Investigating the Economic and Social Impact of the Nigerian Rural Electrification Fund (REF-1) Program through a Gender Computable General Equilibrium Model.

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Abstract

Increasing rural electrification is critical to development and gender empowerment in rural communities. Electrification enhances agricultural, industrial, commercial, and other economic and social activities in rural areas. Moreover, it promotes the use of domestic electrical appliances that reduce the burden of household tasks typically allocated to women. This paper uses a gender-aware modelling approach to investigate the potential impacts of the Nigerian government's rural electrification fund on the development of rural communities and specifically assesses the policy's differential impacts on men and women's employment and income. To that end, a 2019 gendered Nigerian Social Accounting Matrix (SAM) is used to calibrate a gendered CGE model. The findings show that expanding the supply of electricity through the government program increases market employment for women, factor incomes, and output in the agricultural sector. The study recommends that the government subsidy alone is not sufficient to produce the desired economic outcomes but will need to be complemented with policies that enhances productivity and efficiency.

JEL: R11; Q42; H54; C68

Keywords: rural electrification, public spending, renewable energy, gender CGE

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I. Introduction

Energy is a critical component of economic growth and development. Goal 7 of the United Nations Sustainable Development Goals concerns access to clean, affordable, reliable, sustainable, and modern energy for all. In many developing countries such as Nigeria, however, access to electricity remains a challenge, particularly in rural areas. That, in turn, affects people's ability to rise out of poverty while deepening their socioeconomic challenges (United Nations Development Programme, 2014). Only about 23% of the rural population in Nigeria has access to electricity compared to about 87% for the urban population (World Bank, 2019), one of the factors that contribute to rural-urban migration (Fried & Lagakos, 2017). This limited access to electricity in rural areas invariably has a negative effect on economic and social development, especially on women. To a large extent, women in rural areas in Nigeria are more engaged in agriculture-related economic activities than are men: women are estimated to account for about 60-80% of the rural labor force (British Council, 2012; Ogunlela & Mukhtar, 2009). In addition, women are more likely than men to work in or near the home so that they can combine childcare responsibilities with income-generating activities. Therefore, access to energy is likely to reduce the time they spend on household-related activities in favor of income-generating activities.

To improve the economic and social development of rural communities, the Nigerian government initiated the Rural Electrification Fund (REF). The purpose of this fund is to provide support to expand cost-effective electrification and access in rural areas across the six geo-political zones of Nigeria. Therefore, our study investigates the potential economic and social impacts of this fund on rural development and on women. Specifically, we have applied a gender-focused Computable General Equilibrium (CGE) model to examine the differential impact of rural electrification on men and women.

Our central concern in this study is the potential economic and social impact of government spending on electricity for women's rural development, and our specific research questions were:

a) How effective is government spending on electricity in enhancing rural women's employment?

b) What is the impact of increasing access to electricity on rural women's income?

The outline of the paper is as follows. Section 2 presents some of the issues from the literature. This is followed by a description of the data and methodology adopted for the study (Sections 3 and 4). Section 5 discusses the results of the study, and, finally, Section 6 is the conclusion and policy implications.

II. Literature Review

It is well established in the empirical literature that rural electrification significantly raises the quality of life in rural households. The connection between access to electricity and rural development assesses the potential effects of rural electrification projects important. Access to energy had been linked to sustainable livelihoods while lack of access to electricity intensifies the multifaceted development problems of many rural poor. The importance of electricity is clear: it is used by households, businesses, and industries for heating, cooling, and cooking and to support productive activities that promote overall development (Adenikinju, 2011; Akinyemi et al., 2017).

Evidence in the literature also suggests a strong relationship between the lack of modern clean energy and persistent poverty (Bronicki, 2002; Cherni, 2004; Forrest, 2018). Thus, electrification of rural communities can be an effective way of reducing poverty and promoting sustainable development (Akinyemi et al., 2016; Adenikinju & Falobi, 2009; Wilhite, 2017). Over the years, recognition of the importance of rural electrification to rural development strengthened the Nigerian government's commitment to rural electrification as documented in various energy-policy documents ranging from the National Electric Power Policy of 2001, the National Energy Policy of 2003, Electric Power Sector Reform of 2005, and the Rural Electrification Policy of 2009.

The benefits of rural electrification for women are also well documented in the literature. A survey of the gender-energy nexus literature suggest that women often take on more responsibilities than men in such essential home-energy services as lighting, heating, cooking, and cleaning (Wilhite, 2017); consequently, the impact of the lack of electricity is harder on women. Moreover, the fact that most of this work is undervalued and unpaid (Dunaway, 2014) only serves to widen the socioeconomic gap between women and men. The result has been increased calls for gender awareness in energy policy along with assessment of the effects of such policies on both women and men. Many studies have documented the channels through which investment in rural energy infrastructure can boost women's employment, education potential, and health outcomes (see Kanagawa & Nakata, 2008; Costa et al., 2009; Kooijman-Van Dijk & Clancy, 2010; Pereira et al., 2011; Eleri, Ugwu & Onuvae, 2012; Salmon & Tanguy, 2016; Dutta, Kooijman & Cecelski, 2017; Rathi & Vermaak, 2018; ENERGIA, 2019; and Winther et al., 2019).

The most significant impact of electrification on women is the benefit of time (e.g., fewer hours searching for firewood) and the consequent reduction of physical work or drudgery (Wilhite, 2017) which frees women to engage in employment or business for sustained livelihoods. For example, the use of rice cookers and arrival of grinding mills led to reduced drudgery for women in Nepal, thereby increasing their human capital, potential to pursue income-generating activities, and leisure time (Winther, et al., 2019). In their study on assessing gender and time use differences in Sub-Saharan Africa, Blackden and Wodon (2008) noted that, when women's access to alternative sources of energy is enhanced, women can spend less time on domestic activities and transfer more time to income-generating activities in the agricultural sector. In other words, labor employed in household chores (in Nigeria, these include farming and food processing; see Onyenechere, 2010) became more productive with energy availability. The availability of electricity can also extend study hours and enable the use of digital education tools that enhance educational outcomes and women's empowerment. At the same time, the reduction of indoor air pollution using electrical appliances improves health outcomes.

In most cases, the papers reviewed so far have reported descriptive analyses and their authors have used household or individual surveys, case studies, or econometric estimations. In addition, the methods adopted in those papers do not allow an ex-ante assessment of changes in policies related to rural electrification and its impact on gender. In contrast, an economy-wide approach such as a Computable General Equilibrium (CGE) model can overcome this limitation. Specifically, because a CGE model adopts an economy-wide approach, it can assess what impact a policy change in one sector may have on other sectors of the economy. In other words, it can capture interdependencies among sectors, agents, and markets. Nowadays, CGE models are used in the analysis of the economic, social, and distributional impact of energy policies (Adenikinju & Falobi, 2009; Adenikinju, 2011; Akinyemi et al. 2017; Willenbockel, Osiolo & Bawakyillenuo, 2017) and, more specifically, of renewable energy development (Seung & Kraybill, 2001; Wianwiwat & Asafu-Adjaye, 2010; Borojo, 2015). In addition, a gender-sensitive CGE model can capture forward and backward interactions between paid and unpaid activities (Fontana & Rodgers, 2005; Siddiqui, 2004) as well as feedback effects and linkages for both market and non-market sectors that might result from macroeconomic or sector-based shocks.

In the empirical literature, two major approaches exist to gender sensitive CGE modelling (Severini et al., 2019). On the one hand is the gender disaggregation school that distinguishes labor factors, production, and households based on gender. On the other is the two-systems school that expands a standard model to include unpaid domestic and care work in addition to gender disaggregation of labor factors and households. The work of Fontana and Wood (2000) pioneered the second school of thought. They developed a gendered CGE model based on the notion of production in paid and unpaid economies; they used their model to assess the effects of trade liberalization on women. The approach is to expand the accounting framework of a standard CGE model by disaggregating labor based on gender and, together with market sectors, include household work and leisure. The assumption is that the two additional sectors behave qualitatively like their market counterpart such that inputs and outputs respond to demand and supply but differ quantitatively because the social reproduction sector employs more labor by women (Fontana & Wood, 2000).

Both approaches have been applied to the analysis of gender impact of economic policies and reforms in different countries. The first, which is often criticized for not incorporating unpaid work in the economy, was used to assess the gender impact of trade policies in Mozambique (Arndt, Robinson & Tarp, 2006; Arndt, Benfica & Thurlow, 2011) and Italy (Severini et al., 2019) where the latter innovatively disaggregated mixed incomes generated in each production process by gender. Sinha and Sangeeta (2000) evaluated the impact of structural and policy changes on the welfare of women in India with a gender sensitive CGE model that disaggregated factors of production based on gender and informality. The authors' disaggregation based on formality/informality addresses the limitations of the first approach and was based on the notion that women were more engaged in informal activities and, thus, that their income from both formal and informal sectors should be analyzed.

The two-systems approach has also been used in the analysis of the impact of trade policies on women. Fontana (2004) modelled the effects of trade on women in Bangladesh by experimenting a decline in garment export, a rise in world price of grains and an increase in natural gas export to understand how policy changes have a varying impact on women workers based on the level of education, position as household head and geographical location using a highly disaggregated gender SAM. Applying a similar approach to Zambia, Fontana (2004) found that the liberalization of manufactured imports resulted in smaller employment and wage gains for women than for men.

Chitiga et al. (2010) used a gender focused CGE model that integrated both market and non-market activities to examine the impacts of tariff elimination on men and women in South Africa. Their results showed trade liberalization to be strongly biased against women who were more concentrated in the contracting sectors. Siddiqui (2004) also applied a gendered CGE model to Pakistan to assess the gender dimensions of economic reforms and found support for reduction in income-based poverty when trade liberalization was combined with compensatory measures; for other scenarios, meanwhile, employment in the market sector declined. Fofana (2005) conducted a gendered analysis on the labor market impacts of trade liberalization in South Africa and found that the liberalization would have a much more positive effect on men's real wages than on women's real wages. Fofana (2005) attributed the finding to the fact that men received more labor income from sectors with increased labor demand (e.g., mining) while women are more concentrated in textiles and certain service sectors where value-added prices and production fell, and so, eventually, did labor demand.

The application of gender sensitive CGE models is not limited to trade policies but has increasingly been applied to poverty analysis. Fontana and Rodgers (2005) described how a gendered CGE framework could be applied to the analysis of macro-poverty linkages. Cockburn et al. (2007) used the macro-micro analysis of a gender focused CGE model to assess the poverty impacts of trade liberalization in South Africa. Another area in which gender-sensitive CGE models are applied is the analysis of the care economy—that is, the effects of policies and reform programs on care services for the elderly and children. An example is the GEM-Care CGE model, developed under the American University's Care Work and the Economy—Advancing Policy Solutions with Gender-Aware Macroeconomic Models (CWE-GAM) project and fully documented in Lofgren and Cicowiez (2020).[1] GEM-Care covers market sectors, leisure, and the unpaid care economy. For this paper, GEM-Care was extended to allow for the substitution of energy sources both in the market and the non-market (or household) production. In Section 4, GEM-Care is used to assess the potential differentiated impacts of expanding rural access to electricity on men and women in Nigeria.

In summary, the literature review points out that robust information and econometric studies have addressed the relationship and linkages between rural electrification and its economic impact. The literature reflecting efforts to measure the impact of rural electrification projects in Nigeria, however, is sparse, though such information would be important in providing policy support for government. We therefore respond to gaps in the literature in several ways. First, the REF-1 project is a relatively new government intervention, and, to the best of our knowledge, no study has examined its potential impact on rural communities or on women. Conversely, we used a gendered dataset and model in which the social-reproduction sector was disaggregated into seven parts based upon the types of domestic work performed by household

[1] GEM-Care is a gendered dynamic CGE model originally designed for country-level policy analysis with a focus on issues relevant to care in a high-income country like Korea. The starting point for the model specification is GEM-Core (Cicowiez & Lofgren, 2017), which in its turn draws on Lofgren, Cicowiez, and Diaz-Bonilla (2013) and Lofgren, Harris, and Robinson (2002). GEM-Core has been extended and adapted to the requirements of care and gender analysis, benefitting from the literature on gendered CGE modeling, pioneered by Fontana and Wood (2000) and surveyed in Fontana (2014).

members, an approach used essentially to account for the use of men's and women's time in the production of household services. Because women are most greatly affected by energy poverty, such an approach highlights how REF implementation will, directly or indirectly, impact women differently. Second, many impact-assessment studies of rural electrification ignore gender components despite evidence of the importance of gender dimensions in rural energy projects.

III. Data

3.1. Description and Structure of the 2019 Nigerian SAM

The main data for the CGE model we adopted came from a Social Accounting Matrix (SAM), a square matrix designed to capture all the key characteristics of the structure of the economy for a given year (Nwafor, Diao & Alpuerto, 2010). The SAM consists of rows and columns that explain the linkages between and flow of transactions from firms and households to the government and external sectors and vice versa. The double-entry accounting principle in a SAM requires that, for each account, total revenue (row total) must equal total expenditure (column total). Entries indicate the flow of goods and services from the agents and corresponding payments.

The disaggregation of the GEM-Care Nigeria Database is presented in Table 3.1. The major components of the database that we used were the SAM, data on gendered time use, and a set of elasticities (related to production, trade, and household consumption). The role of the SAM is to define the base values for the bulk of the model parameters, including those covering production technologies, sources of commodity supplies (domestic output or imports), commodity demands (for household and government consumption, investment, changes in inventories, and exports), transfers between different institutions, and tax rates. In general, most of the features of the GEM-Care SAM are like SAMs used for other models, though the GEM-Care SAM has usually been extended to cover household (non-GDP) service production.

Table 3.1. Disaggregation of the GEM-Care Nigeria Database

Category	Item
Sectors (activities and commodities)	*Primary (3)*
	agriculture; forestry; mining
	Manufacturing (6)
	refined petroleum; food, beverages and tobacco; textiles and wearing apparel; wood products; metalmechanic; other manufacturing
	Other industry (3)
	electricity; water; construction
	Services (9)
	trade; hotels and restaurants; transport; financial ser; business ser; education; health; other ser; public administration
	*Household non-GDP services (14)**
	firewood; water ; cleaning; cooking; care adults; care children; other
Factors (11)	Labor, rural, female
	Labor, rural, male
	Labor, urban, female
	Labor, urban, male
	Capital, private
	Capital, government
	Land
	Natural resource, forestry
	Natural resource, mining
Institutions (5)**	*Households (2)*
	rural; urban
	Enterprises
	Government
	Rest of the World
Taxes (5)	Tax, activities
	Tax, imports
	Tax, exports
	Tax, commodities
	Tax, income
Investment (3)	Investment, private
	Investment, government
	Investment, change in inventories

*Non-GDP activities and commodities are disaggregated by household. **The institutional capital accounts are for domestic non-government (aggregate of households and enterprises), government, and rest of the world.

We developed a new SAM based on a 2019 Nigeria SAM (NSAM) developed by Equilibria Consult, an economic research consulting firm based in Ibadan, Oyo State. Nigeria. The SAM, in turn, was based on the 2010 Nigeria Supply and Use Table of the

National Bureau of Statistics; other sources of information were the Central Bank of Nigeria and World Integrated Trade Solutions. The breakdown of the activities and commodities in the original SAM are presented in Appendix Table A.1. However, we introduced several modifications and extensions to the Equilibria Consult SAM. Most importantly, we changed the sector split of value added between labor and capital in order to consider mixed income; such an adjustment was particularly relevant in such agricultural sectors as crops and livestock (see, among others, Gollin, 2002).[2] We also introduced these other changes to the Equilibria Consult SAM: we singled out natural resource rents for land and other natural resources such as those used in mining; we split the trade and transport margins among domestic goods, exports, and imports; we singled out institutional capital accounts in order to account for government domestic and foreign (net) borrowing, private foreign (net) borrowing;[3] we split labor payments by sector into four categories according to their location (rural/urban) and gender (men/women); and we split investment between government and private investment. The SAM contains four categories of tax instruments (direct, indirect, import, and export taxes), and Capital accounts collect savings by institutions and finance private and government investment.

In a second step, we made the 2019 NSAM gender-aware by disaggregating the labor factor into men and women and by creating additional sectors and commodities for social reproduction (non-GDP sectors and commodities) along the lines of the works of Fontana and Wood (2000), Chitiga et al. (2010), and Lofgren and Cicowiez (2020). Basically, the social reproduction output and consumption in the SAM is derived using the replacement-cost approach in which the time households spend on non-market activities such as cooking, cleaning, and caring for children and the elderly is valued by using the average market wage for unskilled workers. To value unpaid domestic and care work, we used a wage that represented the cost of "buying" the household service on the market. The justification for using the average market wage for unskilled worker as a proxy for wage paid for domestic work assumes that domestic work can be categorized

[2] Interestingly, the overall labor GDP share increased from the 26.7% in the Equilibria Consult SAM to 46.1% in our SAM. Note that our figure is closer to the one reported by other sources such as PWT 9.1 and GTAP.

[3] Specifically, three institutional capital accounts are added to the SAM: domestic non-government institutions (i.e., households and enterprises), government, and rest of the world.

as work requiring low skills. Thus, their renumeration can be likened to the wage of unskilled worker. The data for time use was obtained from the World Bank Living Standards Measurement Survey on Agriculture: General Household Survey Panel (GHS-Panel) 2018-2019 Wave 4 for Nigeria.

3.2. Share of Value Added by Sector

Table 3.2 presents the structure and share of GDP in the 2019 gendered NSAM for the various sectors for the distribution of value added, production, imports, and exports. Evidently, the mining sector had the highest share of value added (VAshr) (14.46%) followed by the agriculture sector (14.21%), other services (18.44%), trade (13.18%), and construction (10.37%). Jointly, the services sector contributed more than 50% of value added to the Nigerian economy, much higher than the agriculture and manufacturing sectors with 14.33% and 30.44%, respectively.

Because Nigeria is an oil-exporting country, a significant portion of total exports is crude petroleum, and the mining sector had an export share (EXPshr) of 78.92% The metal-working sector holds 10.41% share of total exports by Nigeria. Invariably, the mining sector is the main exporting sector with a major export of crude oil. On the import side (IMPshr), other services had the largest share with 33.45% while agricultural commodities represented 18.16% and financial services was 10.22%. Overall, the structure of imports in Nigeria is such that, services is the largest component with 58.72%, followed by manufacturing goods having 23.08% and agriculture with 18.2%. Generally, the services sector appears to be driving the economy with significant contribution to growth.

Table 3.1: Structure of GDP Activities (percent)

Commodity	VAshr	PRDshr	EMPshr	EXPshr	EXP-OUTshr	IMPshr	IMP-DEMshr
Agriculture	14.21	14.21	27.48	1.66	0.90	18.16	12.18
Forestry	0.12	0.12	9.79	0.01	0.58	0.04	3.58
Mining	14.46	14.46	0.12	78.92	42.09	0.50	0.64
Refined petroleum	0.30	0.30	0.35	0.34	8.54	0.36	12.26
Food, beverages and tobacco	6.65	6.65	2.43	0.26	0.30	2.49	3.88
Textiles and wearing apparel	3.30	3.30	1.16	0.01	0.03	4.37	12.46
Wood products	0.38	0.38	0.95	0.00	0.06	0.10	2.67
Metalmechanic	1.14	1.14	0.94	10.41	70.50	5.34	63.09
Other manufacturing	4.51	4.51	1.92	0.89	1.53	9.92	19.37
Electricity	0.89	0.89	1.50	0.16	1.38	0.00	0.00
Water	0.19	0.19	0.32	0.00	0.00	0.00	0.00
Construction	10.37	10.37	0.63	0.00	0.00	0.00	0.00
Trade	13.18	13.18	15.94	0.00	0.00	0.00	0.00
Hotels and rest	0.86	0.86	1.62	3.66	32.62	6.43	54.26
Transport	2.70	2.70	3.60	1.70	4.86	1.98	7.64
Financial ser	1.63	1.63	2.78	1.42	6.73	10.22	41.91
Business ser	3.11	3.11	3.63	0.00	0.00	2.42	7.73
Education	1.75	1.75	1.84	0.00	0.00	2.84	14.83
Health	0.52	0.52	0.98	0.00	0.00	1.38	22.34
Other ser	18.44	18.44	19.04	0.55	0.23	33.45	16.35
Public administration	1.28	1.28	2.99	0.00	0.00	0.00	0.00
Total	100.00	100.00	100.00	100.00	7.71	100.00	10.43

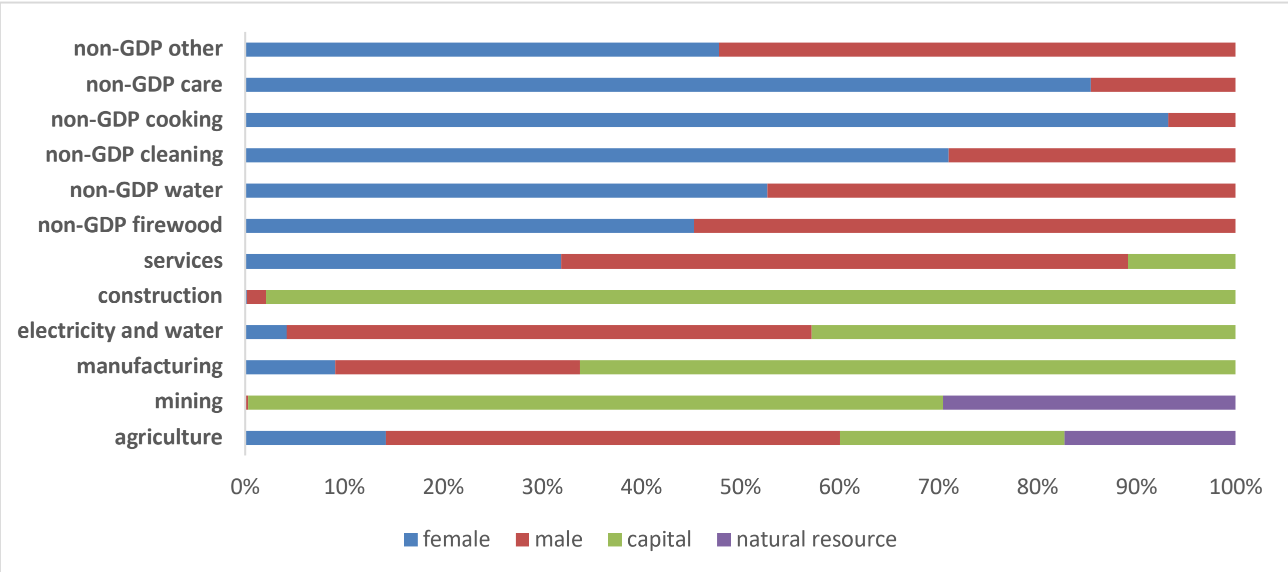
Source: Authors' calculations from the SAM.

3.3. Factor Demand Structure

Figure 3.1 presents the structure of factor demand from the 2019 gender-focused Nigerian SAM for both GDP and non-GDP (household services) sectors. For GDP sectors, the agriculture, electricity and water, and services sectors are labor-intensive. The construction sector had the largest share of capital of all capital-intensive sectors, followed by the mining and manufacturing sector. In addition, natural resources were employed solely in the mining and agriculture sectors. Relating to the non-GDP sector, labor was the only factor used for production in which women's labor was the highest share in cooking activities (a small percentage of men's labor was used). This provided useful insights for our simulation in terms of the ways in which the supply of electricity can enhance the efficiency of household services in which women are engaged.

Women's labor also significantly contributed to caretaking and cleaning services while men's labor was mostly employed in gathering firewood and other household services. In other words, women's labor was engaged more for key household activities in rural areas. Thus, given the different sector-based labor intensities shown in Figure 3.1, an increase in rural electrification that promotes the substitution of firewood and reduces the time required to conduct household chores would be expected to have a larger impact on women than on men.

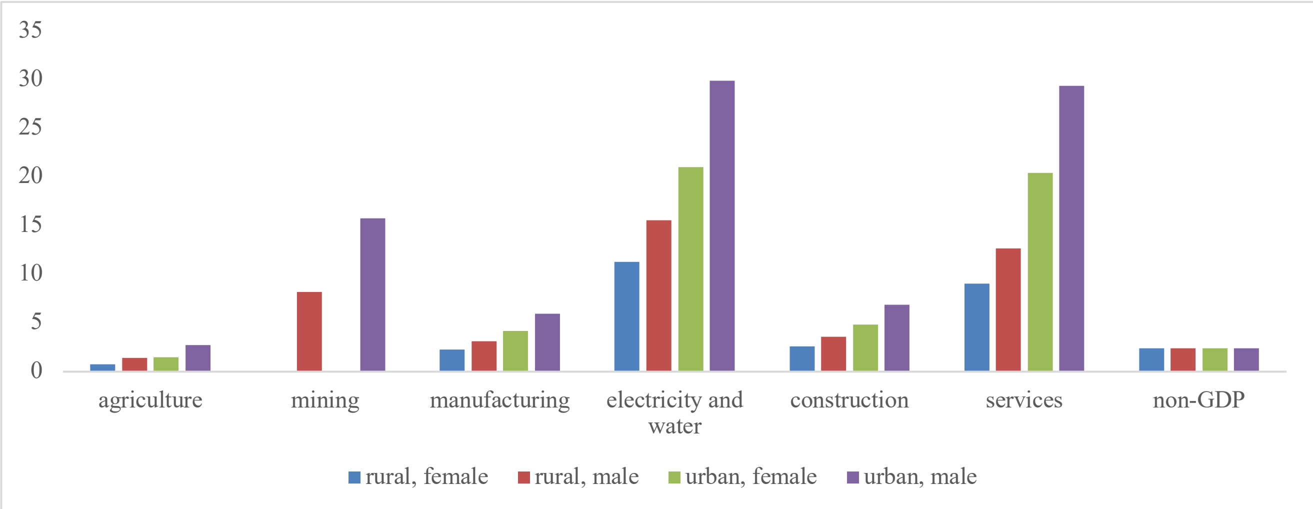
Figure 3.1: Value-Added Composition (Percent) by Sector



Source: Authors' calculations.

Relative wages of the different categories of workers based on gender and geographical location are presented in Figure 3.2. Workers in the urban center received a significant share of wages with men having the largest share compared to women. The disparity in income between rural and urban labor markets emanates from the higher demand for labor in more industrial urban areas. Rural women receive the largest share of income from the electricity and water sector followed by the services sector. Demand for men's labor is predominant in the mining sector with near zero labor engagement of women. Given the higher relative income for women in the services and electricity sectors, expanding access to electricity could enhance the efficiency and productivity of these sectors, thereby supporting income and employment of rural women. In the same vein, self-employment by rural women could be boosted using electricity, which could power equipment such as grinding machines and increase women's ability to open shops for longer hours, which increases income. On average and based on wage estimates from the 2018-2019 GHS-Panel, the gender wage gap in the agriculture and non-agriculture sectors was 46.4% and 29.3%, respectively.

Figure 3.2: Relative Wages (Index; Overall Average Wage=1)



Source: Authors' calculations.

3.4. Non-SAM Data

In our central case, we ran all scenarios under the assumption that labor is a gross complement in both GDP and non-GDP activities (i.e., the elasticity of substitution is 0.8 and 0.5, respectively). We conducted a sensitivity analysis of our results with respect to the value assigned to these key elasticities of substitution.

IV. The Methodology

4.1 Description of the Model

We used a gender-focused CGE modelling approach to assess the potential gender-differentiated economic and social impacts of a government intervention policy aimed at increasing rural electrification in Nigeria. This category of economy-wide modelling approach can simulate the response of the economy to policy shocks, identify patterns of linkages by sector, and recognize their likely gender impacts. Other empirical approaches are limited in their inability to capture indirect effects and linkages by sector within the economy, covering only single variables of interest (Seung & Kraybill, 2001). Additionally, a CGE model can treat many macroeconomic variables as endogenous, compared to econometrics and partial-equilibrium models in which they are treated as exogenous, emphasizing the importance of relative prices (Adenikinju & Falobi, 2006; Benin et al., 2008).

We used the static variant of the GEM-Care model calibrated to the Nigerian SAM described in the previous section. GEM-Care is a Computable General Equilibrium (CGE) model designed for country-level analysis of medium- and long-run development policies with a focus on gender and, more specifically, on the unpaid-caretaking sector (Lofgren & Cicowiez, 2020).[4] Specifically, GEM-Care is a CGE model extended to consider the production of household (non-GDP) services such as cooking, cleaning, and elderly and childcare. In other words, it can model the consumption of household-specific commodities using men's and women's own labor. Its activities and commodities cover both GDP and non-GDP (or household) production, the latter of which includes leisure and household service production for personal consumption.

Technically, the model is made up of a set of simultaneous linear and non-linear equations. It is economy-wide, providing a comprehensive and consistent view of the economy, including linkages between disaggregated production sectors and the incomes they generate, households, the government (its budget and fiscal policies), and the balance of payments. The model is appropriate for analyzing changes in rural electrification because of its integrated ability to capturing household welfare, fiscal issues, and differences between sectors in household preferences, labor intensity, capital accumulation, technological change, and links to international trade and the domestic economy. In each period, the different agents (producers, households, government, and the nation in its dealings with the outside world) are subject to budget constraints:

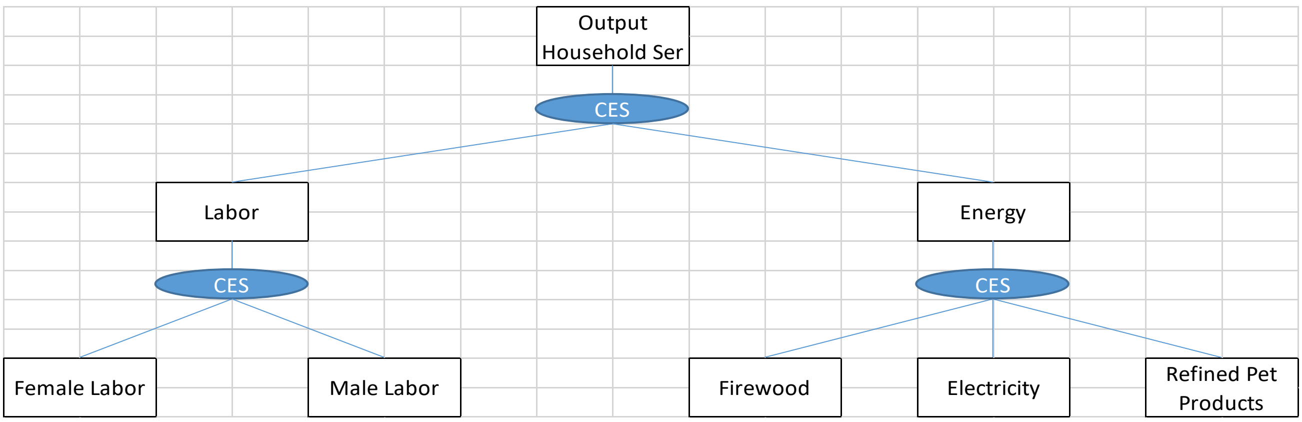
[4] GEM-Care is based on GEM-Core (Cicowiez & Lofgren, 2017), which in its turn draws on Lofgren, Cicowiez, and Diaz-Bonilla (2013) and Lofgren, Harris, and Robinson (2002).

receipts and spending are fully accounted for and, by construction, equal (as they are in the real world).

The decisions of each agent—for producers and households, the objective is to maximize profits and utility, respectively—are subject to these budget constraints. For example, households set aside part of their incomes for direct taxes and savings, allocating what is left to consumption with a utility-maximizing composition. For the nation, the real exchange rate typically adjusts to ensure that external accounts are in balance; other options, including adjustments in foreign reserves or borrowing, are possible but may not work in the long run. Moreover, wages, rents, and prices play a crucial role by clearing markets for factors and commodities (goods and services). For commodities that are traded internationally (exported and/or imported), domestic prices are influenced by international price developments. Given that Nigeria is a small country, it is assumed that international markets demand and supply the country's exports and imports at given world prices.

On the production side, the model consists of a two-level value-added production function with imperfect substitution between women's and men's labor. In the same vein, utility and production functions follow a two-level dimension with imperfect substitution between energy sources (that is, firewood, refined petroleum products, and electricity). Figure 4.1 presents the graphical structure of the production function for household (non-GDP) services.

Figure 4.1: Production Function for Household (Non-GDP) Services



Following the nested structure of production of the model, household services output is produced using labor and energy through a Constant Elasticity of Substitution

(CES) function that equally disaggregates labor by gender using the CES function. On the other hand, energy is decomposed into firewood, refined petroleum products, and electricity by a CES function that follows an imperfect substitution. Furthermore, the model enables endogenous allocation of discretionary time for market and social reproduction. At the macro level, GEM-Care requires the specification of equilibrating mechanisms (or "closures") for three macroeconomic balances: government budget, savings-investment, and balance of payments.

In all simulations, the following macroeconomic closure rules were applied: (a) in order to ensure that simulations were budget neutral, changes in income tax rates on households and enterprises cleared the government budget (i.e., compared to base values, no other changes in taxes or other revenue sources, domestic or foreign, were permitted); (b) in order to ensure that simulations were neutral in terms of changes in country's net foreign assets, foreign savings (the current account deficit) was fixed in foreign currency, an outcome achieved through changes in the real exchange rate; and (c) in order to ensure neutrality across the simulations in terms of investing for the future, real investment was fixed. In addition, we made the following assumptions for factor markets: (a) labor was perfectly mobile across sectors and fully employed; due to lack of data, no labor-leisure choice was considered (implicitly, we assumed that leisure demand was exogenous); (b) capital was perfectly mobile across sectors and fully employed; and (c) natural resources were sector-specific.

4.2 Simulation Scenarios

Using elements of the government's Rural Electrification Strategy and Implementation Plan, we applied GEM-Care to data from Nigeria to simulate four counterfactual scenarios and assess the gender impact of an increase in the supply of rural electricity. First, we assumed a 50% electricity subsidy through the government's REF capital subsidy program to investors who supplied rural households. The justification for the magnitude of this shock was based on the average of the percentages of subsidy grants available to investors. Capital grants for the project are dependent on such factors as coverage, ranging from 35% (minimum) to 72.5% (maximum). The subsidy is presumed to lower the capital costs involved in generating and supplying electricity to rural households which would, in turn, lower the prices rural dwellers pay for electricity.

Second, the study assumed a benchmark shock of a 10% increase in labor productivity in rural household services (cooking and cleaning) based on the theoretical assertion that the availability of or an increase in the supply of electricity would allow the use of electrical appliances and reduce the time women spent on such chores. The aim of this simulation was to capture the efficiency effect of increased rural access to electricity on the production of household services. As a conservative approach, we considered a lower-bound scenario of a 10% shock on labor productivity for household services under the assumption that households would make the corresponding investments required to take advantage of increased electrification. We based this approach on the work of Zidouemba (2019), who assumed that the equitable access of women to productive resources would imply an increase of about 20% in labor productivity. In addition, an analytical review by Morrissey (2018) showed that the impact of rural electrification on household productivity was generally small for all the studies reviewed except for Khandker et al. (2009), who reported substantial positive impacts.

Third, based upon the expected increase in agricultural productivity because of an increase in the availability and use of electricity, we assumed a 5% increase in total factor productivity in agriculture. In other words, agricultural processing is the main occupation for rural households and electric-powered equipment and machines can be used for that purpose. We chose the lower bound of 5% on the presumption that access to electricity would have a greater impact on processing than on other activities such as harvesting or planting because, when agriculture processing is mechanized, diesel-powered equipment is most widely used.

Finally, we considered a fourth scenario that combined the other three to investigate the effects of combining the subsidy with efficiency and productivity effects. In all scenarios, we assumed that households could substitute firewood, refined petroleum, and labor with electricity, but we did not explicitly consider whether the use of electricity would require capital spending by households (such as for acquiring an electric washing machine). Table 4.1 summarizes the simulation scenarios we considered.

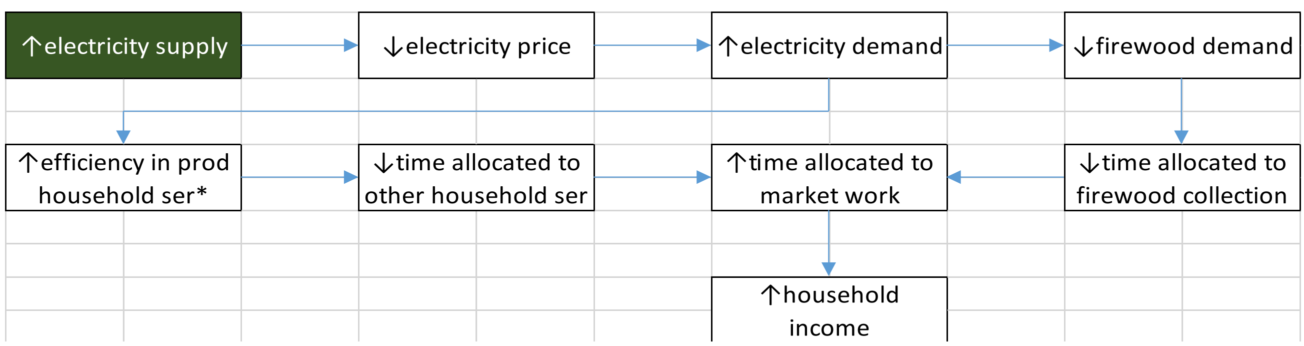
Table 4.1: Simulation Scenarios

Number	Name	Description
Scenario 1	subele	50% electricity subsidy to rural households
Scenario 2	lprdngdp	10% increase in rural labor productivity in household services
Scenario 3	tfpagr	5% increase in total factor productivity in agriculture
Scenario 4	combi	subele + lprdngdp + tfpagr

Transmission Channels

As is evident from the empirical literature, an increase in the supply of electricity and access would be expected to reduce the time allocated by women and men for domestic work such as cooking and cleaning (household labor), which time could then be engaged in market economic activities that improve economic and social outcomes. The policy intervention, then, would theoretically increase the employment and income of women through a channel of transmission in which an increase in the supply of electricity reduces the price of electricity and that, in turn, increases demand. Greater use of electricity implies a decline in the use of firewood for energy and a decrease in the time spent collecting firewood for household cooking. In the same vein, an increase in the demand for electricity would be expected to increase efficiency in the production of household services because less time would be required to do household chores, freeing time that could be deployed in market work and, as a result, increase household employment, wage earnings, and welfare. This transmission mechanism is graphically illustrated in Figure 4.2.

Figure 4.2: Main Transmission Channels



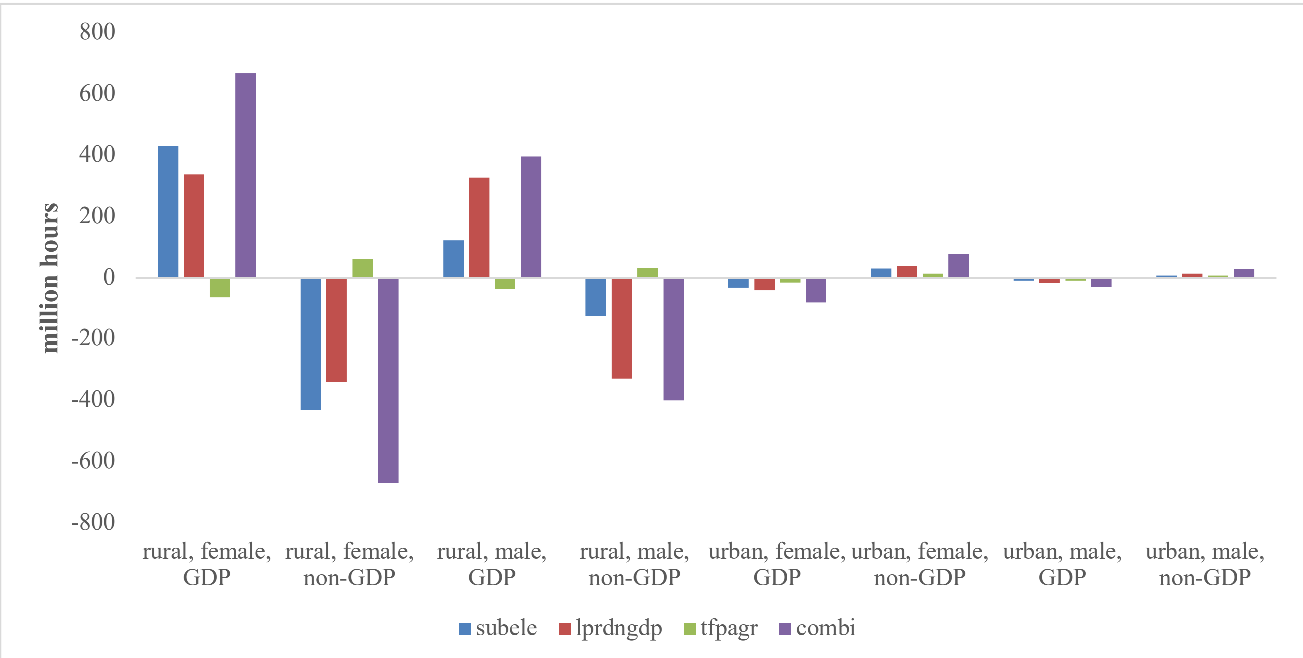
V. Results

Changes in Time Use and Gender Effects

The changes in time use for women and men are presented in million hours and percentage change in Figures 5.1 and 5.2, respectively. They show the magnitude of change in the use of women's and men's labor in GDP and non-GDP activities across the four scenarios. As expected, the direct effect of a 50% government electricity subsidy to support rural electrification was a decrease in demand for electricity combined with an increase in the price of supplying electricity (scenario subele). Thus, both demand for and supply of electricity increased.

The increase in electricity use by rural households promoted a substitution effect in the production of household services which reduced the time women allocated to household activities. More precisely, there was a decrease in the time allocated by rural women and men to the production of household services such as collecting firewood for cooking and food preparation. In turn, time allocated to GDP activities increased. Specifically, the time women allocated to GDP activities increased by 0.65%. Certainly, the increase would have been higher with better job opportunities outside the home (e.g., higher wages for women or a reduced gender wage gap).

Figure 5.1: Changes in Time Use (Million Hours)

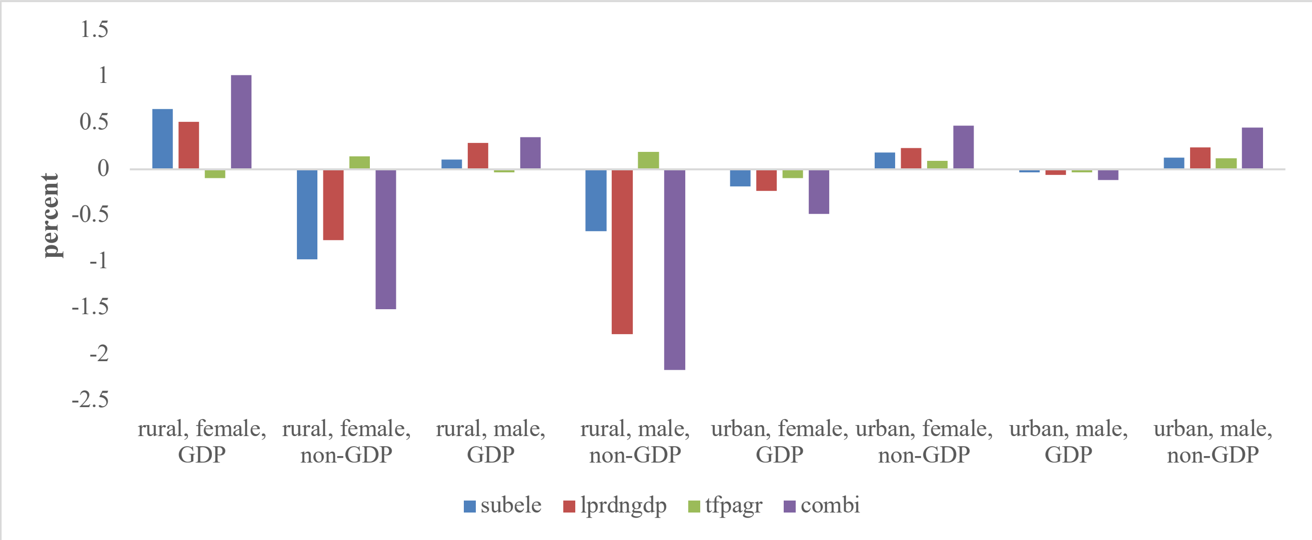


Source: Authors' calculations.

The subsidy scenario produced a decrease in time allocated by rural women to domestic work, although the decrease was lower than that of the combination scenario. Intuitively, this may suggest that subsidizing electricity for rural households alone—without accompanying policies that enhance productivity and raise incomes—may not be effective in enhancing economic benefits such as labor allocation to market work. Further, it echoes the assertion that affordability is significant in expanding rural access to electricity because many rural households are low-income earners. This may also be attributed to the time lag between increases in rural electricity and the economic impact of those increases (e.g. increased economic opportunities that raise incomes as a result of the expansion of electricity).

In the second scenario (lprdngdp), we simulated a 10% increase in labor productivity for non-GDP (social reproduction) sectors, specifically in the production of cleaning and cooking for rural households. This led to a significant drop in the number of hours men and women engaged in non-GDP activities, implying that an increase in the supply of electricity, which enhances the efficiency of such household chores as cooking and cleaning (based on empirical notion of the efficiency effect), reduces time use. Increased availability of electricity supports the use of electrical appliances that further improve the efficiency of domestic work, giving women in households more time for economic activities that improve livelihoods and welfare. This is in line with the study by Winther et al. (2019) at the University of Oslo that found that the arrival of electric grinding mills and the use of rice cookers led to reduced drudgery for women in Nepal.

Figure 5.2: Changes in Time Use (Percent Change w.r.t. Base)



Source: Authors' calculations.

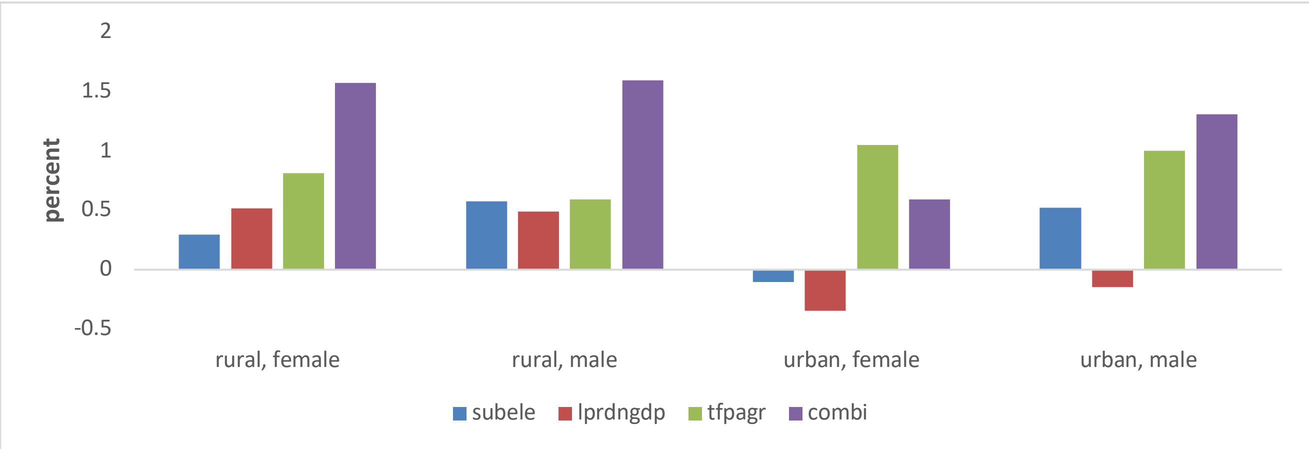
In the agriculture TFP scenario (scenario tfpagr), the time men and women allocated to GDP activities decreased marginally given the marginal increase in time allocated to non-GDP activities. Intuitively, this may not be surprising given the reallocation of labor from agriculture to non-agriculture, in both GDP and non-GDP sectors. Moreover, the agricultural sector in rural areas is not export-oriented, and the domestic market is unable to absorb large increases in agricultural output. Furthermore, even though agriculture is the economic mainstay in rural areas, mechanized agriculture tends to be limited. A large share of agricultural activities such as planting and harvesting are still done with manual tools and with limited use of machines and tractors, especially for women. Because agriculture is significantly labor intensive in Nigeria, and women are more likely to be employed in that sector, increasing electrical supply would have limited impact in reducing time use even with an increase in total factor productivity. The greatest reduction in time allocated to household services was observed in the combination (combi) scenario.

We observed a similar picture in employment effects. Rural women's engagement in economic sectors could increase by 0.65% (Figure 5.2) because of government subsidies to expand the supply of electricity, a finding that was additionally reflected in the second shock, according to which women's labor supply in market sectors increased by 0.51%. The increase was significantly higher under the fourth scenario (the combination of the subsidy for electricity with agricultural and labor productivity in the production of household services). The degree of efficiency in the production of household services because of an increase in electricity determines the magnitude of change in time allocated to other household services. This, in turn, determines the time allocated to market or economic activities outside the home.

Factor Incomes

The simulation of an increase in the supply of electricity for rural households had an impact on factor incomes because of the reduction in the time women allocated to domestic chores as described in the channel of transmission (Figure 4.2). That is, the increase in the supply of electricity improved women's efficiency in performing household work. The reduced time allocated to household production services and improvements in efficiency led to an increase in the time allocated to market work, which raised income and contributed to GDP. As Figure 5.3 suggests, factor income from GDP economic activities increased for both rural men and rural women across all the simulated scenarios. The greatest increase was recorded under the combination scenario, and the smallest effect was observed for the subsidy scenario (for rural women) and the labor-productivity scenario (for rural men). This provides further evidence that a subsidy to expand access to electricity is not, in the absence of complementary policies, sufficient to increase rural women's employment and income.

Figure 5.3: Changes in GDP Factor Income (Wage Bill) in Percentage Change w.r.t. Base

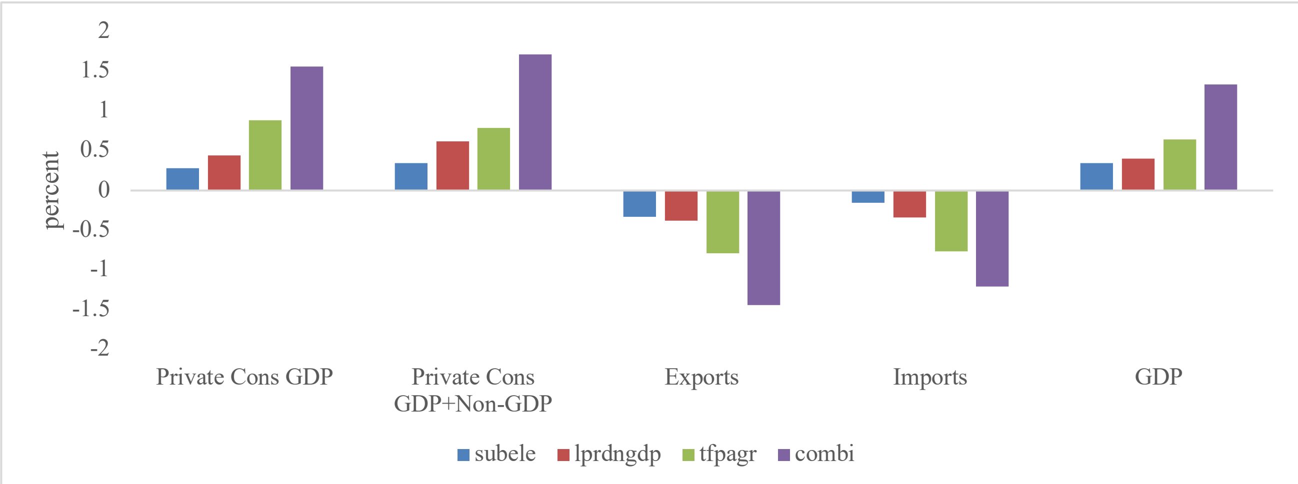


Source: Authors' calculations.

Macroeconomic Impacts

Naturally, changes in time use have an impact on macroeconomic indicators (Figure 5.4). In all scenarios, we noted an increase in the household (private) consumption of both GDP and non-GDP commodities, with the greatest increase recorded under the combination scenario. In fact, the increase in factor incomes from GDP activities allowed the increase in the consumption of GDP commodities. The policy was also found to increase GDP in all scenarios because the availability of electricity improved productivity (supported by the second scenario) and output of industries, yielding positive effects for the economy. In contrast, as a consequence of the change in the sector composition of output (see Figure 5.5), exports (and imports) decreased in all scenarios. Specifically, the decrease in the production of oil and natural gas—the most export-oriented sector in Nigeria—had a negative impact on export. In turn, depreciation of the resulting real exchange rate also led to a decrease in imports.

Figure 5.4: Changes in SNA GDP and Non-GDP Components (Percent Change w.r.t. Base)

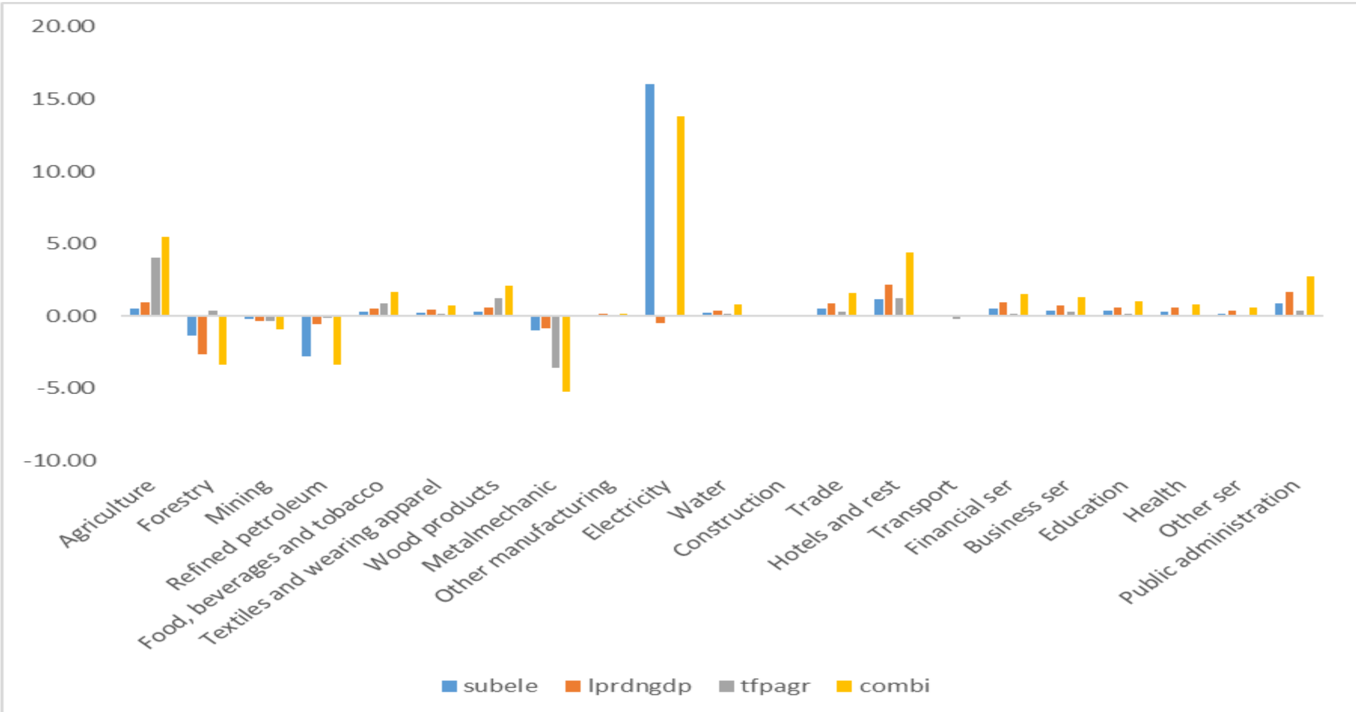


Source: Authors' calculations.

Output Effects by Sector

The effects on output by sector were mixed across sectors and the associated simulated scenarios. Generally, an increase in the supply of rural electricity through the government program resulted in an increase in output of agriculture, beverages, textile, wood products, trade, and services (Figure 5.5). Improvements in labor productivity and efficiency in the most labor-intensive sectors produced a corresponding rise in the outputs of the sectors. In the mining, refined petroleum, forestry, and metal-working sectors, output declined at varying degrees. Interestingly, because deforestation is an environmental problem in Nigeria, the substitution of firewood for electricity reduced the outputs of the forestry sector, producing a positive impact on the environment.

Figure 5.5: Changes in GDP by Sector Output (Percent Change w.r.t. Base)



Source: Authors' calculations.

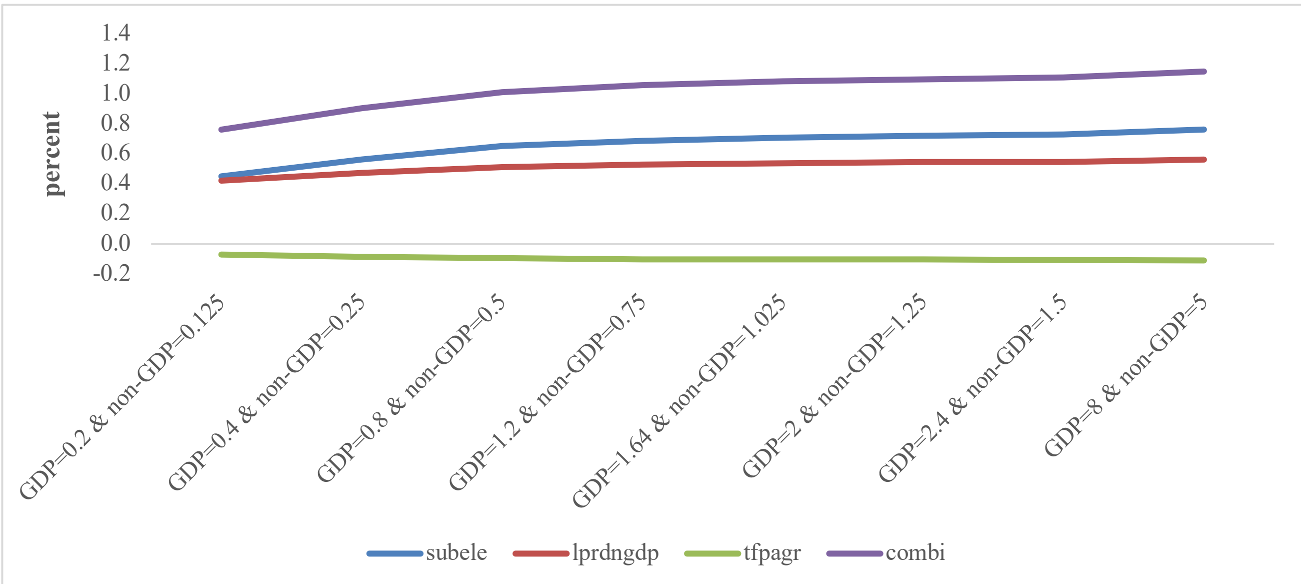
Sensitivity Analysis

Certainly, the elasticities of substitution between working women and men, both in GDP and non-GDP activities, explain the change in women's use of time. In our sensitivity analysis, we focused on two key elasticities: (a) the elasticity of substitution between the production functions of men and women workers, both for GDP and non-GDP activities, and (b) the elasticity of substitution between energy commodities in the production of household services such as cooking (e.g., firewood vs. electricity).

In the first case, and for a given electricity subsidy rate to rural households (scenario subele), the increase in GDP employment and labor income for rural women was higher than the elasticity of substitution between men vs. women workers in the production functions (see Figures 5.6 and 5.7, respectively). In the second scenario (lprdngdp), a similar result is shown (i.e., the increase in labor productivity within the rural household promoted an increase in GDP employment and labor income that was larger than the elasticity of substitution between men vs. women workers in the production functions).

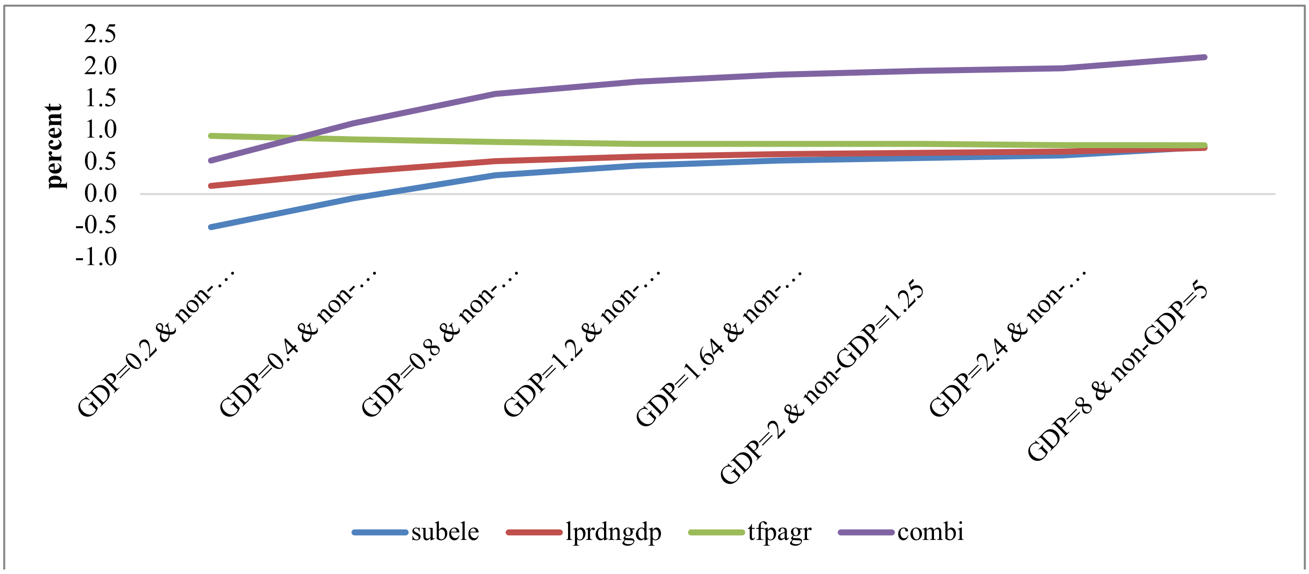
On the other hand, results from the "tfpagr" scenario were less sensitive to the value of this elasticity. In other words, the change in relative prices in this scenario did not promote a large change in GDP employment and labor income for rural women. If anything, the increase in agriculture TFP had a positive effect on GDP incomes and, thus, increased the consumption of household services. In the second case, the higher the elasticity, the easier it was for producers and households to substitute between men's and women's labor. The lprdngdp scenario, which increased labor productivity in the production of household services in rural areas, showed similar results—that is, the increase in labor productivity within the rural household promoted an increase in GDP employment.

Figure 5.6: Sensitivity Analysis for Rural Women's Employment in GDP Activities (Percent Change from Base)—Substitution between Men and Women Workers in GDP and Non-GDP Activities



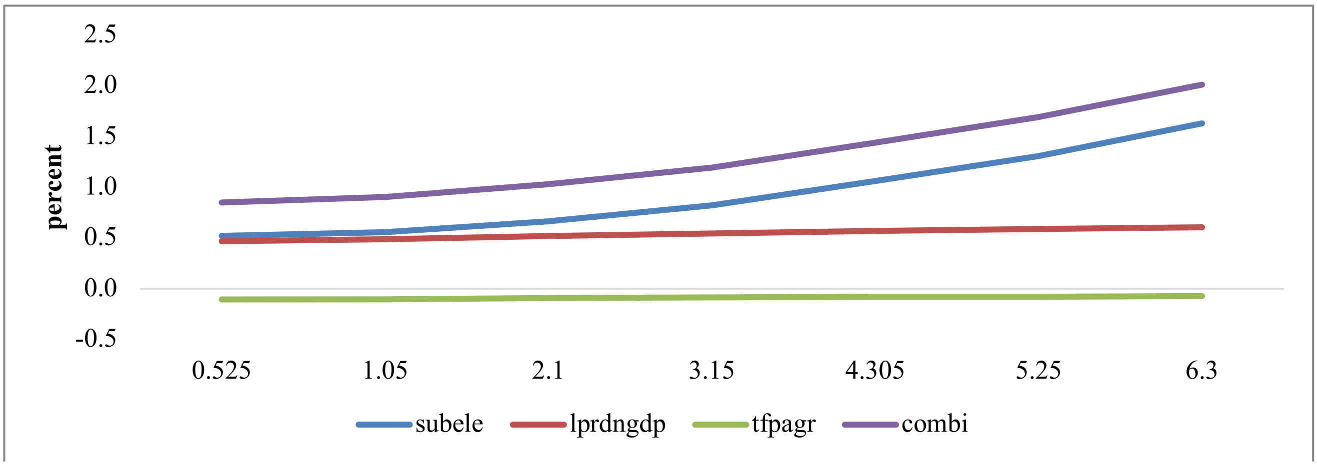
Source: Authors' calculations.

Figure 5.7: Sensitivity Analysis for Rural Women's Labor Income in GDP Activities (Percent Change from Base)—Substitution between Men and Women Workers in GDP and Non-GDP Activities



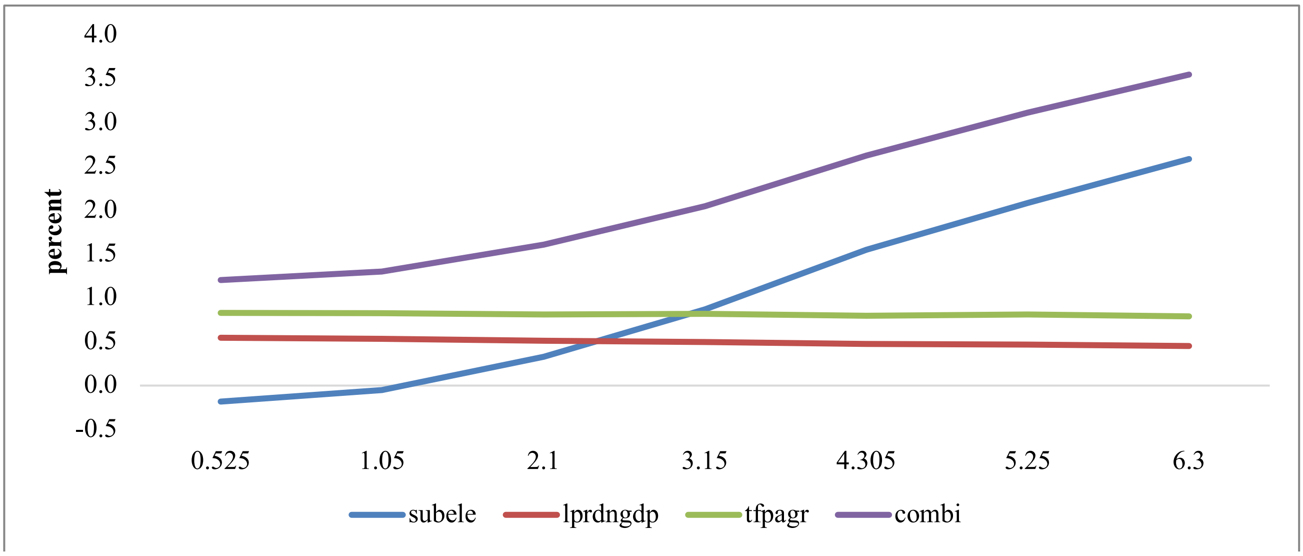
Source: Authors' calculations.

Figure 5.8: Sensitivity analysis for rural women's employment in GDP activities (Percent Change from Base)—Substitution between Energy Commodities (e.g., Firewood vs. Electricity) in the Production of Household Services Such As Cooking



Source: Authors' calculations.

Figure 5.9: Sensitivity Analysis for Rural Women's Labor Income in GDP Activities (Percent Change from Base)—Substitution between Energy Commodities (e.g., Firewood vs. Electricity) in the Production of Household Services Such As Cooking



Source: Authors' calculations.

VI. Conclusions and Policy Implications

Using a gender-sensitive CGE model to show the gender-differentiated impacts of a policy shock, we investigated the economic and social effects of a government program to increase access to electricity for rural households. The rural electrification goal of the Government of Nigeria has been to increase access to electricity to 75% by 2020 and 90% by 2030. As documented in the Nigerian Rural Electrification Strategy and Implementation Plan, the primary objective of the policy is the cost-effective expansion of access to electricity using both grid and off-grid approaches. Using contributions from government and donors, the Rural Electrification Fund (REF-1) is intended to provide a portion of the funding required by investors as a capital subsidy for grid and off-grid connections. Understanding the gender-differentiated impact of government initiatives such as these is necessary because empirical evidence suggests that gender relationships and the situations of both men and women are affected in significant ways by the availability of electricity. Thus, increased rural electrification as a result of the government intervention is expected to increase income and employment opportunities for women which will, in turn, improve welfare for rural households through a reduction in the time women allocate to household and domestic chores and a consequent increase in the time they can engage in market activities that raise employment and income.

We used a gendered SAM implemented in a gender focused CGE model that contained both market GDP and non-GDP (social reproduction) sectors in which labor factors were disaggregated based on gender and geographical location. Our results showed that an increase in the supply of electricity would lead to a drop in women's time use in household production (in line with theoretical expectations). Women's labor dedicated to household production in rural areas reduced across all four simulations, with a more pronounced drop in the combination scenario in which the subsidy was combined with efficiency and productivity effects. This decrease in time allocated to domestic work by women because of the increase in the supply of electricity increased the time they allocated to market and economic work, resulting in an increase in employment and factor incomes.

The findings of our various simulations have policy implications for Nigeria's rural electrification-expansion policies and approaches to implementing economic development. Increasing the supply of electricity to rural households can be effective in enhancing engagement in market and economic activities through an increase in time savings that can be applied to leisure and productive activities. In the same vein, women's economic independence is enhanced with efficiency in the production of household services and an increase in factor income. The government subsidy program alone, however, may not be sufficient to improve rural women's economic and social outcomes. Rather, the program must be combined with complementary policies that promote efficiency and productivity of labor.

We also note some limitations. We excluded the leisure sector in the gendered SAM because of the unavailability of data, and we modelled only certain aspects of the potential impacts of the REF program, focusing on the agricultural sector, the mainstay economy in rural areas. Finally, our modelled scenarios focused solely on labor productivity and did not include capital.

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Appendix

Table A.1: Sectors and Commodities in 2019 Nigeria SAM

	SECTORS	ABBRE		COMMODITIES	
A001	Crop production	CPN	A001	Crop production	CPN
A002	Livestock	LSK	A002		
A003	Forestry	FTY	A003		
A004	Fishery	FHY	A004		
A005	Coal mining	CMG	A005	Forestry	LSK
A006	Crude petroleum and natural gas	C&NG	A006	Fishery	FTY
A007	Metal ores	MOS	A007	Coal mining	FHY
A008	Quarrying and other minerals	QQM	A008	Crude petroleum and natural gas	C&NG
A009	Oil refining	OLR	A009		
A010	Cement	CMT	A010		
A011	Food, beverage, and tobacco	FB&T	A011		
A012	Textile, apparel and footwear	TAF	A012	Metal ores	MOS
A013	Wood and wood products	WWP	A013	Quarrying and other minerals	QQM
A014	Pulp, paper, and paper products	PPP	A014	Oil refining	OLR
A015	Chemical, chemical products, and pharmaceutical products	CCP	A015	Cement	CMT
A016	Non-metallic products	NMP	A016	Food, beverage, and tobacco	FB&T
A017	Plastic and rubber products	PRP	A017	Textile, apparel and footwear	TAF
A018	Electrical and electronics	E&E	A018	Wood and wood products	WWP
A019	Basic metal, iron, and steel	BMIS	A019	Pulp, paper, and paper products	PPP
A020	Motor vehicles and assembly	MVA	A020	Chemical, chemical products, and pharmaceutical products	CCP
A021	Other manufacturing	OTM	A021	Non-metallic products	NMP
A022	Electricity	ELE	A022	Plastic and rubber products	PRP
A023	Water supply and waste mgt	WSW	A023	Electrical and electronics	E&E
A024	Construction	CONS	A024	Basic metal, iron and steel	BMIS
A025	Trade	TRD	A025	Motor vehicles and assembly	MVA
A026	Accommodation and food services	AFS	A026	Other manufacturing	OTM
A027	Road transportation	RTST	A027	Electricity	ELE
A028	Rail transportation and pipelines	RTSP	A028	Water supply and waste mgt	WSW
A029	Water transportation	WTST	A029	Construction	CONS
A030	Air transportation	ATST	A030	Trade	TRD

A031	Transportation services	TTST	A031	Accommodation and food services	AFS
A032	Telecommunications	TELC	A032	Road transportation	RTST
A033	Motion pictures, sound recording, and music production	MPSRM	A033	Rail transportation and pipelines	RTSP
A034	Publishing	PHG	A034	Water transportation	WTST
A035	Post	POST	A035	Air transportation	ATST
A036	Broadcasting	BROD	A036	Transportation services	TTST
A037	Arts, Entertainment, and recreation	AER	A037	Telecommunications	TELC
A038	Financial institutions	FINST	A038	Digital technology	ICT
A039	Insurance	INS	A039	Motion pictures, sound recording, and music production	MPSRM
A040	Real estate	RLE	A040	Publishing	PHG
A041	Professional, scientific, and technical Services	PSTS	A041	Post	POST
A042	Administrative and support services	A&SS	A042	Broadcasting	BROD
A043	Education	EDUC	A043	Arts, entertainment, and recreation	AER
A044	Human health and social services	HHSS	A044	Financial institutions	FINST
A045	Other services	OSER	A045	Insurance	INS
A046	Public administration	PUBA	A046	Real estate	RLE
			A047	Professional, scientific, and technical services	PSTS
			A048	Administrative and support services	A&SS
			A049	Education	EDUC
			A050	Human health and social services	HHSS
			A051	Other services	OSER
			A052	Public administration	PUBA

Source: 2019 Nigerian SAM.