The 4th Industrial Revolution: What Role Does Infrastructure Play in Livelihood Choices and Outcomes of Agrarian Households?

by Temitayo A. Adeyemo

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Abstract

Agriculture is both a player and beneficent in the 4th industrial revolution, leading to changes in the structure of livelihood of many agricultural households. We asked how the Nigerian agricultural sector will fit into the 4IR in view of the present infrastructure level and the livelihood structure. We investigated the effect of infrastructure on the choice of livelihood activities and the impact on livelihood outcomes in two rural Local Government Areas(LGAs) in a state in Southwest Nigeria. An Endogenous Switching Regression Model (ESRM) was fitted to examine the potential impact of access to rural infrastructure on livelihood outcomes of agrarian households. The findings showed an above average access to infrastructure, especially in the Peri-urban LGA. The main livelihood activity was Agricultural production, with a higher proportion in diversified portfolio. Access to infrastructure was highest across Rural Non-Farm employment and least for Agricultural Waged employment. However, on the average, livelihood outcomes had better outlooks with diversified employment, and least with agricultural waged employment. Distributional impact of access to rural infrastructure showed higher returns among the households who currently have access. We recommend higher public investment in rural infrastructure so as to reduce access costs and improve transformation of livelihoods.

Key Words: 4th Industrial revolution, Infrastructure, Livelihood, Agrarian

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1.0 Background

In many countries-developed and developing, agriculture has served as the supplier of much needed food, raw materials, and even human labour in many forward and backward linkages systems. It has been reported that agriculture has been the bedrock of many civilizations and industrialization in the known world(Potts, 2008; Dal Bo et al., 2015; Fuller and Stevens, 2019). Industrial revolutions have thus ridden on the back of agriculture for centuries; but they have also fed into the process of agricultural revolution, thereby transforming the face of agriculture all over the world. The Agricultural revolution that led to the development of the 1st industrial revolution in Britain started with the development of new technology, thereby releasing labour to the industry. This gradually moved up with increased productivity to the agricultural sector as a supplier of raw materials for industry. A cycle of improved agricultural productivity, (labour and capital) and subsequent growth in industrial capacity through improved technology gave way to the present 4th industrial revolution(4IR). Agriculture is therefore both a key player and beneficent in this progress, with the 4IR having the potential to increase agricultural productivity more efficiently than before (Mtshali and Akinola, 2021).

It is noteworthy however that the industrial revolutions rode on the back of improved and progressively more sophisticated technology and infrastructure that could support the ideas of increased productivity and market access (Sawada, 2019). From the first industrial revolution which was based on the development of water and steam engine, to the second industrial revolution driven by electricity; infrastructure development was key to the idea. The third industrial revolution rode on the advent and sophistications in computing and the internet; and the sophistication in turn led to the 4th industrial revolution in which the digital economy is at the fore of work. The 4th industrial revolution is said to be a mix of biological, physical, and digital economies, working on sophisticated infrastructure; and going beyond physical infrastructure to infrastructure that develops skills and creates opportunities, such as education and finance(Alvarez et al., 2020). The 4th industrial revolution thus encompasses advanced artificial intelligence, leading to the development of the Internet of Things (IoT) and many robotic interventions in the workspace, including agricultural systems(Lombardo et al.,2017; Koh et al., 2019). The drive towards the Sustainable Development Goal 9 is a bid to incorporate the development of infrastructure for industrialization among nations of the world (UN, 2015); implying the key role

of infrastructure as the drive for the 4IR is increasing. Thus, the capacity to get a quick uptake of the 4IR for the structural transformation is hinged on available and widely accessed infrastructure and technology (Ndung'u, N., & Signé, 2020; Lele and Goswani, 2017). Much of Africa as at today is however not able to provide that infrastructure base for the 4IR. It is even more worrisome in the agricultural sector, where a greater majority is small holding, and for whom the 4IR may pose rather a challenge than a blessing (Mtshali & Akinola, 2021).

However, it seems that as with previous other industrial revolution, the 4th industrial revolution may elude Nigeria. This among other constraints is the consequence of a grossly inadequate infrastructural base on which to build the productivity, resources and ideas that flow from and catalase revolutions(Babatunde, 2018). This is despite the process of globalization which has led to an increase in the use of many technologies, especially in the internet space and which have been responsible for the growth of the service sector in Nigeria. The infrastructural requirement of the 4IR goes beyond physical infrastructure of road and rail networks to social, digital, and other forms of intangible infrastructure. However, the state of infrastructure in the Nigerian economy is at best constraining (Chima &Ekegbe, 2017), which severely limits the adoption of productivity enhancing technologies in many sectors. This is even more so when viewed from the lens of agrarian communities with extremely low capacity for technology utilization (Cowie et al., 2020). This is unfortunate given that agrarian communities which are mainly rural account for a significant proportion of food produced for consumption within the country (FAO, 2018). Interventions in farming systems and practices have therefore not been commensurate with the expected result without the supporting structure of required infrastructure (Nigerian Communications Commissions, 2021). From roads, to storage, communication, and even social infrastructure; rural areas in Nigeria consistently report low access. Hence, agricultural production and productivity continues in the cycle of subsistence; with pockets of technology use in urban areas.

In Nigeria, agriculture continues to be a major source of income for many households and is looking up as a tool for economic diversification(Fashogbon and Mushunje, 2018). It is not news that up to 70% of Nigerians depend on agriculture for income, and the majority of these are smallhlolder farmers on less than 1.5 ha of land; or on other forms of small-scale systems (Lowder et al, 2016). The share of agriculture in the nation's GDP has also grown from 21% in 2019 to

greater than 30% in Q2:2020 (NBS, 2020). However, the majority of the farming activities have been based on limited technology with pockets of commercial activities going on in some commodity value chains such as Rice (Awotide et al, 2016). It is expected that agriculture will enhance the capacity of the Nigerian economy to shift from the oil dependent revenue system; and take advantage of value additions and growing demand for agricultural produce in the global space. Thus, livelihood modifications are expected within the agricultural system in view of changing expectations and resources. The ability of the Nigerian agricultural system to do this is largely dependent on its capacity to compete with global agricultural systems and induce large scale changes in both the agricultural systems and the industry. The structure of the agrarian system is changing; revealing deep gaps in productivity and value addition. These gaps have been largely the result of structural changes that reflect in movement of labour out of the rural farming systems (Adeyemo et al., 2020).

It is in view of the above that this study examined the role of rural infrastructure in the livelihood of agrarian households in a Southwestern state in Nigeria with the potential move towards inclusion in the 4th Industrial revolution. The research sought to know : what is the extent of access to rural infrastructure in the study areas? What is the effect of access to Rural Infrastructure on choice of livelihood activities? Does rural infrastructure improve livelihood outcomes of agricultural households? Is rural infrastructure able to return positive outcomes within agrarian societies in view of livelihood choices?

2. 0 Concept of Livelihood

The concept of livelihood goes beyond activities that people do for a living. Livelihood encompasses all resources, activities, institutions, and opportunities that are available within a society to sustain life and living De Haan and Zoomers, 2005; Nguyen et al., 2019), Lama et al., 2019) (Ellis, 2000; Phu et al., 2019). From the DFID sustainable livelihood framework, there seems to be a consensus in the main components of the livelihood of a people. Despite some criticism on its inability to introduce macroeconomic dynamics as well as micro level power plays, the sustainable livelihood framework, still provides a basis for understanding livelihood pathways of a people and through which other macro and micro level variables influence. Livelihood of agricultural and rural households have been the topic of discourse in many developmental

literatures. It is apparent however that livelihood is not static, and people have the opportunity to navigate different livelihood options within the context of the assets, their expectations, and the external environment. There has been a great deal of advocate for diversified livelihood among rural societies in view of the many vulnerabilities and lower opportunities available to them (Phu and De, 2019). Evidence has shown that there may have been a massive deagrarianisation in many farming households, leading to newer livelihood activities and consequently livelihood outcomes. (Adeyemo et al., 2019).

It is interesting to note that diversification of livelihood is not altogether all positive. Livelihood may also evolve from low valued activities to diversified options and eventually to some form of higher valued specialization, although not in that order. It is therefore of research interest to avoid the pitfall of bundling livelihood changes and growth solely as a function of a diversified portfolio. However, in many agrarian systems, fraught with the risks inherent in dependence on low technology of production and low value addition, diversification may actually be a better form of adaptation than a specialized livelihood pathway.

3. 0 Data and Sampling Procedure

The study was carried out in a state in the Southwestern region of Nigeria- Oyo state. The economy of Oyo state is primarily agriculture based, and this is practiced at various scales across its 33 local government areas. Moreover, these LGAs have different levels of proximity to the urban centres which have had implications for their inclusions in infrastructure development and consequently on the extent to which they are able to access such for their livelihood activities. In the multistage sampling procedure used to select respondents, Oyo state was purposively selected in the first stage. The state was thereafter stratified into two agroecological zone of Forest and Savanna strata. The third stage was a random selection of two LGAs from the each agroecological strata (for which Ido and Iseyin LGAs were selected, respectively). In the fourth stage, a sampling proportionate to the size of the LGAs was used to randomly select villages from each LGA. The final stage involved a random selection of agrarian households proportionate to the size of the villages viz:

$$s_i = \frac{y_i}{\sum y_i} H_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: s_i is the sample size required; y_i is the population frame of the selected strata, and H_i is the proposed total sample size.

This study was based on a quantitative survey using Primary data obtained from the use of structure questionnaire administered to the agrarian households in the study area. The following information were obtained:

i. Socioeconomic characteristic of respondents.
ii. Livelihood Components (Assets, Activities, and outcomes)
iii. Availability and access to rural infrastructure.

3.1 Analytical Techniques and Model Specification

The main analytical technique in this study was the use of an Endogenous Switching Regression model to estimate the impact of access to rural infrastructure on the livelihood outcomes of the agrarian households. The outcome variable was the monthly household income from the main livelihood sources, while the treatment variable was the binary " access to rural infrastructure" (No access and Access). The treatment variable was derived from a Principal component analysis of an array of rural infrastructure in three dimensions of: Physical, social, and institutional (Emokaro, 2016; Ghosh, 2017). These are found to modify and moderate components of a sustainable livelihood within a society.

3.1.1 Principal Component Analysis: Profiling Access to Rural Infrastructure in Southwest Nigeria

A Principal Component Analysis (PCA), following the models of Vyas and Kumaranayake, 2006, Beyene and Muche (2010); Fry *et al*, 2014) was used.

$$C_{ij} = \sum \frac{F_i(X_{ji} - X_i)}{S_i} \text{.....2}$$

Where, C_{ij} =intensity value for the j^{th} household with access to a series of *'i'* rural infrastructure[2];

F_i is the weight of the i^{th} variable from the PCA;

X_{ji} is the *jth* household value for the i^{th} variable;

X_i and S_i are the mean and standard deviations of the values of the i^{th} variables.

The PCA, a data dimensionality reduction technique is able to reduce the different variables representing rural infrastructure into a desired number of categories (Howe et al., 2008). Much like is done in the construction of wealth indices in survey such as the Demographic and health

[2] See list of infrastructure use in appendix

Surveys (DHS), the PCA helped to generate a weighted linear combination of the original values of the responses to the original infrastructure variables. With the index obtained using the PCA, the households were classed into two groups using the average of the PCA scores as the cutoff point as - "No Access" and "Access" to rural infrastructure, and which formed the basis of the treatment regime used in the impact model. Our position is that agrarian household with at least the average PCA score were at least optimal in the use of rural infrastructure, and those below were not, hence the Categorisation as Non- Access and Access for the treatment group.

3.1.2 Endogenous Switching Regression model (ESRM): Effect of access to rural infrastructure on livelihood outcome

The Endogenous switching regression was used to estimate the impact of access to Rural Infrastructure (RI) on the livelihood outcomes of the agrarian households. The aim was to examine the specific increase in household monthly income that would accrue to the households who have access to RI versus those who do not have such access. The use of ESRM in this study is premised on its ability to correct for selection bias that may arise from access to RI as a result of some observable and unobservable characteristics of the respondents.

Let d_i denote the latent variable that determines the access of the rural household to the composite Rural Infrastructure, with 1=households in regime 1(access); and 0= households in regime 2 (non-access). Then the following is used to describe the latent variable *di:*

$$d_i^* = \omega Z_i + \mu_i; \quad \ldots\ldots 3$$

$$d_i = 1 \; if \; d_i^* > 0 \quad \ldots\ldots 4$$

$$d_i = 0 \; if \; d_i^* \leq 0 \quad \ldots\ldots 5$$

There are two possible outcomes dependent on the access groups which the respondents belong:

$$y_{1i} = \beta_1 X_{1I} + v_{1i} \qquad if \; d_i = 1 \quad \ldots\ldots 6$$

$$y_{2i} = \beta_{2i} X_{2i} + v_{2i} \qquad if \; d_i = 0 \quad \ldots\ldots 7$$

The y_{ji} are the outcome variables of the continuous equations, X_1 and X_2 are vectors of weakly exogenous characteristics; β_1; β_2 and ω are vectors of parameters to b estimated. We also assume

that the three error terms are trivariate normal, with mean zero and a covariance matrix (Lokshin and Sajala, 2004).

$$\begin{bmatrix} \sigma_{\mu}^2 & . & . \\ \sigma_{21} & \sigma_1^2 & . \\ \sigma_{31} & . & \sigma_2^2 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

Where σ_{μ} is the variance of error in the selection equation; while $\sigma_1^2\ and\ \sigma_2^2$ are variances of error in the outcome (continuous) equation. Also, $\sigma_{21} and\ \sigma_{31}$ are the covariances of μ_i and v_{1i}; and μ_i and v_{2i}, respectively.

The endogenous switching regression model above is one in which the error term of the selection equation can correlated with the error terms in the outcome equation, for which the model is able to compensate. The model could be estimated using a two-step approach or a maximum likelihood approach (Madalla, 1986; Lokshin and Sajala, 2004); or a single step Full Information Maximum Likelihood (FIML) estimation procedure(Alene and Manyong, 2006).

The singe state FIML was used in this study, and it presents estimates of determinants of the treatment as well as the outcome based on treatment groups. Apart from variables jointly considered in the model, a set of identification variables, *"Z" (Indigene of the community and cost of access to infrastructure)* which are assumed to be neutral to the outcome variables are included in the treatment model. Predicted estimates from the FIML was used to obtain conditional impacts of access to rural infrastructure as follows:

i. Potential outcome of respondents who have access and self-select into access to RI

$$E(y_{1i}|x_i, d = 1) = X_{1i}\beta_{1i} + \sigma_1\rho_1 f(\omega Z_i)/F(\omega Z_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 9$$

ii. Potential outcomes of respondents who do not have access and self-select into non access RI.

$$E(y_{2i}|x_i, d = 0) = X_{2i}\beta_1 - \sigma_2\rho_2 f(\omega Z_i)/(1 - F(\omega Z_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

iii. Potential outcomes of those who have access to RI, assuming they do not have access

$$E(y_{1i}|x_i, d = 0) = X_{1i}\beta_1 - \sigma_1\rho_1 f(\omega Z_i)/(1 - F(\omega Z_i)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 11$$

iv. Potential outcomes of those who do not have access to RI assuming they had access

$$E(y_{2i}|x_i, d = 1) = X_{2i}\beta_1 + \sigma_2\rho_2 f(\omega Z_i)/F(\omega Z_i) \text{.....12}$$

The conditional outcomes are particularly important in this study. We are able to derive the Average Treatment Effect on the Treated (ATT) which is the impact of access to RI on the outcomes of those who actually have access. The ATT is the difference in potential outcome of households with access to Rural infrastructure who self- select into the group and the outcome of if they had not had access to rural infrastructure.

$$ATT = E(y_{1i} - y_{2i} \ |d = 1) = X_i(\beta_1 - \beta_2) + (\sigma_{1\mu} - \sigma_{2\mu})\omega_1 \text{.....13}$$

4.0 RESULTS AND DISCUSSION

This section presents the results of findings with respect to the data analysis, including the profile of access of respondents to infrastructure, as well as the effect of the access on their livelihoods.

4.1 Description of Sampled Respondents

The findings (Table 1) showed a male dominated system (75%), with average age of about 49 years, such that 6%, 69.5% and 24.5% of the household heads less than 30 0years, 30-60 years and greater than 60 years, respectively. The average household size was 7 members with majority of the households housing more than 6 members (56%). Educational attainment reveals an average year of formal education given at approximately 9 years, with most of the household heads haven attained only a primary (about 32%) and Secondary education (about 30%).

The study also found that only 43% of the household heads were indigenes of the communities in which they reside, while a 73% were members of a social group. Community agency was high with over 97% participating in community development. With respect to their livelihood, the results show that the average farm size was 7.6 ha, with 66% on farm holding of just about 5 ha. The average years of farming experience of the household head was given as 22 years.

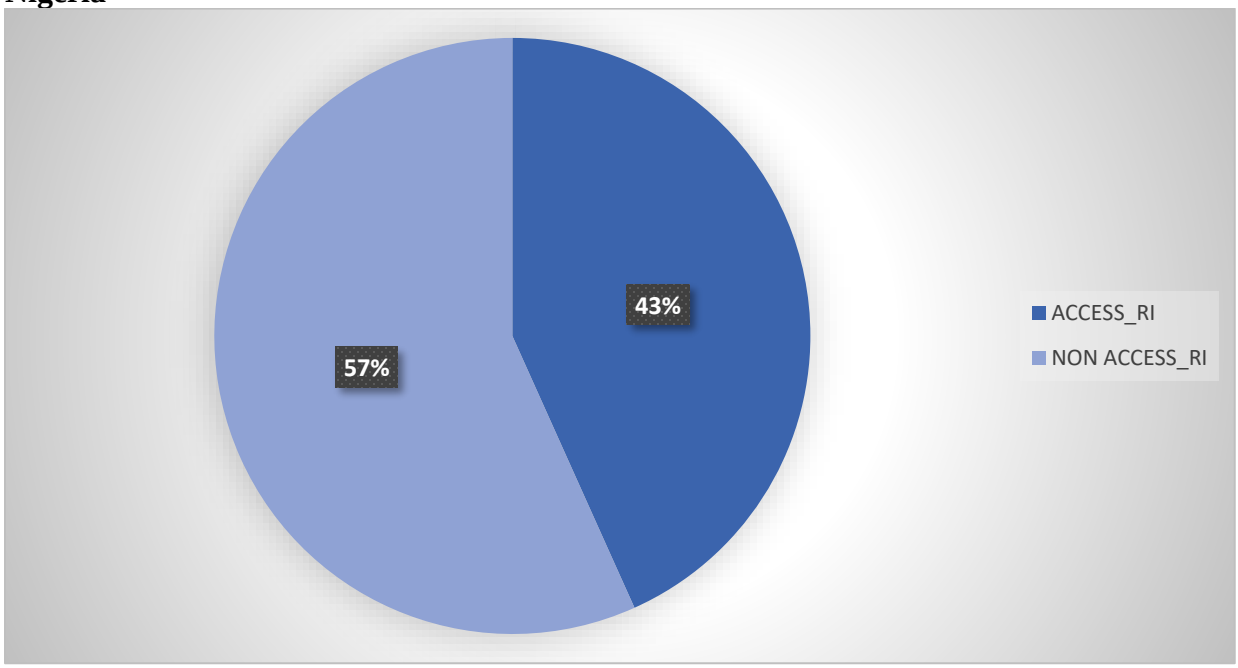
Table 1: Description of Socioeconomic Characteristics of Agrarian Households

Variable	Frequency	Percentage
Sex		
Male	149	74.50
Female	51	25.50
Age		
<30 years≥	12	6.00
30-60 years	139	69.50
>60 years	49	24.50
Average age (years)	48.93(14.75)	
Household size		
<3	22	11.00
4-6	66	33.00
>6	112	56.00
Average household size	7.71(4.23)	
Educational status		
Non-Formal education	34	17.00
Primary	64	32.00
Secondary	60	30.00
Tertiary	43	21.00
Average years of education	8.70(5.31)	
Farm Size		
<5ha	134	66.00
>5ha	68	34.00
Average farm size	7.55(28.56)	
Indigene of community(% of Positive response)	87	43.50
Social Capital(% Positive response)	147	73.00
Community Agency	196	97.99
Years of farming experience		
<10 years	39	19.50
10-30 years	123	61.50
>30 years	38	19.00
Average Years of farming experience	21.97(15.15)	

4.2 Profile of Agrarian Households with Access to Rural Infrastructure

The two categories of Access and Non-Access to rural infrastructure generated form the Principal Component Analysis reveals that (see Figure 1) a majority of the agrarian household had access to rural infrastructure (57%). However, there seems to be a large proportion of the households without access to Rural infrastructure on the aggregate (43%). This result reveals and further strengthens the reasons for some low-level development in rural and farming communities in Nigeria, (Adepoju and Salman, 2013).

Figure 1: Distribution of Respondents by Access to Rural Infrastructure in Southwest Nigeria



Profiling household level characteristics by access to rural infrastructure (Table 2) shows differences in some household characteristics with respect to access to rural infrastructure. The results show that of the two LGAs sampled, households in Ido LGA, had better access to rural infrastructure than those in Iseyin LGA. This is clearly related to the more Peri-Urban nature of Ido LGA due to closeness to the main urban centres in the state. Proximity to urban areas have been implicated as providing a spill over to closer rural communities in terms of infrastructure development and commercialization (Gebre and Gebremedhin, 2019).

Also, findings show that male headed households had higher access to RI than female headed households. Larger household sizes also reflect in significantly higher access to RI, in the same way as a higher education. Having a legal title to land allows for a more than average access to rural infrastructure. The intuition being that legal title confers some permanence that would allow longer term agricultural investment (Lawry et al., 2017).

Table 2: Distribution of Agrarian Households by Access to Rural Infrastructure

Variables/Access to RI	Access(N=114)
Local Government	
Ido	50.00
Iseyin	33.33
Sex	
Male	75.44
Female	24.56
Age	
<30 years	7.02
30-60 years	68.42
>60 years	24.56
Household size	
<3	7.89
4-6	28.95
>6	63.16
Educational status	
Non-Formal education	20.18
Primary	35.96
Secondary	31.58
Tertiary	12.28
Farm Size	
<5ha	63.16
>5ha	36.84
Legal title to land	51.76
Indigene of community(% of Positive response)	47.37
Social Capital(% Positive response)	76.32
Participates in community development	56.12
Years of farming experience	
<10 years	11.40
10-30 years	67.54
>30 years	21.05

4.3 DESCRIPTION OF THE LIVELIHOOD COMPONENTS OF AGRARIN HOUSHEOLDS IN SOUTHWEST NIGERIA

The sustainable livelihood framework shows that livelihood is made up of Assets, livelihood activities and the livelihood outcomes within the context of environmental and macroeconomic complexes. These components with respect to the sampled respondents are presented in this section.

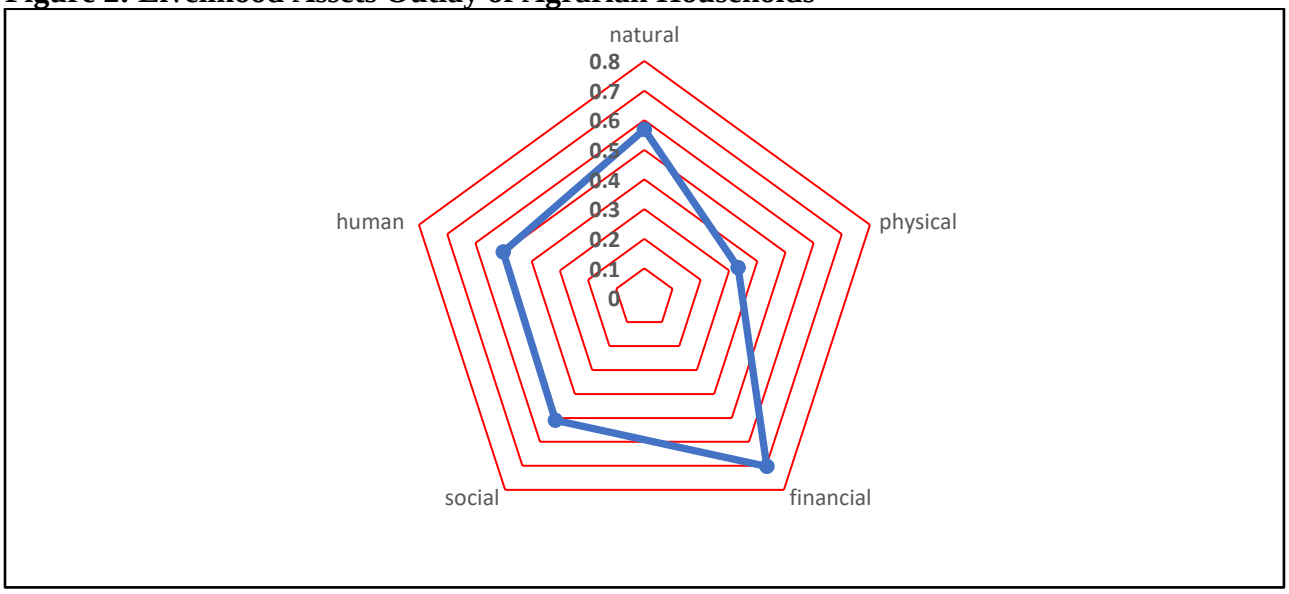
4.3.1 Livelihood Assets

There are five(5) main capital/asset bases for a sustainable livelihood activity system in the SLF; and they have been posited as being able to improve the probabilities of developing sustainable livelihood outcomes (Udoh et al., 2017). These are Natural asset, Physical assets, financial asset,

Human capital, and social capital. We developed a composite livelihood asset score for the respondents following the study of Mao et al., (2020). The weighted average scores of asset components gave an estimated composite asset score of 0.523. This suggests an average livelihood asset status of the agrarian communities, but which may reflect a fragile/vulnerable asset base. The implication may be that these households may not be able to rely on their assets to recover from shocks to their livelihoods.

Asset ownership for the individual assets is as presented in Figure 2. The results revealed that financial assets seem to be the most important asset that could translate to sustainable livelihood strategies, returning a value of 0.702, followed by natural assets (0.569) and social assets (0.510), with human capital averaging 0.501. The least important asset seems to be related to physical assets (0.33). The results are a direct representation of the asset needs of agrarian and rural communities with respect to developing sustainable livelihoods. Literature has shown that finance has been a major constraining factor to sustaining a livelihood in many agrarian communities. The inability to sustain savings, investment and obtain credit facilities to move to higher valued livelihood activities have engendered poverty un many communities (Yang et al., 2018).

Figure 2: Livelihood Assets Outlay of Agrarian Households



The availability of natural assets is also important to agrarian households whose productive activities in many ways are linked to the natural resources around them. This can be a limiting factor in the quest to expand and improve on livelihood activities that could translate to better

outcomes (Babulo et al., 2008). The importance of social assets in driving sustainable livelihoods is made obvious in its ability to employ collective action in driving positive changes. Getz, (2008) found that market social capital was important in improving market access by farmers, thereby expanding their portfolio in Mexico. The need to develop human assets lie in the capability of humans to harness other resources in seeking a livelihood outcome. Human capital includes aspects of training, education, experience and health and other dimensions that improves the capacity of household members to seek a veritable livelihood.

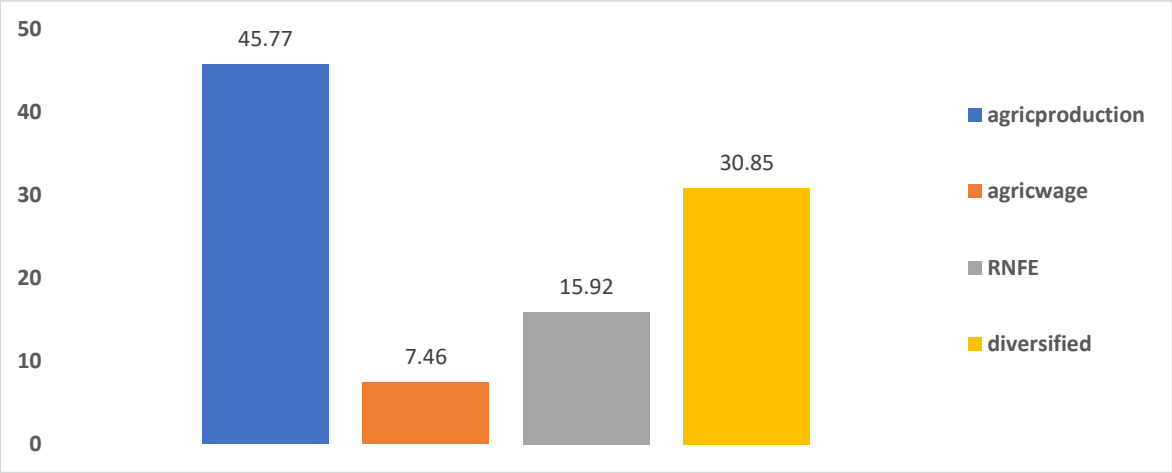
The requirement for physical capital (which includes productive physical assets) is key for agrarian livelihoods. This is especially the case for mainstream agricultural systems. However, the acquisition of these assets is to a large extent a function of access to one or two of the other assets in the livelihood framework. This may account for the below average value of physical assets owned by the agrarian households.

4.3.2 Livelihood activities

Literature has shown that agrarian transformation is shifting rural livelihoods every day (Thornton et al., 2019). Following the studies of Andrade et al, (2008); Alemu, (2012) and Gecho et al., 2014, we posit that the livelihood activities of agrarian households can be broadly categorized as 1. Agricultural production; 2. Agricultural Wage work; 3. Rural Non-farm employment and 4. Diversified. The main criteria for classifying the households were based on proportion of income from the groups, and household labour allocation to the activity.

The livelihood strategies of the agrarian households are presented in Figure 3. The results show that the four main livelihood strategies were Agricultural Production (45.77%), Agricultural Wage(7.46%), non-farm income (15.92%) and a form of diversified livelihood(30.85%).

Figure 3: Distribution of Agrarian Households by Main Livelihood Activities



Agricultural production involves crop production, livestock production or a mix of crop and animal husbandry. On the other hand, agricultural wage encompasses such activities that are related to agricultural production and consumption but for which the household does not perform on its own farm holding. These types of employment may be referred to as "off-farm"; and include labour hires on other farms, processing activities, professional services related to agricultural systems; for which the main income are from the wages paid. Non-farm activities are those related to works not related to farming systems. These include migration works, artisan, professional activities and other clerical works not related to agricultural systems. Classifying a household as involved in non-farm activities imply that these activities make up the largest proportion of the total household income. In a diversified system, no single income generating activity makes up a sizable portion as to be called a majority. Households in this group thus seek livelihood outcomes from a variety of activities which may include farming and nonfarming systems in a bid to improve their livelihood outcomes (Mphande, 2016). This result is in line with extant literature on the livelihood activities in agrarian communities, where agricultural production and agricultural wages dominate, (Babatunde, 2008). However, there have been a shift to non-farm income activities in a bid to improve livelihood income (Adeyemo et al., 2020).

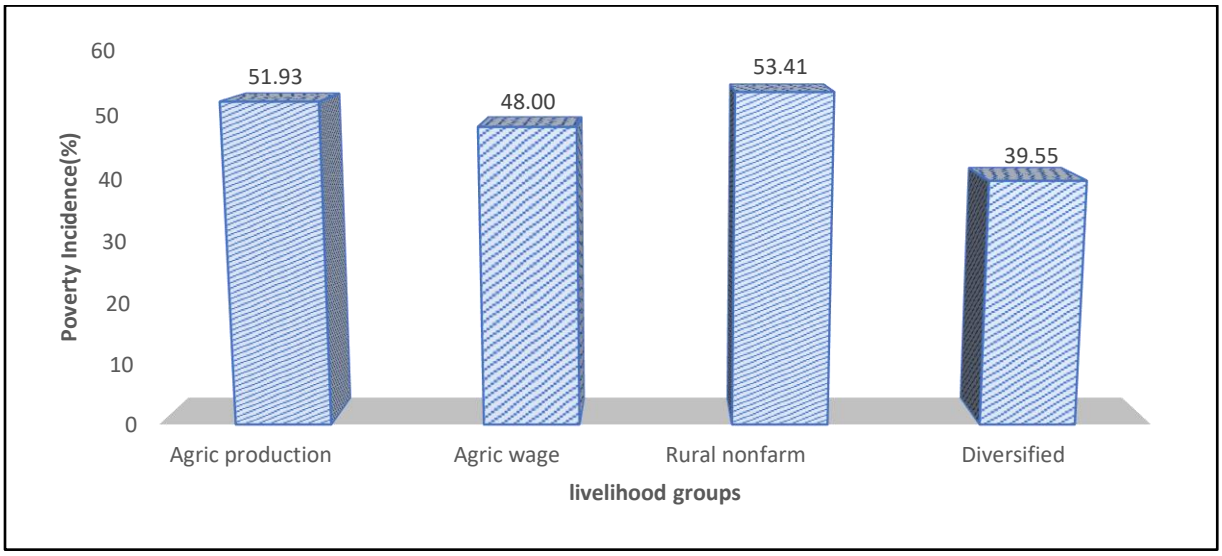
4.3.3 Livelihood Outcomes

The livelihood outcomes of interest in this study are the monthly income from livelihood activities within the household. On the average, monthly household income was estimated at N80, 242.5, and monthly income from a diversified activity was higher than other activities at ₦93196.72. The

next is to be found among those engaged in Agricultural wage work, at ₦ 88333.33/month. The least income however seems to be among those engaged in other forms of Rural Non-Farm activities, with average monthly income at ₦ 71406.25, while those engaged in purely agricultural production had monthly income of ₦ 74222.83/month.

Beyond nominal income levels, we estimated a poverty incidence across the livelihood groups (Figure 4). This was done by using the Foster-Greer and Thorbecke (FGT) relative poverty decomposition procedures (Foster et al., 2010)[3]. We found an overall poverty rate of 48%, which mirrors the poverty rate in the country given as ~40% in 2019(NBS, 2020). Disaggregation of the poverty level by livelihood groups reveals that the poorest households were those in non-farm activities (53.4%), followed by households who are in sole agricultural production (51.9%). n Households in the agricultural wage system had poverty rate of 48%, while the least poverty incidence was found among diversified households (39%). The results align with existing literature of high poverty among rural households in Nigeria-52% in 2019(NBS, 2020), whereas diversification of livelihood has the tendency to reduce poverty levels of such households (Babatunde, 2008).

Figure 4: Livelihood Outcome (Income Poverty) Across Livelihood Groups in Agrarian Southwest Nigeria



[3] $P_{\propto} = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{z-y_i}{z}\right)^{\propto}$; for n as the sample size, z as the poverty line, y_i is the i^{th} lowest income, q is the number of poor people and α is the poverty aversion if ≥0

4.4 Effect of Access to Rural Infrastructure on Livelihood Pathways of Agrarian Households

In this section, we seek to answer the questions: what is the effect of rural infrastructure in the choice of livelihood activities? What is the impact of access to rural infrastructure on the livelihood outcomes of the agrarian households?

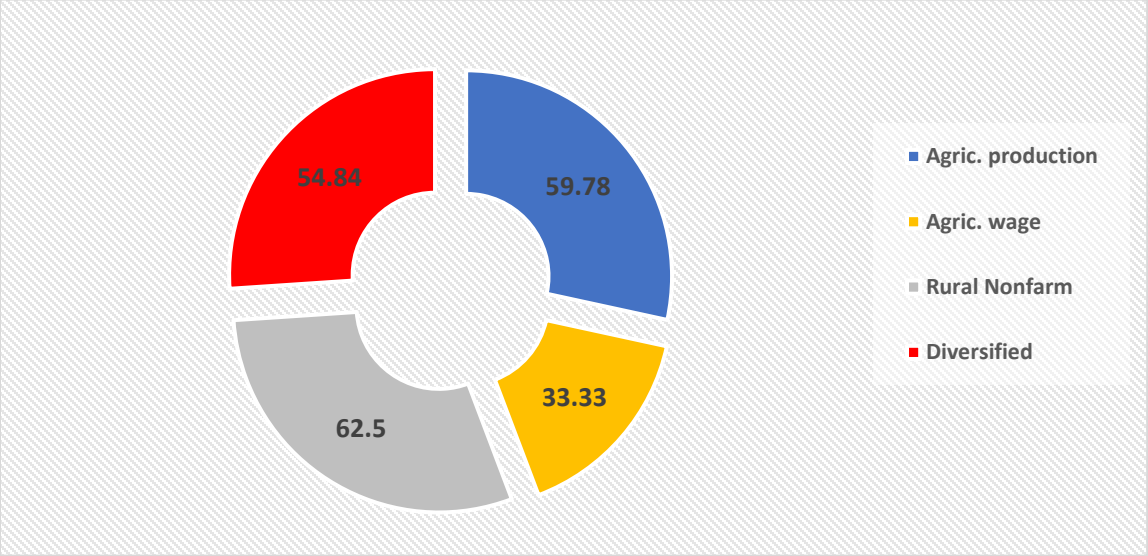
4.4.1 Rural Infrastructure and Livelihood Activities

Profile of Access to Rural Infrastructure by Livelihood Activities

There appears to be a transformation that is shifting livelihood in mainly agrarian communities. The extent and direction of this shift is determined by a number of accelerators, for which Rural infrastructure seem to be one of the most important (Emokaro and Oyoboh, 2016). The structural transformation that could occur from access to rural infrastructure could be sufficient to shift livelihood activities on the one hand; while enhancing the capacity of livelihood activities to improve livelihood outcomes in rural areas.

The result as shown in Figure 5, reveals that the livelihood activities which affords higher access to rural infrastructure involves the Rural Non-Farm activities, with 62% access. This is followed by Agricultural production at about 60% of access. Just about 55% of Households in Diversified livelihood, while only 33% of those involved in Agricultural wage livelihood have access to rural infrastructure. The results reveal the infrastructure need of the different livelihood activities available in rural areas; for which Rural Non-farm activities have the highest need for the RI. Rural Non-farm activities are those that are not mainly farm-based, but which are carried out within agrarian communities as service, and other professionals that may be related to agricultural. They are primarily activities that require higher levels of social amenities and infrastructure above that which is required for on-farm activities (Starkey et al., 2002). The capital formation for such activities is important to drive value addition in the agricultural sector and improve its efficiency in both backward and forward linkages as seen in the case of China (Huang and Ma, 2010).

Figure 5: Percentage Distribution of Access to Rural Infrastructure by Livelihood Sources in Rural Southwest Nigeria



4.4.2 Impact of Rural Infrastructure on livelihood outcomes.

In this section, we seek to find out if access to rural infrastructure is able to improve livelihood outcomes of the rural households. This is on the premise that infrastructure makes it possible for the individual or household to make use of opportunities for value addition in their livelihood activities. Specifically, among rural households, access to infrastructure may be the factor that would move a farmer form subsistence to commercialized system and even to becoming a technology driven agricultural actor (Wickramasinghe, 2015). The extent to which infrastructure is able to modify these activities within the context of the macro economy is observed in the livelihood outcomes from such activities.

We used an endogenous switching regression model to estimate the impact of access to rural infrastructure on livelihood outcomes (household income) of agrarian households in the study area. The use of ESRM is due to the self-selection that could arise from access to Rural infrastructure in the study. This self-selection could be in form of some farmers having greater asset outlay that enables them to better access rural infrastructure than others. On the other hand, it could also mean that the households with low access to rural infrastructure have either chosen not to use it or they do not have the required means to obtain access to the said infrastructure. This self-selection could lead to a bias in the output, hence the need to account for it (Alene and Manyong, 2007). The

ESRM presents a model for the determinants of the binary variable of access to Rural infrastructure, and a separate model for the livelihood outcome of those who have and do not have access to Rural infrastructure.

The result of a Full Information Maximization Likelihood (FIML) to estimate the impact of access to rural infrastructure on the livelihood outcome of agrarian households is presented in Table 3. Predicted outcomes of the FIML are thereafter used to estimate the Average Treatment Effects across the population and chosen samples. The likelihood ratio test of independence is significant (3.83**), implying that an attempt to deal with the endogeneity was appropriate; whereas estimating the impact without accounting for the endogeneity would have returned a bias estimate. The Rho's have similar signs, which indicate hierarchical sorting in access to rural infrastructure (Alene and Manyong, 2007). The Rho's were also significant; and following Abdulai and Huffman, (2014), it can be said that households with access to RI have above average livelihood outcomes, but they would be better off having access to RI than not. On the other hand, household with not access to RI also have above average income at their levels and thus are better off without seeking more access to RI, since the cost of access may be detrimental to their income when they seek to gain more access to RI than they already have.

The results in table 3 shows that the probability of having access to infrastructure was influenced positively by being an indigene of the community (0.37% $p<0.01$). The intuition in this may be related to community ownership of infrastructure and the need to protect such. However, non-indigenes may therefore have to pay higher fees to access such infrastructure; and which may have dire consequences for their livelihoods within the community. Interestingly, participation in agricultural wage employment was found to reduce the probability of having access to infrastructure in the rural areas. This may suggest on the one hand that agricultural waged employees may not necessarily need beyond a basic infrastructure access for their livelihood activities, hence they do not actively seek to access such. On the other hand, the cost of access to such infrastructure may be out of reach of such households.

In the outcome model, the income of households who had high access to RI was influenced by participation in a diversified income (0.41, $p<0.01$), being male (0.49, $p<0.01$); and having a large

household size (0.04, p<0.05). On the other hand, livelihood outcome of household with low access to RI infrastructure have the probability of their income increasing with being in a male-headed household(0.54, p<0.01), age (-0.11, p<0.1) as well as having a large household size (0.07, p<0.01).

Table 3: Estimates of Impact of Access to Rural Infrastructure on Livelihood Outcome of Agrarian Household

Variables	Access Equation (0/1)	Livelihood outcome Equation	
		Income with Access	Income with no Access
Livelihood group(Ref: Agric Production)			
Agric.Wage	-0.737**	0.180(0.361)	-0.326
	0.377)		(0.350)
Non-Farm	-7.7e-05	0.049(0.211)	-0.037
	(0.270)		(0.261)
Diversified	-0.198	0.416***	-0.063
	(0.217)	(0.178)	(0.203)
Sex of household head(Ref: Female)	-0.075	0.500***	0.543***
	(0.222)	(0.180)	(0.215)
Age	-0005	-0.004	-0.109*
	(0.006)	(0.005)	(0.007)
Household size	0.027	0.035**	0.067***
	(0.022	(0.184)	(0.023)
Livelihood asset	-0.418	-0.378	1.181
	(0.964)	(0.732)	(0.816)
Cost of access to RI	-0.001	-	-
	(6.88e-06)		
Indigene of community	0.367**	-	
	(0.164)		
Membership of association	0.058	-	
	(0.193)		
Ln Sigma q	-0.195		
Ln Sigma 2	-0.154		
Rho 1	0.751***		
Rho 2	0.748**		
LR test of independence	3.83**		

*,** and *** represent significant at 10%, 5% and 1%, respectively.

The estimates of impact of access to rural infrastructure is as presented in Table 4. The causal impact of access to infrastructure was found to be highly significant across both groups (low access and high access households). We find that the population impact (ATE) was as high as ₦5598.26 per month. The impact on the population of those who have high access and those who have low access are positive and significant (Table 4). This indicates that access to rural infrastructure has

far reaching impact in transforming livelihood activities to livelihood outcomes among the rural households. We see that the Transitional heterogeneity effect is negative and significant; indicating that the effect of access to rural infrastructure will be more obvious for those who presently have low access to such.

Given such high potential outcome from having adequate access to infrastructure, what could be the constraints in rural areas? We argue that the cost of access may be a very key reason for low access to RI among the rural households. It is therefore important to direct policy properly in the bid to invest in rural infrastructure as indicated in the agricultural plans of the country. The current livelihood systems of agrarian households in such that they are unable to access rural infrastructure (even when such is available) due likely to the high transaction costs involved. Our policy recommendations thus stem from this identified selection bias in accessing rural infrastructure as a percussor for an agricultural revolution in Nigeria.

We posit that in the short term, the rural infrastructure be provided as a public good, so as to reduce the cost of accessing them. This may be sufficient to stimulate the rural economy to stimulate higher valued livelihood and thus the likelihood of transforming the agricultural sector. It is hoped that such a structural transformation will become attractive to investors, and therefore move Nigeria towards a semblance of components of the 4th industrial revolution.

Table 4: Distribution of Impact of Access to Rural Infrastructure on Livelihood Outcomes

	SELECTION TO TREATMENT GROUP		
TREATMENT REGIME ***Livelihood outcomes(Monthly income -₦)***	**Access to RI**	**Non-Access to RI**	**Treatment Effect (Monthly income in ₦)**
Access to RI	66.731.16	24,887.25	ATT=11,528.79***
Non-Access to RI	187,027.5	61,132.79	ATU= 125, 894***
Average Treatment effect			ATE=5,598.26***
Heterogeneity	BH_1=(120,296.34)	BH_2=(36,245.54)	TH=(156,541.88)

Source: Data Analysis, 2020; *** : significance at p<0.01)

5. 0 Conclusion and Recommendations

Findings from the study revealed a slightly above average access to rural infrastructure in the study areas. However, access to rural infrastructure seem to be able to modify some livelihood activities, while it was not a limiting variable in others. Households with access to rural infrastructure was able to return positive livelihood outcomes among the households.

In view of the above, we recommend the following a more intentional development of rural infrastructure within agrarian communities. This is especially important in reducing the costs of access to rural infrastructure in order to promote inclusive access. This is expected to enhance current livelihood activities and shift households to more value-oriented livelihood which may involve technologies that could shift the agricultural system towards an agricultural revolution.

Low participation of indigenes in agricultural production within their communities reflect the extent of out-migration from traditional livelihood systems. Improving rural infrastructure, social amenities and access to markets may be sufficient to deflect out-migration and improve livelihood outcomes. Information asymmetries seem to put non-indigenes of agrarian communities at a disadvantage for higher valued livelihoods. It is therefore important to develop a system of extension education that will be inclusive of current agricultural practices while providing supporting infrastructure for practicing such.

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APPENDIX

Appendix 1: Variable list of Rural Infrastructure for the study

DIMENSION	COMPONENTS	MEASURMENT
Physical Infrastructure		

Road	Paved road	Yes/No
	Cost of transportation	~~₦~~
Electricity	Transformer present	Yes/No
	Connected to grid	Yes/No
	Number of times use light in a week	1] once; 2]twice; 3] thrice; 4] everyday
Social Infrastructure		
Education	Distance to nearest secondary school	Cost to nearest secondary school (~~₦~~)
Health	Distance to nearest health centre	Cost to nearest health centre (~~₦~~)
Institutional Infrastructure		
Research and Extension	Access to extension services	Yes/No
	Number of extension visits in a year	Number
Financial Institution	Has a bank account	Yes/No
	Access to credit	Yes/No
	Distance to nearest bank	Cost of transportation to nearest bank (~~₦~~)