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# TECHNOLOGICAL INNOVATIONS AND STRUCTURAL TRANSFORMATION IN AFRICAN ECONOMIES

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**ABSTRACT**

This paper examines the role of technological innovations on structural transformation on economies of Africa. To attain this objective, it uses a sample of 32 African countries. The estimation techniques are system GMM and two stage least Square. Results indicate that technological innovations, as measured by total patents applications, have a significant effect on per sector value added. This result supports the almost nonlinear relationship of structural transformation since this study shows that manufacturing is the dominant sector in the promotion of structural changes as far as the implementation of technological innovations is concerned. Also, our results highlight that with regards to the African context, manufacturing is the sector in which technological innovation has the greatest impact on per sector value added and by so doing, it promotes structural transformation than other sectors (services or agriculture sector). As policy implication, governments need to encourage technological infrastructure through private and public spending on research and development especially for agricultural development to foster structural transformation.

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## Introduction.

According to Maher et al. (2021), industrial revolutions, whether propelled by steam, assembly lines, or computers, have historically been slow to sweep the African continent. The era of Industry 4.0, clean energy, and artificial intelligence promises to be different - and it has the potential to unleash a surge of innovation that could transform industries and improve well-being across the region. That is because unlike previous waves of industrial change, competing in the digital age does not require deep scientific expertise or massive capital investment. Instead, innovators and entrepreneurs in emerging markets are in a position to tap into flows of talent and digital knowledge and convert them into novel goods, services, and business models. From the ground level, the view in parts of Africa is encouraging. From 2015 to 2020, the number of startups receiving venture capital funding in Africa soared around sevenfold. New public-private African innovation hubs anchored by some of the world's leading technology companies are proliferating. Nonetheless, the region lags in most important measures of innovation capacity.

For the evolution of technological innovation, the different evolutionary stages of technological innovations over the years, giving the different names and characteristics starts with the Industrial revolution, through pervasive influence of steam power as the driving force to the "age of electricity and steel" (1880-1910). The dynamo was an important innovation that made the application of electricity possible (David, 1990). From figure 1, Looking at the different trends, we can observe that the average evolution per year of patents in Africa was not smooth and that patents application for residents are generally more contributive to total patents applications than those of non-residents exceptions been of the years 2003, 2004, 2005 and 2017.

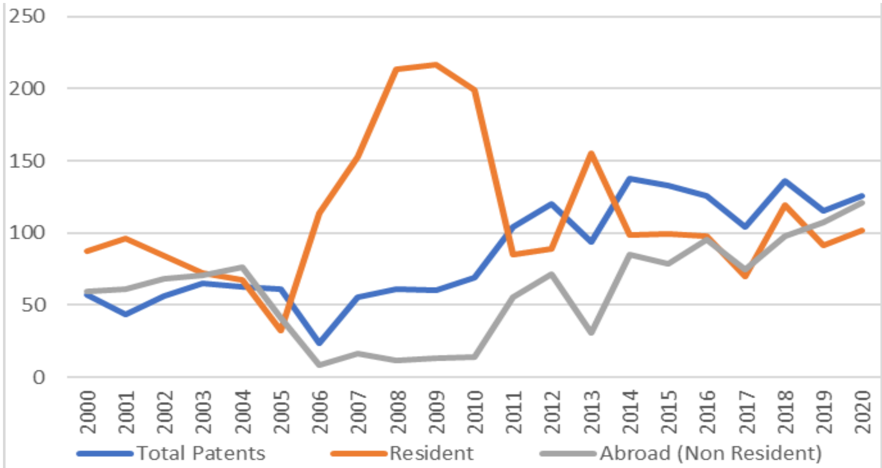


*Fig. 1. Evolution of Technological Innovations in Africa*
*Source: Author from the World Intellectual Property Rights (WIPR) database (2022)*

Looking at Value-added per sector**,** some stylized facts of the pattern of structural change over the course of development have emerged from economic literature. As countries grow, the share of economic activity in agriculture monotonically decreases and the share in services monotonically increases. The share of activity in manufacturing follows an inverted U-shape. Herrendorf et al (2013) document this pattern for a panel of mostly developed countries over the past two centuries, and Duarte and Restuccia (2010) document a similar process of structural change among 29 countries over the period 1956-2004. In terms of composition per sector, data from the World Bank suggest that the service sector has been the dominant sector in SSA, followed by industry, agriculture and manufacturing respectively. A trend analysis on the contribution of each sector to GDP (Figure 2) shows evidence of some dynamics in the structure of economies in the region.

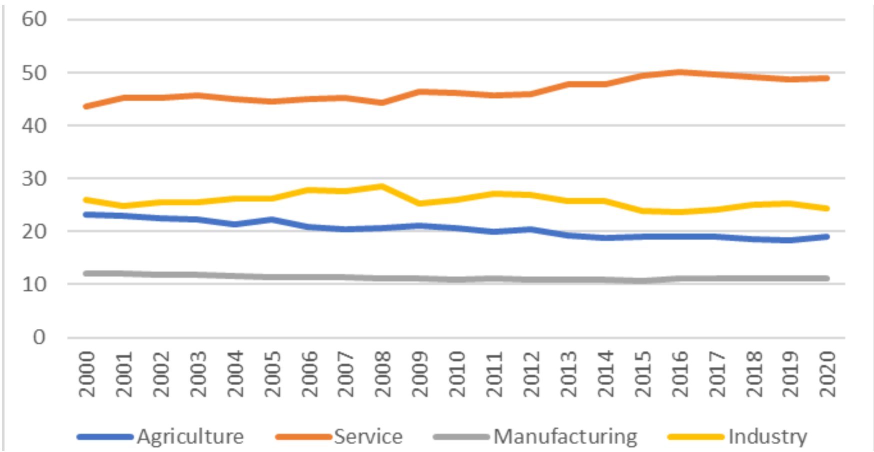


*Fig. 2. Evolution of Sectoral Value Added in Africa*
*Source: Author from the World Bank Development Indicator Database (WDI) (2022).*

As seen on figure 1, structural transformation is still very low in Africa as compared to emerging economies such as those of south East Asia, which have witnessed sharp changes in their composition per sector of their GDP. We generally observe that the African economy is dominated by the service sector. The average contribution of each sector value-added per year are given as follow: A rise from 43.72 per cent in 2000 to 48.94 per cent in 2020;a decline form 12.01 per cent in 2000 to 11.24 per cent in 2020; a fall from 25.89 per cent in 2000 to 24.43 per cent in 2020 and a falling evolution from 23.296 per cent in 2000 to 19.13 per cent in 2020 (mostly due to the fall in the price of raw materials in the World market as it was the case for sub-Saharan African countries in the second decade of the 2000s (World Bank, 2017)); for the service, manufacturing, industry (including manufacturing) and agriculture contribution in the African GDP respectively.

According to Sen (2019), the conventional view of structural transformation is informed by three stylized facts of economic development: (i) all economies exhibit declining employment in agriculture; (ii) economies at an early stage of the process of structural transformation exhibit a hump-shaped share of employment in industry, whereas this share is decreasing for economies at a more advanced stage; and (iii) all economies exhibit an increasing share of employment in services. He observed the share of employment in each major sector: agriculture, manufacturing, nonmanufacturing industry, business services, and no business services in total employment over time for all 39 economies and as expected, the share of employment in agriculture falls steadily over time. The share of manufacturing employment exhibits an inverted U-shaped behavior, again as expected. The share of employment in no business services shows a steady increase. There is virtually no change in the share of employment in nonmanufacturing industry. The share of employment in business services shows a sharp increase after the 1990s.

In the case of African economies, why is the movement of workers from agriculture to manufacturing, and then to services, not respected as conventional economic wisdom maintains that moving productive resources between economic sectors to fill productivity gaps can indeed be a significant driver of growth (McMillan and Rodrik, 2011; McMillan et al., 2014). Instead in the majority of African economies we observe an increasing movement from agriculture directly to service sectors of the economy. What are the drivers of structural transformation (primary to modern manufacturing sectors) and how does technological innovations/advancement affect the shift of resources from less to more productive sectors in the African economies?

**Literature review.**

The study of structural transformations was at the basis of pioneer works of development economics, whether the conditions for the transfer of surplus labor from a traditional to a modern sector (Lewis, 1954).Hence, the expectation that the share of the population employed in agriculture would decrease (Gollin, 2014) or the specific determinants of long-run industrialization and economic specific determinants of the trajectories of industrialization and economic modernization in the long term in lagging countries (Chenery and Taylor, 1975; Kuznets, 1966). Structural change features prominently in the debate on growth in Africa (ACET, 2014). Several key factors have contributed to Africa’s recent transformations and their relative importance varies by country (Jayne et al., 2018; Diao et al., 2017) emphasized endogenous growth of the informal economy, and foreign financial inflows.

Bearing in mind the pioneering works of Kuznets, Kaldor and Lon on structural change and its relation with other aspects of the economy, many works have been done in this direction. For Lavopa and Szirmai (2012), structural transformation has clear implications for employment growth and poverty reduction through its induced impacts, the UNIDO (2015) shows that structural transformation toward manufacturing is positively associated with a number of indicators of social inclusiveness. However, the previous argument is not accepted by all since Ciarli et al. (2021) argue that, economic upgrading following structural change does not necessarily generate social upgrading (access to better work opportunities, including measurable standards, wages conditions, and enabling rights such as freedom of association and non- discrimination). For instance, the position of firms and workers within the value chain, the type of work performed, and the status of workers within a given category of work will influence the capacity to achieve inclusion and social upgrading through structural change (Bernhardt and Pollack, 2016; Tokatli, 2013).

Duarte and Rustuccia (2010) investigate the role of productivity per sector in shaping per sector labor reallocation and aggregate productivity experience across countries. Their analysis illustrates the significant differences explain the broad pattern of structural transformation. Additively, they also find that productivity differences between rich and poor countries are larger in agriculture and services than manufacturing, and a productivity catch-up of poor countries compared to the US exist in agriculture and industry. Dabla-Norris et al. (2013) demonstrates that while country fundamentals, such as income, endowment and population explain a large proportion of the variation in per sector share across countries, structural reforms, globalization and other policies and institutional variables also have significant impact on observed pattern of structural change.

Using data from the UN's industrial statistics Unit in their simultaneous equation model that investigate both supply and demand side factors, Haraguchi and Rezonja (2017) found that income is the most important determinant of per sector development and it explains most of the output variations. Haraguchiand (2017) also discussed the three factor that form the pattern of structural change in manufacturing across counties. These are: the level of economic development, country-specific factors such as geography and demographic conditions, and the speed of development. While labor-intensive primary industries provide the major sources of employment as countries commerce economic development, labor shift to capital and technology intensive industries as average income increase. The speed of the development process is essential in determining the structural pattern in manufacturing, as globalization allows countries more opportunities for technological innovations.

Recently, a large gap in labor productivity between traditional and modern parts of the economy in developing countries has been highlighted by McMillan et al. (2014). Placing emphases on the labor movement from low to high productivity activities in economic development, their findings were that since 1990, structural transformation in Latin America and Africa was growth reducing, with labor moving away from high productivity activities. Through a multi-sector model of growth, built in order to encompass the existing theories on structural transformation, Herrendorf et al. (2014) stresses on the need for quantitative case studies in currently poor countries to conduct theoretical and empirical analysis on the economic forces that drive structural transformation.

Structural change features prominently in the debate on growth in Africa (ACET, 2014). This is evidenced by the continuing and intense discussion among scholars on the observation that African economies are drifting out of the conventional economic wisdom - ranging from the Lewis-Kuznets (1959) model to the endogenous growth approach with regards to structural transformation; yet there is little empirical research on understanding the drivers of structural change in the Africa continent. In the same vein, there has been (and still is) substantial debate about the relative role technological innovations/progress has on structural transformation, industrial structural change, and economic growth (Freire, 2019; Fagerberg, 2000). This is an indication that interest in understanding the interrelated processes of structural change that accompany economic development jointly referred to as structural transformation', especially for African economies is still very relevant today.

Development economists and economic historians (Ngai and Pissarides, 2007; Syrquin 1988) have long been interested in this process of structural transformation and considered it to be inseparable from economic growth. There has been (and still is) substantial debate about the relative role technological progress has on structural transformation, industrial structural change, and economic growth (Freire, 2019; Atalla and Bean, 2017). Endogenous growth theories highlight the fact that a strong causal relationship exists between technological progress and economic growth (Romer, 1994; Grossman and Helpman, 1994). Since the development of these theories, using well-established econometrics, empirical studies have sprung up in abundance to explore the specific effects of technological innovation on economic growth/development and therefore structural transformation.

The strong relationship between technological innovation and growth, hence structural transformation has however been put in evidence in the literature and has been a topic for intense discussions (Lucas, 1998; Romer, 1994). Innovation brings about structural change in economies and societies, and plays a distinctive role in (economic) productivity and development (Takahashi et al., 2020; Muzari, et al., 2012). Equally, Ortega-Argilés et al. (2014) confirmed in their empirical studies that R&D expenditures and innovation generally leads to increasing productivity and growth, though often disruptive (Schumpeter, 1934), and may have distributional consequences (Aghion et al., 2019), hence foster structural transformation and aggregate economic growth. The transformation of economic structures is typically associated to social structures and share increase, mainly via productive employment creation taking into account an increasing number of people into the production process, triggering indirect and induced mechanisms that reinforce the process

(Lavopa, 2012). Global Value Chains are hence a route to technological upgrading and higher value adding activities (Lee and Gereffi, 2015) since technology upgrading in low-income countries relies primarily on the diffusion of new-to-market technologies, rather than new-to-world innovation (Maher et al, 2021).

**Methodology.**

**Data.**

The data used in this work are panel data since it takes into account many countries, each for more than one period; a period being one year. These data were secondary data collected mostly from the World Development Indicator (WDI) as mostly done in the literature (Gbamenou et al., 2020; Martins, 2019; Marouani et al., 2016). The WDI is a compilation of international statistics on sustainable development from the World Bank (WB) that draws on officially recognized sources including national, regional, and global estimates. It provides access to about 1600 indicators for 217 economies and some time series going back even more than 50 years. Some of the WDI indicators are derived from surveys and data collection efforts of the WB group; but the majority are based on data originally collected, compiled, and published by other sources, including other international organizations such as specialized UN agencies (sometimes in cooperation with the WB), national statistical offices, research or monitoring organizations, the private sector, and academic studies. In particular for this study and with respect to the existing literature and previous studies, value added by sector (% GDP) (agriculture, service, industry and manufacturing) and per sector employments (agriculture, manufacturing and services) are taken as dependent variables while patents as well as other variables are considered as independent variables, taken from the World Bank database (World Development Indicators) and employment data from the International Labor Organization (ILOSTAT) also found in the WDI as specified and done by much of the literature. Based on availability data was collected for 32 African countries for the period 2000 to 2020.

**Model.**

Modifying the model in aquation (1) above and adjusting it for this study, we obtain:

$$\mathbf{Y_{it} = \beta_1 + \beta_2 X_{it} + W_{it} + \mu_{it}} \qquad (1)$$

Where, $W_{it}$ is a vector of macroeconomic variables and other variables that capture structural transformation. And hence from the empirical literature (Gbamenou et al.,2020; Martins, 2019; Marouani et al., 2016; Mc millan et al., 2014), our basic model is given as:

$$\begin{aligned} structuralchange = f(&initialconditions,\\ &macroeconomicsstability,\\ &trade\&exchangerate,\\ &financialcapital,\\ &humancapital,\\ &physicalcapital,\\ &governance) \end{aligned} \qquad (2)$$

To this model other variables are added: Sectoral value added and employment are respectively taken as dependent variables for the two questions (Gbamenou et al.,2020). Patent as a chosen proxy for technological innovations amogst others (Song et al., 2018; You et al., 2020).

$$\begin{aligned} structuralchange = f(&initialconditions,\\ &Patents,\\ &macroeconomicstability,\\ &trade\&exchangerate,\\ &financialcapital,\\ &humancapital,\\ &physicalcapital,\\ &governance,\\ &\text{(FDI) and Urbanization}) \end{aligned} \qquad (3)$$

While taking into consideration the hypothesis in our variable, the model of structural transformation can be presented as follows.

$$structuralchange = f(Patents, macroeconomicstability, trade\&exchangerate, financialcapital, humancapital, physicalcapital, governance, (FDI) \text{ and Urbanization}) \quad (4)$$

**Estimation Method**

The study employs two main instrumental techniques: the system GMM and the 2SLS for two specific questions respectively. These methods are employed to address the concern of potential endogeneity and double causality (Nchofoung and Asongu 2022 and Kouladoum et al., 2022). The conditions of applying the GMM strategy have been fulfilled in our study. The study spans from 2000 to 2020, which focuses on 32 African countries fulfilling the main condition of adopting the GMM strategy, which requires the number of individuals to be greater than the time series (Nchofoung et al., 2022). The study also fulfills the condition of adopting the GMM when it concerns panel data analysis as the data is structured in a panel form. The system GMM technique adopted in the study is summarized with the following equations in levels (1) and in first difference (2):

$$VA_{it} = \beta_0 + \beta_1 VA_{i(t-\tau)} + \beta_2 TechIn_{it} \sum_{h=1}^{k} \delta_h Z_{h\,i(t-\tau)} + \mu_i + \gamma_t + \varepsilon_{it} \quad (5)$$

$$VA_{it} - VA_{i(t-\tau)} = \beta_1 (VA_{i(t-\tau)} - VA_{i(t-2\tau)}) + \beta_2 (TechIn_{it} - \beta_2 TechIn_{i(t-\tau)} + \sum_{h=1}^{k} \delta_h (Z_{h\,i(t-\tau)} + Z_{h\,i(t-2\tau)}) + (\gamma_t - \gamma_{(t-\tau)}) + (\varepsilon_{it} - \varepsilon_{i(t-\tau)}) \quad (6)$$

VA signifies value added for the four selected sectors which are the service, industrial, manufacture and the agricultural sectors. TechIn represents technological innovation proxies by patents both the total, the residents and the abroad applications. In equations (2) and (3), Z signifies the vector of control variables. $\mu_i$ represents the country specific effect in panel analysis while $\gamma_t$ is the time-specific constant; $\varepsilon_{it}$ is the error term and $\tau$ the lagging coefficient.

Table 1. Summary table of determinant of structural transformation.

| Independent variables Dimension | Description according to World Bank | Expected Signe | Source (Data base) |
|---|---|---|---|
| Macroeconomic stability: GDP (current) | GDP per capita is gross domestic product divided by midyear population. GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. | +/- | World Bank (WDI) |
| Financial capital: Domestic credit to private sector (% of GDP) | Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable that establish a claim for repayment. For some countries these claims include credit to public enterprises. | +/- | World Bank (WDI) |
| Human capital: Gross enrolment ratio in tertiary (%) | Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. | +/- | World Bank (WDI) |

| | | | |
|---|---|---|---|
| Physical capital and infrastructural development: Assess to electricity (% of population) | The percentage of population with access to electricity. Electrification data are collected from industry, national surveys and international sources. | +/- | World Bank (WDI) |
| Information and Communication Technology: Fixed broadband subscription | | +/- | World Bank (WDI) |
| Urbanization | People living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects. | +/- | World Bank (WDI) |

*Source: Computed by author from literature review.*

**Results and Discussions.**

As summarized in Table 1 above, the determinant of structural transformation according to the existing literature is captured in the analysis under total patents using the GMM technique and the results are presented in Table 2. Table 2 investigates the effect of technological innovations on value added employing four sectors for its estimates. The patent indicator employed at this level is a composite indicator that comprises the resident and the abroad patent applications. The efficiency of our model is confirmed by the probability statistics of the Hansen test, which are all greater than 10% in all equations. The validity of the GMM technique is also confirmed by the auto regressive probabilities of order 1 and 2. The autoregressive probabilities of lag 2 are greater than 10% or (0.10) indicating that the model is efficiently estimated.

The resulting effect of total patent employed as a composite indicator of the residents and the abroad patent applications indicate a positive significant effect on the four sectors. The significance levels differ across different sectors and will be used to compare which sectors are more enhanced by technological innovation. The composite indicator of patent has a statistically significant effect on the manufacturing sector at 1% significance level which is more than what is recorded at the service sector which indicates a 5% significance level and what recorded in the agriculture sector indicating a 10% significance level. The stand in the literature though determining the sectors that technological innovation affects most, still admits the positive significant effect. Patent presents a statistically significant effect at 1% level on the industrial sector but appeared to have a less significance on the agricultural sector, though still maintaining a positive synergy effect. The findings on the positive effect of technological innovation on value added in all the four sectors indicate how the transfer of technology enhances them. The findings of the study are in conformity with the hypothesis that uneven technological progress across sectors is one of the central explanations for structural transformation in the macroeconomics and economic history literatures (Ngai and Pissarides, 2007; Rogerson, 2008).

Though most studies in literature have found out that technological innovation enhances value added of these sectors but there are certain exceptions if there is a low technological diffusion.

Considering other determinants of value added in these sectors apart from technological innovation, we found that ICT measured by fixed broadband enhances value added in the service and the agricultural sectors. The positive effect of (telecommunication services) fixed broadband on value added is in conformity with the findings of Mensah et al. (2016) whose results depicts that fixed broadband is a factor that could enhances the mentioned sectors even though the telecommunication sector is also fraught with challenges as call drops, low internet speed, and limited coverage are highly associated with service delivery. Likewise access to reliable and efficient telecommunication services can boost output of the sector by enhancing market accessibility via reducing the informational asymmetries in the market for agricultural produce.

Table 2: The effect of technological innovations (total patents) on value added (GMM Technique)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | Manufacturing | Services | Agriculture | Industry |
| | | | | |
| L. manufacturing | 0.937*** | | | |
| | (0.00567) | | | |
| **Total patents** | **0.000970*** ** | **0.000401** ** | **0.000667* ** | **0.00137*** ** |
| | **(0.000300)** | **(0.000186)** | **(0.000329)** | **(0.000368)** |
| Fixed broadband | 0.00170 | 0.0258* | 0.0292** | -0.0348 |
| | (0.00525) | (0.0147) | (0.0108) | (0.0244) |
| schlenrtsecgrsset | -0.0350*** | 0.00809 | -0.00966* | -0.0232*** |
| | (0.00218) | (0.00596) | (0.00510) | (0.00465) |
| dmcrdprsec | 0.00504*** | 0.00778*** | -0.00223** | 0.00938*** |
| | (0.000873) | (0.00240) | (0.00102) | (0.00106) |
| gdpcurrent | 6.56e-13** | -1.06e-12 | - 1.15e-12** | 1.11e-12** |
| | (2.69e-13) | (1.41e-12) | (4.61e-13) | (4.90e-13) |
| accesselec | 0.00726** | 0.00804*** | -0.00154 | -0.00447 |
| | (0.00283) | (0.00281) | (0.00285) | (0.00429) |
| lurban | -0.0195 | -0.115 | 0.154*** | -0.163** |
| | (0.0266) | (0.0993) | (0.0494) | (0.0655) |
| L.services | | 0.917*** | | |
| | | (0.00620) | | |
| L.agriculture | | | 0.985*** | |
| | | | (0.00729) | |
| L.industry | | | | 0.965*** |
| | | | | (0.00897) |
| Constant | 0.669 | 5.337*** | -1.849** | 3.269*** |
| | (0.394) | (1.715) | (0.792) | (1.137) |
| Observations | 173 | 179 | 168 | 178 |
| Number of id | 25 | 25 | 24 | 25 |
| Prob> A(1) | 0.0251 | 0.00976 | 0.106 | 0.0265 |
| Prob> A(2) | 0.225 | 0.671 | 0.448 | 0.274 |
| Instruments | 25 | 25 | 25 | 25 |
| Prob>Sargan | 0.00148 | 0.00182 | 0.0359 | 0.00342 |
| Prob> Hansen | 0.448 | 0.227 | 0.522 | 0.580 |
| | | | | |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
*Source: Authors from STATA 14*

The level of education appeared not to be a factor that enhances value added in the agricultural, manufacturing and the industrial sectors but maintains a positive relationship with the service sector. These results are contrary to the results of Gbemenou et al. (2020) who found a positive effect of human capital on structural transformation. This lowering effect of education on the manufacturing sector connects to the findings of Martins (2019) and Jha and Afrin (2017) for manufacturing sector but not for agriculture sector and divert from the study of Mensah et al. (2016) for the manufacturing sector. Jha and Afrin (2017) argue that a reorientation of education program may be needed such that the primary and secondary programs should be complemented with a rigorous program of tertiary education and skilling with the objective of servicing an expanding manufacturing sector in accord with the previous works of Fleet et al. (2012) on the educational behavior in Africa. This confirms the claim that it is possible to have rapid structural change without significant improvements in the "fundamentals" such as infrastructure, education, and institutions (McMillan et al., 2017).

Financial capital (development) proxied by domestic credit to private sector on its part enhances value added in all the sectors, even though negatively in the agricultural sector. These results are in accord with that of Martins (2019) for who financial capital is an important determinant of structural change in the service sector and contrary to that of Mensah et al. (2016) who highlights the challenges faced by the private sector in securing credit from the financial sector in most SSA countries (exorbitant interest rates, high inflation, currency depreciation and a general macroeconomic instability) making the cost of credit too high for the average African firm to afford.

Table 3. The effect of technological innovations (resident patents) on value added (GMM Technique)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | manufacturinggdp | servicesgdp | agricgdp | industrygdp |
| | | | | |
| L.manufacturinggdp | 0.981*** | | | |
| | (0.00269) | | | |
| Residentpats | 0.00107*** | 0.00210*** | -0.000927 | 0.00425*** |
| | (0.000113) | (0.000354) | (0.000590) | (0.000687) |
| Fxbrdbadsubs | -0.0699*** | 0.0243 | 0.0397** | -0.180*** |
| | (0.0155) | (0.0295) | (0.0166) | (0.0611) |
| schlenrtsecgrsset | -0.0532*** | 0.0162** | -0.00978 | -0.0238*** |
| | (0.00668) | (0.00650) | (0.0185) | (0.00745) |
| Dmcrdprsec | -0.00178** | 0.00184 | -0.00559 | -0.00234 |
| | (0.000817) | (0.00230) | (0.00508) | (0.00347) |
| Gdpcurrent | 6.96e-13 | -1.05e-12 | 1.56e-12 | -6.23e-12** |
| | (6.57e-13) | (7.24e-13) | (1.09e-12) | (2.62e-12) |
| Accesselec | 0.0246*** | 0.00354 | -0.00772* | 0.0222*** |
| | (0.00180) | (0.00389) | (0.00373) | (0.00589) |
| Lurban | -0.463*** | -0.341*** | 0.111 | -0.525** |
| | (0.0694) | (0.0875) | (0.101) | (0.221) |
| L.servicesgdp | | 0.931*** | | |
| | | (0.00820) | | |
| L.agricgdp | | | 0.961*** | |
| | | | (0.0354) | |
| L.industrygdp | | | | 0.951*** |
| | | | | (0.0217) |
| Constant | 6.943*** | 8.195*** | -0.252 | 8.864** |
| | (1.032) | (1.326) | (2.165) | (3.783) |
| | | | | |
| Observations | 113 | 117 | 103 | 116 |
| Number of id | 22 | 22 | 18 | 22 |
| Prob> A(1) | 0.0193 | 0.0273 | 0.00515 | 0.145 |
| Prob> A(2) | 0.202 | 0.300 | 0.467 | 0.0185 |
| Instruments | 25 | 25 | 25 | 25 |
| Prob>Sargan | 0.0457 | 0.112 | 0.161 | 0.416 |
| Prob> Hansen | 0.610 | 0.743 | 0.971 | 0.838 |
| | | | | |

*Source: Authors from STATA 14Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1*

Macroeconomic stability, measured by GDP appear to be a determinant of value added in the manufacturing, agricultural and industrial sector. Though negative in the agricultural sector. This relation between the share of value added in these sectors and GDP is in accords with the works of Jha and Afrin (2017) Panel data (fixed effects) regression, arguing that for the manufacturing there is an inverted U-type relation for Africa as a whole. Hence a Kuznets-type structural transformation in Africa may be true for some countries for some periods of time but not for the continent as a whole and major country grouping.

Assess to electricity which is a measure the level of physical capital and infrastructural development enhances value added in the manufacturing and service sectors. This result highlights the fact that the more a country is structurally transformant the higher its level of physical capital and infrastructural development. These results are in accordance with those of Martins (2019) and Gbemenou et al. (2020) for whom Physical capital play a vital role in boosting structural change; contrary to that of Mensah et al. (2016) for the agricultural and industry sector arguing that improvement in social amenities offers great potential to the agricultural sector as access to electricity can help in the transition towards a more mechanized since technology-based agriculture are marred with huge inefficiencies in their service delivery as frequent power outages has increased cost of production and in some cases resulted in the shutting down of some industrial plants due to inadequate supply of energy in the sub-Saharan Africa. Urbanization which measures the demographic indicator is a factor that could enhance value added in the agriculture and industry sector. The positive relationship between urbanization and the above-mentioned sector is in conformity with the works of (Michaels et al., 2012).

Finally, the constant variable significantly affects service, agriculture and industry. This means that apart from prevalence technological innovations, fixed broadband subscription, tertiary school enrollment, domestic credit to private sector, GDP, access to electricity and urbanization, there exist other variables which affect these up mentioned sector but which are absent in these models.

As table 2, table 3 and 4 still investigates the effect of technological innovations on value added employing four sectors using the GMM technique. The patent indicators employed at this level are the resident and the abroad patent applications for each table respectively. The efficiency of these models is all confirmed by the probability statistics of the Hansen test which are all greater than 10% in all equations. The indicator of the residents and the abroad patent applications indicate a positive significant effect on the manufacturing, service and industrial sectors while being not significant in the agricultural sector.

This may be due to the low level of technological diffusion in this sector as compared to the other sectors. The significance levels are the same for the resident patents applications showing that technological innovation contribute at the same level to value added of the concerned sectors. The difference in significance levels for the abroad patents applications across different sectors is used to deduce which sectors is more enhanced by technological innovation.

Table 4. The effect of technological innovations (abroad patents) on value added (GMM Technique)

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | manufacturinggdp | servicesgdp | agricgdp | industrygdp |
| | | | | |
| L.manufacturinggdp | 0.947*** | | | |
| | (0.00626) | | | |
| Abroadpats | 0.000246* | 0.00126*** | 0.000433 | 0.000982*** |
| | (0.000136) | (0.000428) | (0.000531) | (0.000210) |
| Fxbrdbadsubs | 0.00530 | 0.00841 | 0.0290*** | -0.0495** |
| | (0.00639) | (0.0195) | (0.00670) | (0.0197) |
| Schlenrtsecgrsset | -0.0307*** | 0.00894 | -0.00698 | -0.0230*** |
| | (0.00353) | (0.0132) | (0.00428) | (0.00306) |
| Dmcrdprsec | 0.00454** | 0.0106** | -0.00300* | 0.00623*** |
| | (0.00193) | (0.00405) | (0.00150) | (0.000879) |
| Gdpcurrent | 7.32e-13 | 1.03e-12 | -1.08e-12 ** | -1.06e-12 |
| | (6.79e-13) | (9.07e-13) | (4.73e-13) | (9.23e-13) |
| Accesselec | 0.00696*** | 0.0112*** | 0.000734 | 0.00629** |
| | (0.00245) | (0.00292) | (0.00193) | (0.00266) |

| | | | | |
|---|---|---|---|---|
| Lurban | -0.00198 | -0.327*** | 0.179*** | -0.0488 |
| | (0.0228) | (0.113) | (0.0493) | (0.0747) |
| L.servicesgdp | | 0.881*** | | |
| | | (0.0118) | | |
| L.agricgdp | | | 0.992*** | |
| | | | (0.00638) | |
| L.industrygdp | | | | 0.959*** |
| | | | | (0.00617) |
| Constant | 0.290 | 10.00*** | -2.449*** | 1.375 |
| | (0.344) | (1.932) | (0.748) | (1.244) |
| | | | | |
| Observations | 162 | 162 | 151 | 167 |
| Number of id | 24 | 25 | 24 | 25 |
| Prob> A(1) | 0.0272 | 0.0203 | 0.109 | 0.0282 |
| Prob> A(2) | 0.215 | 0.299 | 0.455 | 0.357 |
| Instruments | 25 | 25 | 25 | 25 |
| Prob>Sargan | 0.00184 | 0.0618 | 0.0260 | 0.00686 |
| Prob> Hansen | 0.254 | 0.368 | 0.648 | 0.455 |
| | | | | |

*Source: Authors from STATA 14, Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The indicator of abroad patent has a statistically significant effect on the manufacturing sector at 10% significance level which is less than what is recorded at the service and industry sector which indicates a 1% significance level. These results all confirm the fact that technological innovation has a significant effect on all these sectors and hence on structural transformation. Technological innovation is there for crucial for addressing the challenge of structural transformation in Africa.

**Robustness checks.**

Table 5. Robustness checks (Estimation by the Two Stage Least Square (2SLS) Technique).

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| VARIABLES | services | manufacturing | Agriculture | Industry |
| | | | | |
| **Total patents** | **0.0220*** | **0.00450** | **0.00767*** ** | **0.0181*** ** |
| | **(0.0125)** | **(0.00773)** | **(0.00288)** | **(0.00617)** |
| Fixed broadband | 0.198 | -0.103 | 0.387*** | -1.154*** |
| | (0.138) | (0.0851) | (0.117) | (0.181) |
| Schlenrtsecgrsset | -0.0583 | 0.0936* | -0.0941 | 0.357*** |
| | (0.0836) | (0.0530) | (0.0608) | (0.0772) |
| Dmcrdprsec | 0.150*** | -0.0286* | -0.0367*** | -0.0719*** |
| | (0.0223) | (0.0161) | (0.00950) | (0.0201) |
| gdpcurrent | 0 | -0 | -0*** | 0*** |
| | (0) | (0) | (0) | (0) |
| accesselec | 0.0387 | 0.0720*** | -0.208*** | 0.0133 |
| | (0.0435) | (0.0266) | (0.0248) | (0.0349) |
| lurban | -3.509*** | 1.091** | 3.415*** | -2.767*** |
| | (1.006) | (0.496) | (0.554) | (0.707) |
| Constant | 93.41*** | -9.709 | -21.03** | 62.23*** |
| | (15.08) | (7.503) | (8.687) | (10.90) |
| | | | | |

| | | | | |
|---|---|---|---|---|
| Observations | 210 | 241 | 212 | 212 |
| R-squared | 0.465 | 0.338 | 0.690 | 0.213 |
| Instruments | 0.165 | 12.09 | 3.507 | 4.774 |
| rss | 11337 | 8077 | 7013 | 9361 |
| R2_Adjusted | 0.446 | 0.318 | 0.679 | 0.186 |
| chi2 | 461.3 | 172.2 | 723.4 | 84.70 |
| iterations | 1 | 1 | 1 | 1 |
| rank | 7 | 7 | 7 | 7 |

*Source: Autor, Robust standard errors in parentheses*** $p<0.01$, ** $p<0.05$, * $p<0.1$*

They are in line with the rich empirical literature general concluding that the manufacturing sector as well as technological improvement in this sector has been the main engine driving economic growth and generally associated with the expansion of manufacturing industries and, within them, the expansion of high-tech industries, though its importance has changed across regions and over time in the recent decades (Rodrik, 2016; Wells and Thirlwall, 2003).

Hence, from the observation of our results, technological innovations captured through patents application have positive effects on the value added of all the sectors in the African economies. Moreover, an estimation of the model by the Two Stage Least Square (2SLS) permit to maintain this same sign for the contribution of technological innovations on explaining structural transformation and per sector; value added and hence structural transformation highlighting the robustness of our results.

In sum, we can affirm with regards to our results that technological innovations have a positive impact on per sector value added and hence on structural changes in the African economies. Also, our results show that with regards to the African context, the manufacturing sector (industry sector, including the manufacturing sector) is the sector in which technological innovations (proxied by total patents application) has the greatest impact on sectoral value added and by so doing promoting structural transformation than the other sectors (services or agriculture sector). These results enable in validate our hypothesis that the manufacturing sector is the sector in which technological innovations has the greatest impact on structural transformation in Africa.

**Conclusions and Policy Implications.**

This paper discusses the relation between technological innovations, and structural transformation in the African continent. The major finding of this paper on the linkages between technological innovations (measured by patents applications and the number of scientific and technical journal articles) and structural transformation (measured by per sector value added and employment) has brought to the limelight once more the importance of technological innovations in enhancing the ongoing structural transformation process in Africa. The major finding indicated that technological innovations measured by total patents applications have a significant effect on per sector value added. This result supports the almost nonlinear relationship of structural transformation since this study showed that manufacturing sector is the dominant sector in the promotion of structural changes as far as the implementation of technological innovations is concerned while the agricultural sector still remains underdeveloped with many severe cases of famine in the continent. The finds corroborate other results from previous scholars on the subject matter and aligns with the Schumpeterian literature on economic growth that the interaction of demand growth and technological learning induces structural change in an economy towards technology-intensive sectors resulting in higher growth rates (Cimoli et. al. 2011; Schumpeter 1934). It is clear that whenever new technology is introduced and diffused, it tends to have a structural impact because it leads to an increase in activities that rely on the new technology and a decrease in those activities associated with older technologies. The policy implication is that governments should promote the development of technological infrastructure by creating environment conducive for technological innovations with policies promoting both private and public spending on research and development (main source of technological innovations), more strengthened intellectual property rights protection, entrepreneurial (innovative) educational systems as the promoting or promoting free production factors as well as goods mobility.

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