while sectoral productivity is computed by dividing each sector's value added by the corresponding level of sectoral employment. Please refer to McMillan et al. (2014) and Diao et al. (2019) for more detailed explanations of constructing within-sector and structural change components for African countries.