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Gains from Information Infrastructure: Impacts on Nutritious Diets and Women's Economic Empowerment in Ghana

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Summary

Recent developments in information infrastructure and communication technologies have generated considerable interest over their use as a means of overcoming information constraints and improving welfare outcomes. However, little is known about the impact of the various kinds of information infrastructure on nutritious diets and women's economic empowerment in sub-Saharan Africa. This study examined the impacts of such projects on consumption of nutritious diets and women's economic empowerment in Ghana. It also assessed the effects of infrastructure support policies on access to information infrastructure and on these outcomes. To investigate these, we used the Marginal Treatment Effects (MTE) approach, which incorporates the observed and unobserved factors affecting placements of infrastructure projects, nutritious diets, and women's economic empowerment to estimate the treatment effects, and the Policy Relevant Treatment Effects (PRTE). We used nationally representative datasets from the sixth and seventh rounds of the Ghana Living Standards Survey, consisting of 16,772 and 14,009 households, respectively, to construct a pseudo-panel across communities. The GLSS datasets are panel in most communities but not panel at the level of households because the data were not collected from the same households but from the same communities in most of the communities across these rounds. These datasets were complemented with data from focus group discussions and key informant interviews. The findings of the study are:

- The study revealed that residing in a community with internet cafés, ICT centres and community radios results in higher vitamin A-, protein-, and iron-rich food intake, respectively, but the effect of internet cafés on nutritious diet intake appears to be lower in magnitudes compared to the treatment effects of the other information infrastructure.

- The study also revealed that in the untreated state, farm households were observed to be consuming significantly lower vitamin A-, protein-, and iron-rich foods compared to nonfarm households. However, the presence of the information infrastructure allows farm households to at least catch-up in nutritious diet intake with the nonfarm households.

- The slopes of the MTE curves show a positive selection on gains for internet cafés and a mixed pattern of selection observed for ICT centres and community radios which also differs across the nutritious diet indicators.

- Extension access on inputs access and use, and market prices of farm inputs and output are the important immediate mechanisms through which the information infrastructure affects nutritious diet intake, whereas farm output and farm revenue are the important intermediate mechanisms.

- Regarding women's economic empowerment, the results show that living in a community with an information infrastructure significantly increases the average empowerment index, gender parity index and thus, women's economic empowerment, although the impacts of ICT centres and community radios are also slightly higher in magnitudes than the impacts of internet cafés.

- Also, whereas women in farm households have a lower average empowerment index, gender parity index, and women's economic empowerment than women in nonfarm households without any of the infrastructure, they tend to more than equalize, with the information infrastructure, by having a higher average empowerment index, gender parity index, and women's economic empowerment than women of nonfarm households. And this is due to worse economic empowerment conditions of women in farm households in the untreated state.

- The heterogeneities in the treatment effects reveal reverse selection, suggesting that women in communities that are least likely to have the information infrastructure tend to benefit more from having the infrastructure in terms of economic empowerment.

- The results further revealed that engagement in production, hours worked, and attendance of town meetings are potential impact mechanisms through which the information infrastructure affects women's economic empowerment.

- Finally, the Policy Relevant Treatment Effects (PRTE) indicate that expansion of electricity coverage increases the likelihood of the communities having internet café, ICT centre and community radio, and the magnitudes in increased likelihood of getting the information infrastructure are even higher for farm communities.

- But more importantly, an expansion in electricity increases the impact of the information infrastructure on nutritious diet intake and women's economic empowerment per household and women shifted, respectively, which is suggestive of the importance of an enabling environment on increasing farm households and women's access to information infrastructure, and on improving their nutritious diet intake and women's empowerment.

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Abbreviations and Acronyms

FGD	Focus Group Discussion
GLSS	Ghana Living Standards Survey
GoG	Government of Ghana
GPI	Gender Parity Index
GSS	Ghana Statistical Service
ICT	Information and Communication Technology
IINDWEGE	Infrastructure's Impacts on Nutritious Diets, Women's Empowerment and Gender Equality
ISSER	Institute of Statistical, Social and Economic Research
KIIs	Key Informant Interviews
LEAP	Livelihood Empowerment Against Poverty
MoFA	Ministry of Food and Agriculture
MTE	Marginal Treatment Effect
NCA	National Communication Authority
NORSAAC	Northern Sector Action on Awareness Centre
PRTE	Policy Relevant Treatment Effect
URT	Unobserved Resistance to Treatment
VHF-FM	Very High Frequency-frequency modulation
WEAI	Women's empowerment in Agriculture Index
WEEI	Women's economic empowerment Index
WFP	World Food Programme

1. Introduction

Infrastructure is seen as key to economic growth and transformation. This is because of the long-held assertion that the level of investment and the stock of infrastructure constitute important foundations for productivity increase and economic growth (Smith 1776; Gibson & Rioja 2019). Unfortunately, the state of infrastructure in sub-Saharan Africa is worrying and remains one of the top developmental challenges of the region. Inadequate infrastructure such as transport, water, electricity, and communication are major challenges to economic growth, efficiency, and competitiveness of the sub-region (Gollin & Rogerson 2014). However, recent developments in information infrastructure and the widespread growth of information and communication technologies (ICTs) have generated considerable interest over the use of ICTs as a means of overcoming information constraints and improving welfare outcomes, particularly in sub-Saharan Africa (Aker & Ksoll 2016).[1] Despite the views of experts that the developments in information infrastructure seem to be manifesting in nutritional transition (Han 2012; Alssafi & Coccia 2019; Hidrobo et al. 2021)[2], little is known about the impact of these information infrastructures on the consumption of nutritious diets and women's economic empowerment in sub-Saharan Africa.

Existing studies have either concentrated on the content and quality of the information communicated by focusing on the effects of exposure to TV and radio commercials, hours on TV and interactive radios, (Freisling et al. 2009; Huffman et al. 2012; Hudson et al. 2017) or on the effect of individual use of ICT tools such as television, radio, mobile phones, and internet (Parlasca et al. 2020; Muange & Ngigi 2021; Ragasa et al. 2022), but with mixed findings. In particular, whereas studies such as Freisling et al. (2009) and Huffman et al. (2012) observed that exposure to TV and radio commercials is negatively associated with dietary quality, others show a positive association between the use of mobile phones, TV/radio, and interactive ICT on one hand, and dietary diversity and quality due to improved access to food on the other hand (Hudson et al. 2017; Parlasca et al., 2020; Muange & Ngigi 2021; Ragasa et al. 2022). Similarly, studies on the association between information infrastructure and women's economic empowerment are very rare, and the few attempts that consider women's empowerment as an outcome have also focused on either the ICT services such as internet use, mobile cellular, and telephone subscriptions (Shade 1998; Shirazi 2012; Goyal 2011: Nikulin 2017) or on the use of devices such as computers, computer accessories, and mobile phones among others (Prasad & Sreedevi 2007; Ngoa & Song 2021). The other few that considered information infrastructure also defined information infrastructure in terms of customer subscriptions (Ndubuisi et al. 2021), network coverage, and investments in fixed broadband networks (Ford & Seals 2021; Aimene et al. 2021). In addition, these studies focused on employment, labour market, and home adoption of fixed broadband outcomes, and have mostly reported positive effects of subscriptions, network coverage, and investments on these outcomes (see, e.g., Ndubuisi et al. 2021; Aimene et al. 2021). Unfortunately, none has considered the impact of the physical presence of these information infrastructures on women's economic empowerment.[3] An optimal investment in information infrastructure will require detailed information

[1] Wantchekon & Riaz (2019) reported higher correlation between mobile phone use and food access; Ejemeyovwi et al. (2021); and Akinboade et al. (2021) document positive and significant association between male utilisation of ICT and food security. Hidrobo et al. (2021) examine farmers' willingness-to-pay (WTP) for a digital platform which provides nutrition-sensitive information in Ghana, but with emphasis on the demand for this intervention.

[2] Soriano (2007) and Flor (2001) argued that ICTs have the potential of scaling up and accelerating the impact of interventions in value chain targeting poverty alleviation and food security; Han (2012) noted the potential of mobile phones in enhancing accessible and increasing convenience in offering services to customers; McKinley & Wright (2014), and Alssafi & Coccia (2019) observe that provision of information in a virtual environment can encourage and enhance people's search for a healthier lifestyle and improve choices in fruit and vegetables consumption.

[3] In particular, Ndubuisi et al. (2021) examined the effect of digital infrastructure on services sector employment using data on 45 sub-Saharan Africa countries and measured digital infrastructure as the first principal component of the use of internet, mobile cellular, and fixed telephone subscriptions. Ford & Seals (2021) investigated the effect of government-owned broadband network in the USA but also with focus on labour market outcomes, whereas Aimene et al. (2021) examined the effects of co-investment on Fibre to the Home adoption and competition in the French fixed broadband market.

about the impact of the physical presence of the infrastructure on household welfare indicators, including nutritious diets, on women's economic empowerment, and how this mediates in the nexus between women's economic empowerment and nutritious diet intake.

This study contributes to the literature the following ways. Firstly, it contributes to the literature on information and communication technology, information infrastructure, and food security and nutrition (Hudson et al. 2017; Parlasca et al. 2020; Ragasa et al. 2022). Several studies exist on the effect of information and communication technology on food security and nutrition, yet little is known about the effects of the physical presence of information infrastructure on nutritious diets. Studies on nutrition have focused on the effects of individual ownership and use of ICT tools (such as mobile phones, internet, social media, computers among others), TVs and radio (Huffman et al. 2012; Hudson et al. 2017; Parlasca et al. 2020; Ragasa et al. 2022), whereas those on the effects of information infrastructure dwelled on the effects of network coverage, fixed broadband and services on non-nutrition outcomes, including employment (Ndubuisi et al. 2021), labour market (Ford & Seals 2021), household adoption of ICT (Aimene et al 2021), and income and food security (Hudson et al. 2017). This study seeks to bridge this seeming divide by emphasizing the effect of the physical presence of the information infrastructure at the community level on household nutritious diet intake.

Secondly, the study relates generally to the literature on physical infrastructure and food security and nutrition (Thapa & Shively 2018; Nkegbe & Abdul Mumin 2022; Omotilewa et al. 2018). The literature on the relationship between physical infrastructure and food security and nutrition has evolved and the recent efforts in this regard are noteworthy (e.g., Balineau et al. 2021; Fagundes et al. 2022; Nkegbe & Abdul Mumin 2022). However, not much is known on the distribution of returns to these physical infrastructure across different segments of the population. We highlight how the presence of specific information infrastructure at the community level might affect agents with different levels of motivation to having an information infrastructure in the area by estimating the heterogeneities in returns to the information infrastructure associated with nutritious diet intake. Furthermore, we contribute to the literature on public and private capital, infrastructure development and household welfare. Many authors on public capital and infrastructure productivity suggest that household welfare is an auxiliary means by which infrastructure benefits agents (Haughwout 2002). Also, there exists research on the effects of infrastructure services on household welfare such as health, income, expenditure and poverty, economic growth, and development (Agenor 2010; Skoufias & Olivieri, 2013; Gibson & Rioja 2019). Unfortunately, there is not much insight into how infrastructure support policies stimulate information infrastructure development and the impact of such infrastructure development on household welfare (see, Mensah et al. 2014). Our study emphasizes such support infrastructure as a key stimulant in the supply of information infrastructure and on engendering the welfare effects of information infrastructure.

The study is also relevant for policymakers by contributing to the policy discourse on information infrastructure and consumption of nutritious diets in developing countries. There is a call for investment in infrastructure that enhances food supply chains through reduction in the cost of accessing nutritious foods to tackle malnutrition (FAO et al. 2021). However, there are also indications that despite the recent increase in access and growth in use and range of application of ICTs in developing countries (Akinboade et al. 2021), the prevalence of malnutrition and undernourishment has been on the increase in sub-Saharan Africa (Glover & Poole 2019; FAO et al. 2021). For instance, the prevalence of undernourishment in the sub-region increased from 19.4% in 2015 to 20.4% and 20.6% in 2018 and 2019, respectively (FAO et al. 2021). While these appear seemingly contradictory, there is little theoretical justification and empirical evidence to show that improvement in physical presence of information infrastructure will lead to changes in nutritious diet intake in sub-Saharan Africa.

This study also contributes to the growing literature on women's economic empowerment and their access to information infrastructure and use of ICTs (Dixon et al. 2014; Fang et al. 2018; Aimene et al. 2021). Growth in information infrastructure can improve women's access to ICTs, increase their economic opportunities, and narrow gender gaps in wage and consumption choices (Gurumurthy 2006; Brimacombe & Skuse 2013). Existing literature has focused on how infrastructure development affects empowerment mainly through employment prospects, labour market participation and reduced violence

against women (Mohun et al. 2016). Another strand of studies that relates information infrastructure and empowerment considered drivers, prospects, and challenges (Matangi et al. 2013), and the association between information and communication technology and empowerment (see, Dhaundiyal & Moid 2023 and the references therein). In this study, we took a step further from access and services and rather emphasize the effect of the infrastructure on women's economic empowerment.
It also relates to the literature on digital gender gaps and digital inclusion. Increased availability and access to information infrastructure can create a digital divide along gaps in social and economic contexts, which can widen inequity and inequality across gender and other socioeconomic factors (Dixon et al. 2014; Fang et al. 2018).[4] Knowledge of these relationships – although critical for determining whether information infrastructure can stimulate women's empowerment, and reduce gender inequality gaps – is mostly absent from the existing literature on information infrastructure, and women's empowerment. The significant penetration, variation, and data on internet and mobile phones have led to the existing analysis of the digital divide and gender gaps focusing on access to and use of internet and mobile phones without reference to the infrastructure support base of these devices and services (Broadband Commission, 2013; Santosham & Lindsey 2015; Fatehkia et al. 2018). Our study sets itself apart from these by considering the infrastructure support for internet, ICT, and radio in highlighting the effect of the infrastructure on women's empowerment and gender parity. Beyond the focus on intergroup assessment of digital divide and digital gender gaps, our study also provides insights into intragroup differences by showing how returns to information infrastructure vary across women in households with different observed and unobserved comparative advantage situations.

We further contribute to the literature on social economics and social justice (Stiglitz 2000; Perkins 2009). Information infrastructure lies at the heart of economic decisions and research on information economics because of the prohibitive investment cost which makes the initial production of these infrastructures unprofitable (i.e., a form of market failure), making crucial the discussion about their production and provision as well as the roles of government and private sector in this case (Stiglitz 2000). Also, the social justice theories suggest that information services and access on women's empowerment and behavioural change can bring forth awareness and knowledge on the importance of social justice and gender equity (Perkins 2009; Ragasa et al. 2022). Yet, little is known about the effect of information infrastructure on women's economic empowerment and gender parity (Ragasa et al. 2022). We emphasize how the presence of information infrastructure might reduce gender disparity and improve women's economic empowerment. In addition, our results speak to the role support policies may play in enhancing the provision of information infrastructure, as a way of meliorating the market failure associated with the prohibitive provision cost, and women's economic empowerment in developing country settings.

Lastly, this study provides evidence on the effects of infrastructure support policy interventions (such as increasing mobile phone network and electricity coverage). Despite the increasing interest in information infrastructure effect on women's empowerment and nutrition, there is basically no study directly testing the policy effects of information infrastructure boosters on these outcomes (Huffman et al. 2012; Muange & Ngigi 2021; Ragasa et al. 2022; Dixon et al. 2014; Fang et al. 2018). This study adds to the literature and contributes to informing infrastructure policies by showing the policy relevant treatment effects of such supportive interventions.

1.2 Research Objectives

This study was undertaken in Ghana because the situation in Ghana provides the desired context for such investigation. Substantial attention has been given to infrastructure, nutrition, and gender equality and women's empowerment in Ghana. In fact, successive governments have shown vested interest in improving infrastructure, nutrition, and women's empowerment through several legal, institutional, administrative, and policy frameworks since independence (MoGCSP 2015; ILO 2019). Also, budgetary allocations and investments in information infrastructure, nutrition, as well as gender equality, women's empowerment, and social protection have increased over the past two decades (MoCD 2022). However, whereas such investment in information and communication sectors have resulted in some gains as

[4] International Telecommunication Union (ITU) (2017) reported that the percentage of women with access to ICT is decreasing, with women utilisation of ICTs being 11% and 12% less than men in 2013 and 2016, respectively.

revealed by Ghana's infrastructure development rankings, which has increased from 15th in 2016 to 12th in 2018 (AfDB 2018), Ghana's infrastructure indicators remain low when compared to other middle-income African countries (ILO 2019). Furthermore, there are persistent challenges in the provision of these information infrastructures, and in enhancing nutrition and women's empowerment (GoG 2003; Ghartey 2010; MoGCSP 2015), which have generated substantial heterogeneities in infrastructure availability as well as in access and use of ICT across products, genders, and regions in Ghana (GSS 2019).

This study, therefore, examines the impacts of information infrastructure, such as internet cafes, ICT centres, and community radio stations on consumption of nutritious diets and on women's economic empowerment in Ghana. This was realised through the following specific objectives:

1. Examining the impact of community internet cafés, ICT centres, and community radio stations on household intake of nutritious diets
2. Assessing the impact of community information infrastructure on women's economic empowerment.
3. Estimating the effects of infrastructure support policies on access to information infrastructure, and on infrastructure's effects on nutritious diets and women's economic empowerment.

1.3 Theory of Change

In Ghana, the incidence of extreme poverty[5] witnessed an increase by 9.1% between 2013 and 2017 with the situation being quite worrying for households in the agriculture sector and women (GSS 2019). In 2017, the incidence of poverty was highest (42.7%) among households in the agricultural sector. Also, whereas the incidence of poverty in general decreased by 26.1% between 2005 and 2017, that of women decreased by 20.4% over the same period. In particular, the prevalence of obesity and anaemia among women of reproductive age (15-49 years) remains very high at 40% and 42%, respectively, while 41% of pregnant women had no coverage of iron for at least 90 days (USAID 2021). Laar and Aryeetey (2015) indicated that women's vulnerability is largely due to their lower empowerment status which is partly due to their inadequate access and unequal distribution of infrastructure and other opportunities across space and groups. Further analysis reveals that low and inadequate nutrient intake levels are due to thin extension services, weak market linkages and poor command of resources by women which constrain their growth in productivity, income, and consumption (MoFA 2017).

The development and improvement of information infrastructure and services have been considered important in global development agendas (such as the SDGs) and Ghana's national policy efforts. Information infrastructure interventions will produce information services as the output, which will produce three clear immediate outputs: productivity support system, marketing information system, and enablement and inclusivity (Figure 1). The productivity support system, if properly designed, will result in increased production of staple crops and nutritious products through provision of extension services and emergency responses. This support system will also minimise waste of production inputs and loss of output through input use efficiency, and storage and processing (Flor 2015; Dubéa et al. 2020).

Increased output and minimised waste will lead to intermediate outcomes of increased income and expenditures which will ultimately result in increased household nutritious diet intake. On the other hand, Figure 1 also shows that the presence of information infrastructure in a village will lead to increased access to market information services. This will reduce transportation and distribution inefficiencies, through increased access to time-sensitive information, by allowing for the diffusion of pricing information and the elimination of inventory build-ups or shortages (Jensen 2007; Ingram 2011). These will lead to increased household incomes and equitable food distribution across locations, time, and groups, thereby increasing food security and nutritious diet intake by these groups. Finally, the presence of information infrastructure will assist policymakers and households in initiating and formulating inclusive food production, processing, and distribution systems. Women who engage in agriculture and other trades are conduits through which many partners communicate and market, and

[5] Extreme poverty defines the state in which the standard of living is insufficient to meet the basic nutritional requirements of the household even if the household were to spend the entire consumption budget on food (GSS 2019).

these introduce them to new practices in crop production, food processing and preservation, and marketing. Given the central role of women in the production and marketing of foodstuffs in many West African countries including Ghana (e.g., we have the *ohemma* or the Queen Mothers in Ghana) (Hafkin & Odame 2007; Djane & Ling 2015), this will lead to increased women's income and command of resources as the intermediate outcomes, which will deliver increased women's economic empowerment.

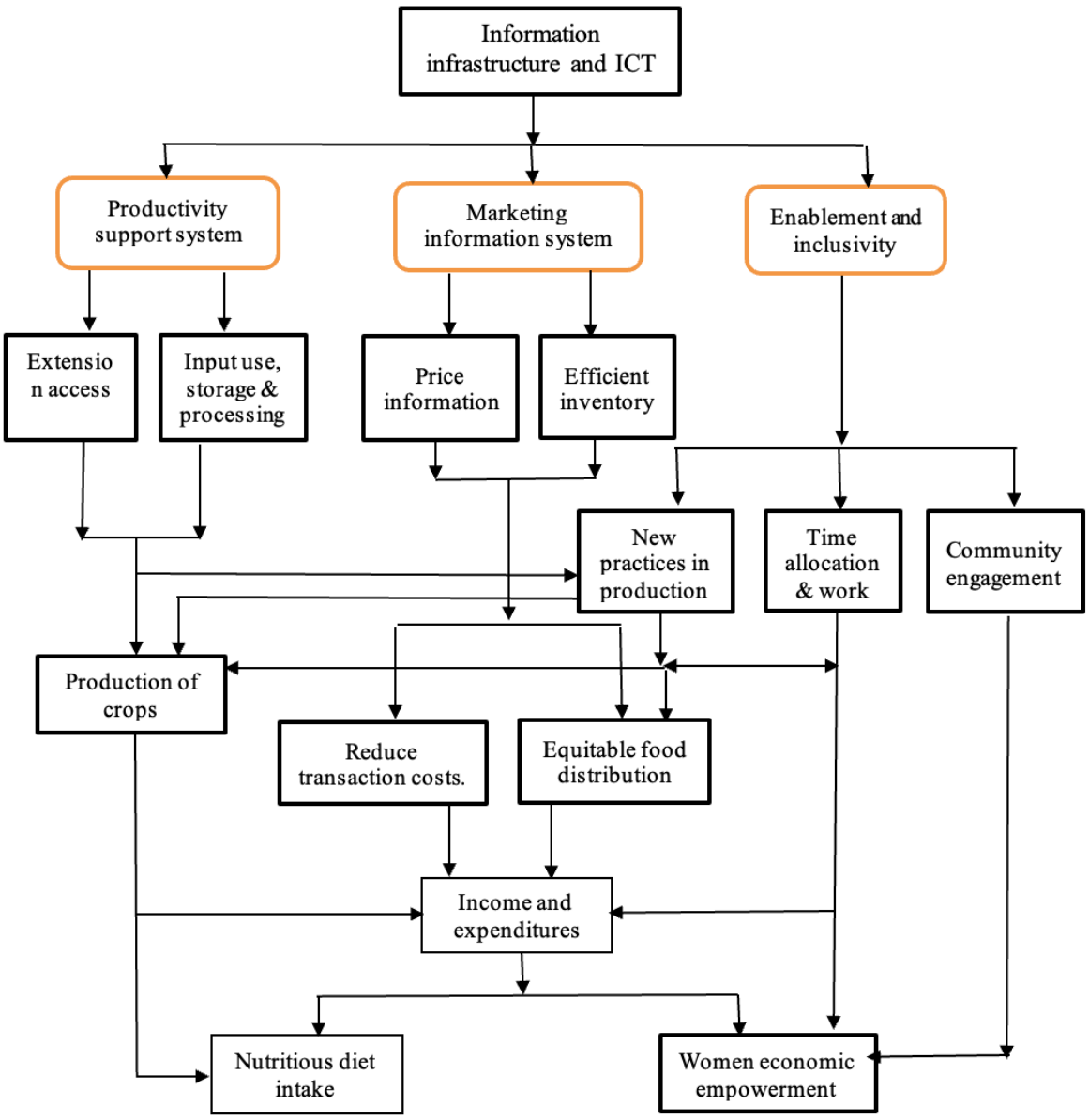

Figure 1. Impact pathways of information infrastructure on nutritious diet intake and women's economic empowerment
Source: Adapted from Flor (2015)

From the theory of change discussed, four key impact mechanisms can be deduced. *The first* mechanism is that information infrastructure can immediately affect women's economic empowerment and nutritious diet intake through access to information that creates agents' awareness and improves their abilities in realising these outcomes. This will happen using ICT devices and access to information, supported by this infrastructure, that promote the outcomes. *The second* mechanism deduces that this infrastructure can affect these outcomes through productivity and income where the infrastructure indirectly contributes to improved and efficient production which ends up affecting women's economic empowerment and nutritious diet intake through increased household productivity and income. *The third* mechanism is through marketing (specifically prices and incomes) where information infrastructure opens marketing opportunities which lead to better prices and household income resulting in women's

command of resources and nutrients intake. *The last* mechanism is through time use for family work. Information infrastructure can increase agents' exposure to resources and knowledge needed by caregivers to provide the required home-keeping services. This can result in changes in time allocation to family work by women, given that they are mostly involved in family work than men in Ghana (GSS 2019). Whereas an increase (decrease) in time use for family work may lead to higher (lower) quality nutritious diets through improved (reduced) care and food processing, this can also result in reduced (improved) women's economic empowerment by limiting (enhancing) women participation in income generation activities and command over productive resources.

1.4 Context

Ghana, like other sub-Saharan African countries, is placed to take advantage of the growing information and communication technological revolution that is driving socio-economic development of most countries worldwide. Although most policies on infrastructure at independence focused on energy, railway, education, road, and health sectors with very little or no deliberate attention given to information infrastructure, the policies, and interventions on information infrastructure sector after this period were also on a short-term, and in some cases on ad hoc, basis (ILO 2019). Deliberate attempts on information and communication technology policies were not made until the early 2000s with the development of the Ghana ICT for Accelerated Development (ICT4AD) Policy. This policy aimed at simultaneously developing the ICT sector and industry in Ghana and the use of ICTs as a broad-based enabler of development goals of all other key sectors of the economy. The relevant priority focus areas of this policy were the deployment and spread of ICTs in the communities, rapid ICT and enabling physical infrastructure development, as well as the modernization of agriculture and development of competitive values-added services sector. Despite this initial effort, subsequent interventions in information infrastructure sector are based on the Medium-Term Expenditure Frameworks (MTEF) of the Ministry with the current framework spanning 2022 to 2025. This framework has been the basis for specific interventions in the ICT sector in Ghana including ICT infrastructure development and the budget allocations for such development (MoCD 2022).

These developments have contributed to increasing the budgetary allocation to the subsector. Budgetary allocation to the ICT sector has witnessed substantial increase from about GHS 30 million in 2016 and GHS 42.9 million in 2017 to about GHS 148 million in 2019. This represented over 300% increase over the allocation in 2016. The allocation to the sector in 2020 was in two folds which cumulatively amounted to GHS 251 million in that year. In 2021 and 2022, the sector's budgetary allocations increased to GHS 351 million and GHS 506.8 million, respectively, representing 39.9% and 44.3% increase over the 2020 allocation (MoCD 2022). These policies and allocations have resulted in substantial expansion of the information infrastructure in Ghana. Available statistics show impressive developments in the frequency modulation (FM) radio and television (TV) broadcasting industry in Ghana. In fact, the number of broadcasting firms has expanded from a total of 405 FM stations and 67 television (TV) stations in 2017 to 684 FM stations and 142 authorized TV stations in 2021, which represent 68.9% and 111.9% increase between these years (NCA 2022). Also, about internet, the total number of fixed broadband access increased from 56,810 subscriptions in 2017 to 77,022 in 2020 and 113,722 in 2021. Although this expansion also resulted in a rise in penetration rate from 0.25% in 2020 to 0.37%, this was after a drop-in penetration rate from 0.20 in 2018 to 0.19 in 2019. Furthermore, the total number of towers managed by the tower companies in Ghana increased from 4,271 in 2017 to 4,980 and 5,133 towers in 2020 and 2021, respectively, with a compounded average growth rate of 4.7% over this five-year period. This development is generating opportunities across all sectors in the country including new employment opportunities, wealth generation and express marketing and e-commerce (GoG 2003; NCA 2018).

The nutrition sector and women's empowerment issues also had their fair share in terms of policies in Ghana. The first nutrition policy in Ghana was formulated between 1951 and 1957 as part of the Accelerated Development Policy focusing on health. Following independence, the National Food and Nutrition Board was formulated in 1961 to promote nutrition by undertaking nutrition education and food demonstration in schools and communities, and to ensure that food was prepared under hygienic and acceptable conditions. However, these approaches to nutrition were a manifestation of the lack of understanding of nutrition issues among professionals (Ghartey 2010). Unfortunately, this continued to

characterize nutrition policies and intervention until 1974. During this period, nutrition was seen mainly as a food intake issue, and largely failed in addressing specific micronutrient deficiencies. After the 1974 World Summit on nutrition, Ghana's nutrition policy from 1979 to 1987 focused on preparation of weaning food for malnourished children. This was characterized by a campaign to introduce weaning foods. The micronutrients emphasis of policies intensified from 1987 to 1990 during which nutrition policies focused on addressing iodine deficiency through salt iodization. The period 1990-2000 defined the era of a positive process of change in nutrition policies in Ghana, during which further policies on micronutrients were formulated.

However, the major setbacks in these previous policies and interventions were the lack of multi-sectoral approach to these policies and the lack of government commitment in relation to human and financial resource allocation (MoH 2013). Hence, a multi-sectoral committee, National Plan of Action on Food and Nutrition, was formulated covering 1995 to 2000 (Ghartey 2010; MoH 2013). The strategic focuses of the Food and Nutrition action plan were to improve household food security, ensure adequate intake of food, micronutrients and other nutrients by individuals, and prevention against nutrition related diseases. These policy objectives remain central and have featured in national strategic and policy documents on nutrition including the Vision 2020 policy framework; the Medium-Term Health Strategy (1997-2001); the Ghana Poverty Reduction Strategy Papers (2001-2013) and the National Nutrition Policy (NNP) (2013-2017). In particular, the NNP is the current nutrition policy framework in Ghana which aims at promoting food security, food quality, food safety, and optimal nutrition and health for individual, household, community, and national levels (MoH 2013).

Also, Ghana's efforts in promoting gender equality and women's empowerment involves a blend of legal, institutional and policy measures. The Women Members Bill in 1960 was the first conscious efforts in this respect, where 10 women were appointed to the legislature (MoGCSP 2015). This was followed by the establishment of the National Council on Women and Development (NCWD) in 1975 as the first national machinery for Gender, with the task of supporting government's efforts in the empowerment of women through income generation, social mobilization, and social development. Subsequently, the NCWD proposed an Affirmative Action and Gender mainstreaming in 1995, which culminated in the formulation of guidelines for the promotion of gender equality, and women's rights and opportunities in Ghana. This also paved the way for the creation of Gender Desk Officers in most Ministries and Departments to improve existing administrative frameworks for addressing affairs of women (Manuh 2007). This was also to ensure the incorporation of gender issues and concerns into sectoral policies, plans and programmes. However, this setup made gender and women's affairs in policies auxiliary and not germane in those policies which led to a re-consideration of the institutional and administrative framework for the promotion of gender equality and women's empowerment.

Realizing this, in 2001, the government established the Ministry of Women's and Children's Affairs which launched the National Gender and Children Policy in 2004. The aim of this policy was to improve the social, legal, civic, and economic as well as cultural conditions of women and children in the national development process (MoGCSP 2015). This policy and associated interventions precipitated the consideration of gender and children's concerns as key focus areas in national policies such as the Ghana Poverty Reduction Strategy (2003-2005), the Growth and Poverty Reduction Strategy (2006-2009), and Ghana Shared Growth and Development Agenda (2010-2013). To provide comprehensive policy guidelines, strategies, and institutional frameworks for government's commitments in achieving its national vision of *a stable, united, inclusive and prosperous country with opportunities for all*, the National Gender Policy was launched in 2015. This policy aims at enabling stakeholders to have shared understanding of the concerns and strategies for addressing gender inequality and social injustice. This policy considered the promotion of social protection by advocating for the development of a Social Protection as well as the Child and Family Welfare Policies (MoGCSP 2015).

These policies and potentials, notwithstanding, there are challenges that have generated substantial heterogeneities across products, gender, and region in access and use of ICT products in Ghana (GSS 2019). For instance, whereas 74.3% of the population aged 12 years or older use mobile phones, only 7.2% own at least one type of computer device, with 21.1% and 2.0% of the population having knowledge of ICT skills and have used e-commerce in trading, respectively. Similarly, women have

consistently lagged men in terms of ownership, knowledge, and use of these products in Ghana. In fact, male ownership of computer, use of computer, use of mobile phones, ICT skills and use of e-commerce are 10%, 10%, 8.2%, 12.8% and 1.8%, respectively, more than that of females (GSS 2019). This also coincides with the situation of women's empowerment and nutrition in Ghana. Available evidence suggests that while the total employed population below the poverty line is 8.7%, the percentage of women below the poverty line is 9.6% compared to 7.9% of men. Furthermore, there is substantial difference in the proportion of the population above statutory pensionable age receiving pension between men (21%) and women (7.2%) in Ghana (UN Women Data Hub 2016). Also, existing evidence suggests that malnutrition is a gendered phenomenon in Ghana, as reports show that improving maternal care is associated with reduction in malnutrition (de Groot et al. 2020). The situation in Ghana, therefore, provides an appropriate context for the current study.

2. Methodology

2.1 Data

We used mixed methods (i.e., quantitative, and qualitative) in this study but with a focus on secondary data for the quantitative analysis. The secondary data were complemented by qualitative interviews where we conducted some key informants' interviews and focus group discussions. In respect of the quantitative methods, we used data from two major secondary sources, with focus on households and women in Ghana. The main data sources were the sixth and seventh rounds of the Ghana Living Standards Survey (GLSS) which were conducted by the Ghana Statistical Service between October 2012 and October 2013, and October 2016 and October 2017, respectively. Our decision to use secondary, and specifically the GLSS, datasets is motivated by two main reasons.

First, the fact that some of the information infrastructure is very scarce, even at the district levels, implies that the use of primary study will require we survey a relatively large number of villages and districts to have sufficient households in villages and districts with and without each of the infrastructure, which the timelines and the finances in hand will not permit us to do. This leads to the second reason: the samples for the two rounds of the GLSS datasets are nationally representative (see GSS 2014; GSS 2019) and provide information on most of the physical information infrastructure under consideration at the community level. The sixth and seventh rounds of the survey consist of 16,772 and 14,009 households in 1,200 and 1,000 enumeration areas, respectively. The GLSS datasets are panel for most communities but not panel for the households since it was communities and not households that were observed at the two rounds. Given that our analysis was conducted on households, when these datasets are appended together it gives a pseudo-panel across rounds and a total of 30,781 households.

These data provide detailed and valuable information on the living conditions and well-being of households and communities in Ghana. The datasets cover community level information on completed and on-going information infrastructure, other community development projects, markets, and prices for various products in communities. In respect of information infrastructure, the GLSS datasets provide community level information on the existence of post offices, internet cafés, ICT centres, and to a lesser extent community level information on community radio/TV and telecom mast. However, the data points on community radios and telecom masts, which had to be extracted from the other community development projects option in the community questionnaire, are very few. To circumvent this limitation, we used data obtained from the National Communications Authority's (NCA) report on the list of authorized VHF-FM radio stations in Ghana for the fourth quarters of 2013 and 2018. This report contains information on the name, address, date of first and last renewal of authorisation, assigned frequency, status, type of station, and more importantly the location (i.e., town/city) of the station (NCA 2013; 2018). Information obtained from these reports were used to calculate the descriptive statistics on community radio station in Table A1.

The interest in this study is to examine the physical presence of information infrastructure in a community on the outcomes. This calls for observation on whether a household resides in a community

with an infrastructure or not. Given this reason and the availability of data from the two main sources, we used information on internet cafés, ICT centres, and community radios as the indicator variables for the physical presence of each of these infrastructures in the communities. Pulling all the datasets together resulted in us having observations on 19,707, 19,399 and 19,704 households for internet café, ICT centre and community radio, respectively. Each of these was used as a dependent variable in the first stage model (i.e., the selection variable) in the estimation of drivers of households' residence in a community with an information infrastructure for each of the objectives. The outcomes for objective 1 are vitamin A, protein, and hem-iron intake by households and so the unit of analysis was the household. To achieve this, we used data from the food item consumption model of the GLSS datasets. The datasets contain information on household consumption of specific food items over seven visits. The datasets cover household consumption of staples, pulses, dairy, meat, fish and eggs, vegetables, fruits, fats, and sugars which are required for the construction of the nutritious diets outcomes to be used. Specifically, we used the food consumption score-nutrition which considers the frequency of vitamin A-, protein-, and Hem-iron-rich food intake in the household (WFP 2015). The vitamin A-rich foods consist of dairy, organ meat, eggs, orange and green vegetables, and orange fruits; protein-rich foods involve household consumption of pulses, dairy, flesh meat, organ meat, fish, and eggs; and Hem-iron-rich foods entail the intake of flesh meat, organ meat and fish (click here description calculation in supplementary file). The calculated consumption scores were used as the outcome variables in equations (1) and (3) (discussed in the next subsection).

In objective 2, which is primarily on women's economic empowerment, we constructed a proxy index of women's economic empowerment using information related to the indicators of the Women's Empowerment in Agriculture Index from the GLSS datasets. Thus, the unit of analysis is women. Although the GLSS datasets do not have the comprehensive information required to construct the Women's Empowerment in Agriculture Index (WEAI)[6], these datasets contain household and individual socio-demographic and economic information that makes it possible to construct proxy measures of the Women's Economic Empowerment (WEE) in line with some of the components of the WEAI. Specifically, the datasets cover information on household members' participation in income-generating activities; person responsible in deciding use of income from wage and salary; ownership, responsibility and values of land, farms, non-farm enterprises, household consumer durables, and other assets as well as access to credit, among others. The data also contain information on individuals in a household responsible for household expenditure and detailed expenditure items, and the hours of work by individual household members across major economic and household activities. These were used to construct the women's economic empowerment index (WEEI), which served as the outcome in the case of objective 2.

The qualitative methods used were Key Informants Interviews (KIIs) and Focus Group Discussions (FGDs). To ensure that the qualitative data collection exercise represented views of experts and, especially farm households across Ghana, we divided Ghana into three zones, namely, northern, middle, and southern for the interviews. Also, given the interest in soliciting views from information and communication technology, nutrition and empowerment experts, the collection exercise ensured that we covered experts across these themes. Specifically, KIIs were conducted for nutrition experts, women's empowerment experts and information experts. In the southern zone, KIIs were conducted for two (2) experts each across these thematic areas. For the middle zone, we interviewed two (2) nutrition experts, three (3) women's empowerment experts and two (2) information infrastructure and services experts. Finally, we interviewed three (3) nutrition experts, two (2) women's empowerment experts and two (2) information infrastructure and services expert in the northern zone (click here for Table A2 supplementary file for the list, designations and organizations of the experts interviewed).

For the FGDs, we conducted these along the three zones (i.e., southern, middle, and northern zones). In each zone, we targeted two (2) communities, at least one rural and one urban/peri-urban, in which there

[6] The WEAI constructs a measure of women's economic empowerment in agriculture by collecting detailed information on individual household members' participation, ownership and decision making in operations and use of proceeds along five dimensions. These dimensions are: 1) role in household decision-making around production and income generation; 2) access to productive capital and credit; 3) individual leadership and influence in the community; 4) decision making; and 5) time allocation.

is at least an information infrastructure, and then conducted one focus group discussion in each of the communities. The targeted participants of the FGDs were farm households and this was organized along gender lines. Thus, we ensured that one FGD was held exclusively for women in one of the two targeted communities, and the other FGD in the second community was organised for men. These qualitative methods were used to address questions relating to why one information infrastructure may be preferred to another in a community or setting, specific uses of the information infrastructure, why they think the information infrastructure is beneficial or not, and why they think the information infrastructure is contributing to increasing nutritious diet intake and women's economic empowerment or not, among others. These KIIs and FGDs were transcribed for use in the report.

2.2 Analytical Framework

Our objectives require analysing the impact of each information infrastructure and the impacts of infrastructure support policies on the outcomes of interest (i.e., intake of nutritious diets such as Vitamin A, Protein, and Hem-iron, and women's economic empowerment). We used the Marginal Treatment Effect (MTE) approach. The MTE framework is based on the generalised Roy model, which assumes that treatment (i.e., whether a household or a woman resides in a community with an information infrastructure) is a binary variable, denoted by C_i, and takes the value of 1 if household/woman i resides in a community with an information infrastructure and 0 otherwise. The household's/woman's potential outcome under the hypothetical situation of being treated ($C_i = 1$) and not treated ($C_i = 0$) are denoted as Y_{1i} and Y_{0i}, respectively. Let D_i denote dummies for regional fixed-effects, and Λ_t represent time dummies for time trend (across round). We express the potential outcomes as in Heckman and Vytlacil (2005) as:

$$(1) \qquad Y_{ji} = \rho_j X_i + \delta D_i + \Lambda_t + U_{ji}, \qquad j = 0,1.$$

where U_{ji} denotes the error terms assumed to have a mean of zero [i.e., $E[U_j|X = x,\ D = d, \Lambda = \lambda] = 0$] and constant variance (σ_U^2), X_i is a vector of household and community characteristics and other factors that differ across households/women and community, while ρ_j, and δ are parameters to be estimated.

For the decision about information infrastructure placement, we assume this is determined both by exogenous factors (including policy and firms' investment decisions) and other internal conditions of the area such as population size, income levels and economic opportunities. Also, households/women can move from one community to another to access opportunities and better services. These factors imply that observing a household in a community with or without an infrastructure may not be free from selectivity concerns (i.e., selection into treatment). We thus express household/woman i's residence status as living in a community with an information infrastructure in the following latent variable discrete choice model:

$$C_i^* = \beta_X X_i + \beta_D D_i + \eta_t + \beta_I I_i - \varepsilon_i$$

$$(2)9 \qquad C_i = 1 \text{ if } C_i^* \geq 0, \qquad C_i = 0 \text{ otherwise}$$

where C_i^* is the latent propensity of residing in a community with an information infrastructure by household/woman i. The observed determinants of residing in a community with an information infrastructure include household and community characteristics such as heads' gender and income, and other factors that vary across households and community, X_i, regional and time fixed effects (D_i and η_t respectively) and at least an instrument, I_i, that is excluded from eq. (1). The β's are parameters to be estimated and ε_i is an i.i.d. error term representing the unobserved heterogeneity in the propensity to reside in a community with an information infrastructure, and thus enters the selection equation with a negative sign. Because this enters the equation with a negative, it is referred to as unobserved resistance to treatment (Cornelissen et al. 2018).

Marginal and Average Treatment effects

Objective 1 examined the impact of community internet cafés, ICT centres, and community radio stations on household intake of vitamin A-, protein-, and hem-iron-rich foods, whereas objective 2

examined the impact of the information infrastructure on average women's empowerment, gender parity and women's economic empowerment. This is implemented following the analytical framework in section 2.2 by estimating a first stage probit model of drivers of households'/women's residence in communities with a particular information infrastructure. Following the estimated first stage models (i.e., eq. (2)), we retrieved the propensity score estimates from each of the first stage models which were then used to estimate second stage models of determinants of household nutritious diet intake and women's economic empowerment in equation (1) and the marginal treatment effects (MTE) of each of the physical information infrastructure on the nutritious diets and women's economic empowerment outcomes. If we assume that there exist a first stage and a valid instrument (discussed in section 2.2.4), and that the MTE is additively separable into observed and unobserved components (Cornelissen et al. 2018), we can express the MTE as:

$$\text{MTE}(x,\ d,\ u_E) = E(Y_{1i} - Y_{0i} | X = x, D = d, U_E = u_E), \tag{3}$$

$$= x(\rho_1 - \rho_0) + E(U_1 - U_0 | U_E = u_E).$$

Thus, the MTE expresses returns to the infrastructure for a household/woman with observed characteristics evaluated at the means (i.e., $X = x$), which is in the u_Eth quantile of the distribution of the resistance to having the infrastructure in the community, ε. That is, $x(\rho_1 - \rho_0)$ and $E(U_1 - U_0 | U_E = u_E)$ show estimates of the treatment effects heterogeneities in observed and unobserved characteristics, respectively. Next, we estimated the average treatment effect (ATE), average treatment effects on the treated (ATT) and the average treatment effects on the untreated (ATU) by aggregating the MTE in equation (3) over the U_E and the appropriate distributions of the covariates as:

$$\begin{aligned} &\text{ATE} = E[Y_{1i} - Y_{0i}] \\ &\text{ATT} = E[Y_{1i} - Y_{0i} | C_i = 1] \\ &\text{ATU} = E[Y_{1i} - Y_{0i} | C_i = 0] \end{aligned} \tag{4}$$

These treatment effects parameters deliver estimates of the average effect of an information infrastructure on vitamin A, protein and hem-iron for: a household randomly selected in the population (ATE); a household randomly selected in a population of households with a particular information infrastructure given that the household resides in a community with that information infrastructure (ATT); and a household residing in a community without the infrastructure if the household resides in a community with that infrastructure (ATU), respectively. Similarly, these parameters provide estimates of the average effect of an information infrastructure on women's economic empowerment index for: a woman in a household randomly selected in the population of women; a woman in a household randomly selected in a population of women in a community with a particular information infrastructure given that she resides in a community with that information infrastructure; and a woman in a household residing in a community without the infrastructure if she resides in a community with that infrastructure, respectively.

The treatment effect of infrastructure across farm status on nutritious diets and women's economic empowerment, as part of X_i, was also computed following the observed component of equation (3) as:

$$\text{ATE}_X = E[Y_{1i} - Y_{0i}] = E[\rho_1(X_i) - \rho_0(X_i)]. \tag{5}$$

The coefficient of $E[\rho_1(X_i) - \rho_0(X_i)]$ can either be positive or negative and shows the difference in gains of nutritious diet intake and women's economic empowerment associated with the presence of the infrastructure between farm and non-farm households. Following the model described in the previous section and given a sound identification strategy (discussed in 2.2.4), we estimated the model using the local instrumental variable estimator.

Estimation of impact mechanism

We briefly discuss the framework used to estimate the impact mechanisms in this section. We used the principal stratification approach which entails the construction of statistically comparable groups based on the potential values of the treatment and the impact mechanism (Flores & Flores-Lagunes 2009; Lee 2009; Zhang et al. 2015). This framework is used because of its ability to enable us to obtain causal effects of the parameter estimates of interest (Frangakis & Rubin 2002). If we define a mechanism variable as M, and for simplicity denote the treatment effect by the ATE $= E[Y_1 - Y_0]$[7], then the analysis of the impact mechanisms involves estimating the part of the treatment effect that works through the mechanism variable M. Given that M is affected by the treatment (C) in eq. 2, we define the potential values of the impact mechanism as M_1 and M_0. Thus, M_1 is the effect of the post-treatment variable a household or woman gets if exposed to the treatment, and M_0 is the effects the household or woman gets if exposed to the control situation. On this basis, we can decompose the ATE into the part of the effect due to the change in the mechanism, M, that is attributed to the information infrastructure (mechanism effect) and the part of the effect that is net of the mechanism effects (net effect) as:

$$(6) \qquad TATE = E[Y_1(M_1) - Y_1(M_0)] + E[Y_1(M_0) - Y_0(M_0)].$$

This equation shows the Total Average Treatment Effects (TATE), which simply estimates the total effect of an information infrastructure on nutritious diet intake and women's economic empowerment. The term $E[Y_1(M_1) - Y_1(M_0)]$ is the Average Mechanism Treatment Effect (AMTE) which represents the effect of a change in the mechanism variable, M, associated with the information infrastructure, C, on the outcomes, Y. Hence, this is the effect of a change in a mechanism (e.g., access to extension) due to the presence of an information infrastructure on nutritious diet intake, holding all other effects of information infrastructure on nutritious diet intake constant. The second term, $E[Y_1(M_0) - Y_0(M_0)]$, is the Net Treatment Effects (NTE) which represents the effect of the information infrastructure on the outcomes when all post-treatment variables are held constant at M_0. In other words, this is the effect of the information infrastructure on the outcomes that is net of the effect of the impact mechanism.

Our interest is in the estimation of the first term of the equation, which was done by partitioning households or women into groups such that all members have the same mean value of the post-treatment [$M_0 = m_0, M_1 = m_1$] within each group (i.e., principal stratification). Given that the principal strata are not affected by the treatment variable, this makes individuals within that group comparable and the estimate of the effects with respect to a principal stratum as causal effects (Flores & Flores-Lagunes 2009). Hence, if we condition on the strata, we express the total average treatment effects as:

$$(7) \qquad TATE = E\{E[Y_1(M_1) - Y_1(M_0)|M_0 = m_0, M_1 = m_1]\}$$
$$+ E\{E[Y_1(M_0) - Y_0(M_0)|M_0 = m_0, M_1 = m_1]\}$$

Based on this, we define the average mechanism treatment effect (AMTE) as:

$$(8) \qquad AMTE = E\{E[Y_1(M_1) - Y_1(M_0)|M_0 = m_0, M_1 = m_1]\}$$

To the extent that selection into the treatment is not random in our setting, we face the problem of accounting for self-selection in this estimation. Also, given the difficulty in finding valid instruments, we employ a selection on observable assumption based on the propensity score matching technique to estimate the impact mechanisms. Using the unconfoundedness assumption and the principal strata approach we express the confounded treatment and principal strata as $[Y_1(M_1), Y_1(M_0), Y_0(M_0) \perp \{C, M_1, M_0\}|X]$. This implies that households or women in different strata are comparable conditional on the set of covariates, X. It also suggests that treated and control units in different strata, but with the same covariate values, are comparable. Hence, the covariates correct for selection into both the treatment and the principal strata such that the treatment received by a household or woman is independent of the potential outcomes and values of the impact mechanism given the set of the covariates, X.

[7] We supress the i-subscript for notational simplicity.

We also assumed the existence of an overlap [i.e., $0< \Pr(C = 1|M_1 = m_1, M_0 = m_0, X = x) < 1$] within which we compared treated and control groups for all values of the covariates. This overlap assumption ensures that there will be both treated and control households or women at each $X, M_1,$ and M_0. Thus, the estimate of the average mechanism treatment effect also involved conditioning on the observed characteristics, X, as:

$$AMTE = E\{E[Y_1(M_1) - Y_1(M_0)|M_0 = m_0, M_1 = m_1, X = x]\} \quad (9)$$

This estimate is a causal effect since this is an average over effects defined within the principal stratum. Following Flores and Flores-Lagunes (2009), we implemented this by estimating a weighted-least square regression of the outcomes on the treatment, impact mechanism, and the X's, over the subpopulation of households or women in the common support. The estimated model uses the propensity scores (pscore) from a first-stage model of the treatment on M and X as weights and up to cubic pscore as regressors.

As stated earlier, previous studies have used this approach. For instance, Lee (2009), and Zhang et al. (2015) focused on estimating the effect of a randomly assigned training program on wages by considering that wages are only observed for those individuals who are employed, which makes employment status a mechanism through which training affects wages. However, the limitation with the approach used in the above studies is that the impact mechanism, which is employment status, is binary which makes it quite restrictive in our context where we have count (e.g., number of town meetings attended by a woman) and continuous (such as farm output and income) variables as impact mechanisms. Ours is closer to the implementation by Flores and Flores-Lagunes (2009) who estimate the net direct effect of change in gestation due to smoking during pregnancy on birth weight. However, whereas their focus was on the imputation of the average mechanism treatment effect from the estimation of the net direct effect of smoking during pregnancy on birth weight, our approach involves a direct estimation of the average mechanism treatment effect since this is the parameter of interest in our case.

Policy Relevant Treatment Effects (PRTE)

Heckman and Vytlacil (2005) argue that the conventional treatment parameters discussed in section 2.2.1 often present estimated effects of interventions in gross terms.[8] However, to perform appropriate cost-benefit analysis of policy interventions, it is imperative to compute policy-relevant treatment effects (PRTE). Given our interest in simulating policy intervention options that seek to increase supportive facilities (i.e., electricity coverage), which we used as potential instrument for physical information infrastructure, we will estimate the aggregate effects of policy changes that increase access of some communities and the households/women without electricity coverage to these services. If we define C_i as presence of the infrastructure under a baseline policy and $\check{C}_i$ as the presence of the infrastructure under an alternative policy, the unconditional PRTE is defined as:

$$\begin{aligned} \text{PRTE} = {} & E\left[Y_{1i} - Y_{0i}\middle|\check{C}_i = 1\right]E\left[\check{C}_i\right] - E[Y_{1i} - Y_{0i}|C_i = 1]E[C_i] \\ & + \frac{E\left[U_{1i} - U_{0i}\middle|\check{C}_i = 1\right]E[\check{C}_i] - E[U_{1i} - U_{0i}|C_i = 1]E[C_i]}{E[\check{C}_i] - E[C_i]} \end{aligned} \quad (10)$$

This shows the average policy effect of going from the baseline policy to the alternative policy per net person shift in access to information infrastructure (Heckman & Vytlacil 2005). The PRTE was estimated for both objectives 1 and 2. For both objectives, the PRTE first provides estimates of shifting households from residing in communities without the given infrastructure into communities with that infrastructure that are due to the policy simulation. Following this shift, the PRTE of the shift in households/women from not having the given infrastructure into having on nutritious diet intake (as in objective 1), and on women's economic empowerment index (as in objective 2) was calculated.

[8] For instance, the ATT estimates the information infrastructure effects in gross terms, whereas MTE estimates the gross gain from a marginal increase in the information infrastructure (Heckman & Vytlacil 2005).

Identification and exclusion restriction

A critical issue for the identification of the effects of information infrastructure on the outcomes in the MTE framework is the existence of a valid instrument. We use electricity coverage in the round 6 (i.e., 2012/2013) as an instrument for the presence of an information infrastructure conditional on regional and round/time dummies. The regional and time dummies are crucial in accounting for location-constant and time differences across regions and rounds of survey. For the instrument to be valid, it must be relevant in explaining the presence of the information infrastructure in a community, and exogenous, where it should not affect the nutritious diets and women's empowerment outcomes directly but only through the information infrastructure (Wooldridge 2010). In fact, the provision of electricity to communities in Ghana can be said to be exogenously driven by government policies which can be traced back to pre-independence period (i.e., before 1957).

The first public electricity generation system was set up in 1914 by the Gold Coast Railway Administration, which, by 1955, was supplying electricity to major cities (such as Accra, Takoradi, Kumasi, Tema, Tamale and Bolgatanga) in Ghana (ISSER 2005). Electricity access to the rest of the country, including rural areas, considerably improved from just about 6% in the 1990s to about 60% in 2015 (World Bank 2016), an achievement attributed to the establishment of the National Electrification Scheme by Government in 1989. Notwithstanding the possibility of other energy sources available, this expansion was mostly due to these government policies and interventions on increasing the number of communities connected to the national grid[9] (Adusah-Poku & Takeuchi 2019). The two main arms of the National Electrification Scheme are the National Electrification Program (NEP) and Self-Help Electrification Program (SHEP). The National Electrification Program extended electricity to all district capitals in the country, whereas the SHEP encouraged community participation to extend electricity to communities. Even though the requirement of households in communities to provide some of the utility poles appears as a potential threat to the exogeneity of the instrument[10], the involvement of the government again makes this unlikely since the government was responsible for providing the remaining poles, transmission equipment, materials, and the construction work (Adusah-Poku & Takeuchi 2019).

Intuitively, we expect electricity coverage of a place to be important in predicting the information infrastructure for several reasons. Firstly, the citing of these infrastructures depends on the availability of electricity because having electricity in the area contributes to reducing the investment costs of citing the infrastructure. Secondly, the operation of the infrastructure relies on electricity to the extent that none of the information infrastructure can operate in the context of our study without electricity. In fact, electricity is needed to power the entire structure and to support the operations of equipment such as computers, internet servers, speakers and transmitters before an internet café, ICT centre or radio station can operate. Hence the absence of electricity of any sort in a place means that the infrastructure cannot function in that place. Thus, we expect that a community with electricity is more likely to attract or have the information infrastructure than a community without electricity. Also, electrification has been argued to have the potential to change nutrition, and gendered customs and norms through increased use of ICT devices and access to information (Fujii et al. 2018; Clark 2021). These can increase exposure to nutrition and gender-sensitive information which can result in improved nutrition and equal valuation of women and men (Winther et al. 2017; Clark 2021). This clearly shows that electricity in this case is expected to affect households' nutrition and women's economic empowerment through the information infrastructure which supports their use of ICT devices and access to information. We used previous electricity coverage to circumvent the potential simultaneity due to the contemporaneous correlations between the instrument and the outcomes variables. In this case, we only expect the instrument to explain the presence of the infrastructure, but it is not possible that current infrastructure, nutrition, and empowerment status will influence past electricity status of the community.

This notwithstanding, there exist some concerns that may threaten the validity of our instrument. The

[9] In fact, existing evidence show that the role of other electricity sources such as solar is insignificant and contributes less than 1% to the total electricity supply in Ghana (Adusah-Poku & Takeuchi 2019).

[10] Communities within 20 km of an existing 33 kV or 11 kV sub-transmission line are qualified for electrification if they will pay for the cost of low- voltage poles needed for the distribution network in the community, and communities that could not afford to pay for these poles were supported by their respective local governments (Kemausuor & Ackom 2017).

first concern is when regional and community characteristics at the 6th round predict electricity expansion in the community, thereby, threatening the exogeneity of the instrument. This is because of the requirement of the SHEP that communities will have to participate by providing standard-volt poles for the distribution within the community. To check this, we regress the change in electricity coverage between the two rounds (which is 1 if the community had no electricity in round 6 but had electricity in round 7) on regional dummies and community characteristics. The results in Table A3 show that some of the regional and community characteristics at the 6th round indeed predict electricity expansion in the community. However, although those characteristics at the 6th round predict electricity expansion in the community, it would not generally invalidate our identification strategy because these regional characteristics at the 6th round mostly reflect time-constant differences, which together with the other community characteristics are accounted for by the inclusion of regional dummies and community characteristics in our specifications and estimation (Cornelissen et al. 2018).

The other set of threats to identification is the possibility that electricity coverage that leads to reduced drudgery and increased economic opportunities could reduce women's time poverty and boost business activities in the community. This implies that apart from the information pathway, increased income and wealth is another potential mechanism by which electrification can affect nutritious diet intake (Fujii et al. 2018), whereas alleviation of time poverty; participation in paid work and income; as well as education are other potential routes through which electrification can affect women's economic empowerment (Clark 2021). We explore the possibilities of these routes as a threat to the validity of our exclusion restriction. One approach to test these pathways for evidence that the exclusion restriction is invalid or otherwise will be to estimate the effect of electricity coverage on women's time poverty status, food processed, employment status and household income (see Dillion et al. 2015). If strong correlations exist between the electrification and these pathways, the exclusion restriction would be clearly violated.

As stated above, the concerns of the time poverty, labour market participation and income will be the case if electrification results in increased opportunities and income for the household or in reduced drudgery and freeing up more time for engagement in paid work, which in turn affect households' nutritious diet intake and women's economic empowerment. In the literature, drudgery is possible only when the woman or household can purchase and reliably use appliances such as electric kettles and cook stoves, rice cookers, refrigerators, and blenders among others which can reduce the time spent on activities like milling, grinding and food processing (ENERGIA 2020, Clark 2021). Also, the use of these types of appliances typically requires at least tier 3 electricity supply (Clark 2021). Thus, if households or women's use of these appliances is low or tier 3 supply of electricity is low among the population, then electrification could have no effect on drudgery, time poverty, and paid work participation. Table A4 contains the estimates of a direct test of the relationship between electrification on one hand and women's time poverty status, food processing, employment status and household income on the other (columns 1-4). Further, we present estimates of the relationship between electrification and land size to cater for the wealth pathway in column 5, and community market to check the possibility of the effect through engagement with the local market in column 6. The results show no significant relationship between electrification and any of these pathways.

The other threat is that expansion of electricity may positively affect the outcomes through improved education, where households and women who are better educated become more informed about nutritious diets, and women's rights and empowerment. Beyond accounting for household head's education in all specification and estimation, we further conduct a direct test of the relationship between electrification and average years of education in the household. The result is reported in column 7 (click here for Table A4 in supplementary file at the Appendix) which shows no significant correlation between electrification and years of schooling. A final concern is the issue of endogenous mobility and social interaction. Households may move from areas without electricity to those with electricity, which can lead to increased population, social interaction and living conditions in areas with electricity. This may lead to electricity coverage predicting the outcomes through the population and changes in living conditions in the area. Under such conditions, households in populated areas might have higher interaction intensity and better living conditions, which can increase their access to nutritious diets and improve women's economic empowerment. For this, we estimated the effect of electrification on community population and community living conditions and the results are reported in columns 8 and

9, respectively (click here for Table A4 in supplementary file at the Appendix). Although for community population, electrification appears to have some effect on it, the lack of measured effect for most of these pathways suggests that the exclusion restriction is not violated through the information infrastructure and devices pathway.

This is not surprising because existing literature on the relationship between electrification and these pathways are not clear cut, and with much of the studies in sub-Saharan Africa finding unexpected or no effect at all (Koolwal & van de Walle 2013; Clark 2021). In fact, Lee et al. (2020) argued that the variance in studies' findings on the relationship between electrification on one hand and female labour force participation and education on the other may be due to electrification programs or context issues. Our observed test results and this argument are plausible in our study context for two reasons. First, electricity access and perennial supply is a major challenge in Ghana with over half of the population with access to electricity having tier 1 supply which is largely not sufficient to support heavy energy consumption appliances such as washing machines, microwaves, water heaters, electric cookers, and grinding mills (Clark 2021). It is estimated that, all things being equal, only about 40% of the population will reach tier 2 or tier 3, and only 18% will reach tier 4 by 2030 in Ghana (SEforALL & Dalberg Advisors 2021), thus highlighting the challenges in electricity access which might constrain the utilization needed to produce any significant effect through these other means. Finally, we present some descriptive statistics in Table A5 to show the use of the needed appliances in round 7, as the necessary condition for drudgery and alleviation in time poverty (ENERGIA 2020). The statistics show that the use of these appliances is very low in Ghana. Except for refrigerators, freezers, and washing machines, which are owned by about 23.15%, 26.97% and 18.58% of households, respectively, the other appliances are hardly owned by more than 10% of the households in Ghana.

2.3 Measurement of nutrition and gender outcomes

Nutritious diet intake

The food consumption score-nutrition was used, which focuses on how often a household consumed foods rich in three key nutrients namely, protein, vitamin A and iron (hem iron). The calculation of this was done by first grouping food items into 8 food groups (without condiments) and with 7 subgroupings for 3 of these 8 main groups, yielding a total of 15 food groups. These groups are staples; pulses; dairy; proteins (flesh meat, organ meat, fish, and eggs); vegetables (orange vegetable and green vegetable); fruits (orange fruit); fats and sugars (World Food Programme 2015). The consumption frequency of these food sub-groups by a household are summed up to obtain nutritious diet intake outcomes as follows: *Vitamin A-rich foods intake* was calculated as whether a household consumed any dairy, organ meat, eggs, orange, and green vegetables, and/or orange fruits during seven visits to the household. *Protein-rich foods intake* was calculated as whether a household consumed any pulses, dairy, flesh meat, organ meat, fish, and eggs, whereas *hem iron-rich foods intake* was calculated as whether a household consumed flesh meat, organ meat and/or fish during the seven visits to the household. Finally, for each nutrient-rich food group (i.e., vitamin A, protein, and iron), we summed the number of days out of the 7 days the household consumed each food item to obtain the frequency of consumption of vitamin A-, protein-, and iron-rich foods consumption.

Women's economic empowerment measures

We used a proxy of Women's Empowerment in Agriculture Index (WEAI)'s five domains (Alkire et al. 2013) because our datasets do not have information on all the domains and the various dimensions and perspectives of each of the domain. From the datasets at hand, we had information only on whether specific members of a household own, participate or gets involved in decisions about key issues related to these WEAI domains and the time allocation of household members. Hence, we called this women's empowerment measure as the Women's Economic Empowerment Index (WEEI). Given this information, we constructed the measure of the women's economic empowerment based on information on the domains of the WEAI available as follows:

1. *Agricultural production decisions*: we used information on household members' ownership and/or responsibility for a farm, livestock and fishing, or their participation in farming activities, livestock rearing and fishing. Responses to each of this by household members were binary (0/1) in which a household member who owned, responsible for or participated in an activity

was coded 1 and 0 if not. A composite measure of input in production decisions was computed where a member was classified as having input in decisions if s/he owns, responsible or participates in at least two of these sub-domains.

2. *Access to and decision-making power over productive resources*: this was constructed using information on household members' farm ownership, livestock ownership, fishpond or business ownership, ownership and management of non-farm enterprise, ownership of house, and land ownership. These were also binary variables (0/1) where one represented owning a resource and zero otherwise. The composite measure of this domain was the number of types of these productive resources owned.
3. *Access to and control over credit*: In this sub-domain, we used information on individual access to and sources of credit from the datasets. This is also a binary (0/1) set of variables defined as one if a member had access to loan, or obtained loan from either government source, formal sources, non-governmental organizations, friends and relatives, groups, and associations, or from other informal sources, and zero otherwise.
4. *Control over use of income*: this was constructed as a set of binary variables (0/1) on whether an individual decides or has an input in the decision regarding the use of income from wage and salaried employment, household decision on use of income, and decision on household expenditure. After this, we constructed a composite measure as the number of domains an individual has some input in income or expenditure decisions or feels can make decisions.
5. *Time allocation*: This was measured as household members' time allocation in hours among work, household activities and leisure time.

Based on the WEAI approach, we re-coded these binary indicators of adequacies into inadequacies in which a value of 1 means the individual lacks adequate achievement in that indicator variable and a zero otherwise. We computed separate scores for male and female respondents in a household and these were used to construct the Empowerment Index, Gender Parity Index and Women's Economic Empowerment Index as follows:

***Empowerment Index* (E_Index)**

The index was constructed by first coding the indicators described under the domains above to show adequacy in an indicator by assuming the value of 1 if the individual does not have adequate achievement in that indicator and zero otherwise. Thus, inadequacies across all indicators were used to compute an inadequacy score (A_IS) for each person in the household by adding the weighted[11] inadequacies to obtain a ratio measure between 0 and 1 for each person, with one meaning the person experiences inadequacy on all the indicators, and zero implying the person has no inadequacy. Following this measure, we used a threshold of 0.2 (i.e., 20%) (which shows the share of weighted inadequacies a woman must have to be classified as disempowered) to define who is disempowered (Alkire et al. 2013). We then re-coded the weighted inadequacies scores into 0 and 1 such that those with inadequacy scores greater than the disempowerment threshold of 0.2 is denoted 1 (i.e., disempowered), and zero otherwise (H_DHC). These two indicators were combined to compute the disempowerment index (M_0) as the product of the intensity of individual inadequacies (A_IS) and the incidence of individuals whose weighted inadequacies is more than the threshold (H_DHC). Finally, the empowerment index (E_Index) is calculated as one minus the disempowerment index (i.e., 1-M_0).

***Gender parity index* (GPI)**

This is a ratio between 0 and 1, with 1 indicating the household achieved gender parity in a dual-adult households and 0 indicating no gender parity in the household. We first computed the extent of gender parity in the household by using information on whether the female is disempowered and her inadequacy score (based on the 20% threshold) is higher than the inadequacy score of the male counterpart. Specifically, the GPI is derived using two measures: the percentage of women who lack parity relative to the male counterparts in the household (H_{GPI}), and the extent of the empowerment inadequacy between the women who lack parity and their male counterparts in the household (I_{GPI}). We next computed the gender parity index (GPI) as one minus the product of the percentage of women with no gender parity (H_{GPI}) and the average empowerment gap (I_{GPI}).

[11] The weights used were based on those used by Alkire et al. (2013).

Women's economic empowerment index **(WEEI)**
The women's economic empowerment index was then computed as the weighted average of the empowerment index and the gender parity index, with the weight of the empowerment index and GPI sub-indexes as 90% and 10%, respectively. The WEEI was computed as the weighted sum of empowerment index, [(1-M_0) (0.9)], and the GPI, [(GPI) (0.1)]. This resulted in the WEEI which is a score measured as a ratio between 0 and 1, with 1 being the most empowered.

3. Result and Discussions

3.1 Sample Characteristics

Table 1 presents descriptive statistics of the variables of interest for this study. The summary statistics of the physical presence of information infrastructure show a generally low presence of these infrastructures in communities in Ghana. In fact, the proportion of households in communities with an internet café is 14.3% whereas the proportions of households in communities with an Information and Communication Technology (ICT) centre and community radio are 9.8% and 7.8% respectively. Regarding the outcomes, Table 1 presents the summary statistics of the nutritious diets' intake outcomes in Panel B. The variables are measured as the frequency of a household consumption of vitamin A-, protein-, and iron-rich foods over seven visits during the data collection. The average frequency of consumption of vitamin A-, protein-, and iron-rich foods by households are 6.5, 6.5 and 4.7 times. Table 1 also presents summary statistics for the women's economic empowerment outcomes in Panel C. Given that the GLSS datasets do not have the required information to calculate the women's empowerment in agriculture and related indexes, we relied on proxies of these measures by using information from the datasets that are relevant to the women's empowerment in agriculture index (WEAI) (click here for Table A1 in supplementary file at the Appendix)[12]. The key variables used as outcomes in measuring women's economic empowerment are the Empowerment Index (E_Index); Gender Parity Index (GPI) and the Women's economic empowerment Index (WEEI).

The empowerment index measures the level of individual women's empowerment in the household and is calculated as one minus the disempowerment index (M_0). The disempowerment index is also calculated as the product of the disempowerment head count and the average inadequacy score. The disempowerment head count (H_DHC) shows that 94.0% (6.0%) of women are disempowered (empowered), whiles the average inadequacy score (A_IS) shows that these 94.0% of women who are disempowered have an average inadequacy achievement in 51.7% of the empowerment domain indicators used in this study. This suggests that in addition to the high incidence of disempowerment among these women, they also have a post adequacy achievement in 48.3% of the domain indicators. The disempowerment index of 0.51 indicates that average empowerment of women is 0.49. The Gender Parity Index (GPI) shows that 90.0% of women have gender parity with the primary males in their households ($1-H_{GPI}$), and of the 10.0% of women with no gender parity (H_{GPI}), the average empowerment gap (I_{GPI}) is quite small at 1.7% between them and the males in their household. This results in an overall GPI of 70.5%. Finally, we compute the proxy WEEI as the weighted average of the empowerment subindex of 0.495 and the gender parity subindex of 0.705. The empowerment index is weighted 90% and the GPI is weighted 10%. This gives a WEAI of 0.677 from the datasets. Even though our computation of WEEI relied on proxy indicators that are not extensive and detailed as required by the WEAI model, the estimate of the WEEI is still comparable to estimates of WEAI at 0.714 in the SADA zone of Ghana (Zereyesus et al. 2014) and in Guatemala of 0.702 (Alkire et al. 2013).

[12] In Table A1, we see that the percentage of women participating in income generation activities within households increased from 29%, 17% and 4% in round 6 for crop farming, non-farm activities, and wage and salary employment to 31%, 20% and 6% in round 7, respectively. Similarly, the proportion of women owning or responsible for productive capital such as farmlands, non-farm enterprises and fishpond increased from 13%, and 14% in round 6 to 23% and 16% in round 7, respectively. Also, the percentage of women responsible for household purchases within households increased from 33% in round 6 to 47% in round 7. Finally, whereas the time allocated to most activities by women, including domestic work, decreased between the rounds, the number of hours (on average) allocated to free time increased between these rounds.

Table 1. Variable description and summary statistics

Variable	Description	Mean	Std. Dev.
Panel A: Information Infrastructure			
Internet cafe	1 if household resides in a community with internet cafe	0.143	0.350
ICT Centre	1 if household resides in a community with ICT centre	0.098	0.298
Com radio	1 if household resides in a community with a community radio	0.078	0.269
Panel B: Nutritious diet outcomes			
Vitamin A	Household frequency consumption of rich vitamin A foods over 7 days	6.476	2.568
Protein	Household frequency consumption of rich hem iron foods over 7 days	6.527	2.404
Iron	Household frequency consumption of 12 food groups over 7 days	4.732	2.685
Panel C: Women's economic empowerment outcomes			
H_DHC	Disempowerment head count	0.940	0.206
A_IS	Average inadequacy score	0.517	0.084
M_0	Disempowerment Index	0.505	0.100
E_Index	Empowerment Index (1-M_0)	0.495	0.194
H_{GPI}	Percentage of women with no gender parity (H_{GPI})	0.100	0.033
I_{GPI}	Average Empowerment Gap (I_{GPI})	0.017	0.015
GPI	Gender Parity Index	0.705	0.232
WEAI	Women's empowerment in Agriculture Index	0.677	0.192
Panel D: Household level variables			
HSex	1 if the household head is male, 0 otherwise	0.701	0.458
HAge	Age of the household head in completed years	46.022	15.902
HPrimary	1 if the household head has primary education, 0 otherwise	0.132	0.339
HSecondary	1 if the household head has secondary education, 0 otherwise	0.269	0.443
HPostsecondary	1 if the household head has post-secondary education, 0 otherwise	0.165	0.372
HMarried	1 if the household head is married, 0 otherwise	0.569	0.495
HSize	Household size	4.235	2.822
HHHouse	1 if the household own a house, 0 otherwise	0.294	0.456
HHland	Household total land size owned in acres	3.741	148.15
HHlivestock	Value of livestock owned by the households in '000 GHS	0.19	3.02
HHExpenditure	Per-capita annual household expenditure deflated in '000 GHS	0.219	0.328
HHOwnFood	1 if the household consumes any of the own food produce, 0 otherwise	0.524	0.499
FarmOutput	Total crop harvest in '000 kilograms	1.99	15.54
FarmRevenue	Total revenue from sale of crops and animals in '000 GHS	12.82	207.62
PriceMarket	Unit price of farm produce in GHS	53.99	62.85
FarmStored	1 if the household stored any own crop produce, 0 otherwise	0.466	0.499
FarmProcessed	Quantity of crop produce processed by the household in '000 kilograms	0.400	2.02
WomenProduce	1 if the household has a woman involved in agricultural production, 0 otherwise	0.696	0.46
WorkHrs	Number of hours that women in the household work per week	3.658	5.262
Meetings	Number of times women in the household attend town meetings	1.631	0.952
NotAllowed	1 if a woman is not allowed to participate in community level activities for gender reasons, 0 otherwise	0.257	0.437
Panel E: Community level variables			
CPopulation	Population of the community in '000	3.91	20.32
Ccondition	1 if perceived community living condition is better, 0 if worse	0.392	0.488
PriceIndex	Local price index in the community	51.678	46.493
CMotorable	1 if motorable road extends to community, 0 otherwise	0.566	0.496
CMarket	1 if the community has at least periodic market, 0 otherwise	0.201	0.401
CUrban	1 if the community is urban, 0 otherwise	0.437	0.496
CExtAgent	1 if the community has an extension agent, 0 otherwise	0.207	0.405
CPost	1 if the community has a post office, 0 otherwise	0.085	0.278
CElecticity	1 if the community has electricity or generators/solar power, 0	0.614	0.487

	otherwise		
CElectricity2013	1 if the community has electricity or generators/solar power in 2013, 0 otherwise	0.347	0.476
Panel F: Regional dummies			
Western	1 if household resides in the Western region, 0 otherwise	0.099	0.299
Central	1 if household resides in the Central region, 0 otherwise	0.095	0.293
G. Accra	1 if household resides in the Gr. Accra region, 0 otherwise	0.108	0.31
Volta	1 if household resides in the Volta region, 0 otherwise	0.096	0.294
Eastern	1 if household resides in the Eastern region, 0 otherwise	0.104	0.305
Ashanti	1 if household resides in the Ashanti region, 0 otherwise	0.121	0.326
Brong Ahafo	1 if household resides in the Brong Ahafo region, 0 otherwise	0.095	0.294
Northern	1 if household resides in the Northern region, 0 otherwise	0.101	0.301
Upper East	1 if household resides in the Upper East region, 0 otherwise	0.092	0.288
Upper West	1 if household resides in the Upper West region, 0 otherwise	0.090	0.286

Notes: Std. Dev. denotes standard deviation

Generally, there are improvements in the information infrastructure, nutritious diet intake, and the women's economic empowerment indicators between the two rounds. Table 2 shows that the percentage of households residing in communities with physical presence of information infrastructure increased from about 1.6% for internet cafés, 1.4% for ICT centres and 3.5% for community radio stations in round 6 to 25.4%, 17.5% and 11.7% in round 7, respectively. For the nutritious diets' intake, the frequency of consumption of vitamin A-, protein-, and hem-iron-rich foods increased from 5.0, 5.2 and 3.2 in round 6 to 8.2, 8.2 and 6.5, respectively, in round 7.

Table 2. Descriptive statistics of Information Infrastructure and outcome variables across rounds

	Round 6 (2013-14)		**Round 7 (2017-18)**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
Information infrastructure				
Internet café	0.016	0.127	0.254	0.435
ICT Centre	0.014	0.116	0.175	0.380
Com radio	0.035	0.183	0.117	0.321
Nutritious diets				
VitaminA	4.995	1.572	8.225	2.408
Protein	5.153	1.215	8.149	2.449
Iron	3.204	1.042	6.517	2.890
Women's economic empowerment				
E_Index	0.479	0.167	0.513	0.219
GPI	0.668	0.234	0.789	0.203
WEEI	0.582	0.199	0.748	0.150

Notes: Std. Dev. denotes standard deviation

Table 2 further shows general improvements in the women's economic empowerment indicators between the rounds. The women's empowerment index value in round 7 of 0.513 is higher than the value of 0.479 in round 6. Similarly, the GPI has a higher value of 0.789 in round 7 than the value of 0.668 in round 6. This generally translates into higher WEEI of 0.748 in round 7 compared to the value of 0.582 in round 6 suggesting an overall improvement in women's economic empowerment between the two rounds.

Table 1 also shows the descriptive statistics of household and community level characteristics as well as the proportion of the sample across regions. Most of the households (70%) are headed by males with an average age of 46 years. About 13% of household heads have primary education whereas about 27% and 17% have secondary and post-secondary education, respectively in the sample, which suggests the

level of educational attainment is still low among majority of these household heads. Also, up to 52.4% of households consumed at least some of their own farm produce whiles 46.6% of the households stored some of their farm produce (FarmStored). Households on average had a total farm harvest of 1,990 kilograms, total revenue from sale of crops and animals of GHS 12,820 and processed about 400 kilograms of their farm produce. Table 1 further shows women were involved in agricultural production in the sample (69.6%), worked on average for 3.66 hours per week and attended about 1.6 town meetings. At the community level, whereas 39.2% of communities perceived community living conditions to be better, the local price index in the communities (on average) is 51.7. Also, the percentage of communities with at least periodic market, extension agent in the community and post office is quite low with values of 20.0%, 20.7% and 8.5%, respectively. Finally, we reported two descriptive statistics for community electricity. The first (CElectricity) is the proportion of communities with electricity or generators/solar power when we pool both rounds 6 and 7. This contains communities with electricity either in round 6 (2014), round 7 (2018) or both (i.e., 2013 and 2018) and 61.4% of the communities in the sample had electricity when defined this way. We contrasted this with another measure (CElectricity2013) that considered whether the community had electricity in only round 6 (i.e., 2012/2013). Based on this, 34.7% of communities covered in both rounds had electricity in 2013.

We also compared the outcomes and households' observable characteristics across information infrastructure status (Table A6 in the Appendix). The estimates show significant differences in all the outcomes and in most of the observed characteristics between households residing in communities without an information infrastructure and those residing in communities with the information infrastructure. These are suggestive of substantial heterogeneities and the possibility of selection on gains among households across information infrastructure statuses of communities. This partly motivates our choice of the analytical framework in this study to be able to deal with potential selectivity concerns and to highlight heterogeneities in returns, if any, to the information infrastructure.

3.2 First-Stage Selection Estimates

We briefly present the first stage of the determinants of households' residence in a community with the information infrastructure and highlight the overlap in the propensity scores between the treated and untreated group. We present the parameter estimates of the first-stage probit selection equation (2) in Table A7. To ease interpretation, we present marginal effects of the estimates. The estimate of whether the household is a farm household or non-farm is estimated to have statistically significantly effect. Specifically, farm households have 1% and 1.3% lower probabilities of residing in communities with ICT centre and community radio than their non-farm counterparts. This implies that farm households are more likely to reside in communities without the information infrastructure than non-farm households. Our instrument, Celectricity2013, is a strong predictor of the presence of the information infrastructure in a community. The sign of the marginal effects is as expected and shows that having electricity at the sixth round (i.e., in 2012-2013) is associated with 24.1%, 3.0% and 4.3% probabilities of having an internet café, an ICT centre and a community radio in a community, respectively. This is also statistically significant at 1% in all the information infrastructure. As discussed in the identification section (2.2.4), the effects suggest that communities with electricity are seen to have the necessary infrastructural support base for the establishment and operation of the information infrastructure in an effective and efficient manner.

The first stage produces large common support for the propensity score generated by variations in both the instrument and the covariates. In the case of the nutritious diet outcomes, the common support ranges from 0.01 to 0.90 for internet cafés, 0.01 to 0.85 for ICT centres and 0.01 to 0.66 for community radios (Figure A1). Figure A1 also shows that the common support ranges from 0.01 to 0.94, 0.01 to 0.90 and 0.01 to 0.80 for internet cafés, ICT centres and community radios, respectively for the women's economic empowerment outcomes. These common supports are sufficient to identify the marginal treatment effects (MTE) given that MTE is estimated within the region of the common support (Caneiro et al. 2011), which Figure A1 shows there is substantial overlap for this.

3.3 Impact of Information Infrastructure on Nutritious Diet Outcomes

Average treatment effect measures

We now turn to the treatment effect estimates of the information infrastructure on household nutritious diet intake. We first report the standard treatment effect parameters (i.e., ATT, ATE and ATU) in Panel C of Table 3. The results show significant ATT across the nutritious diet indicators suggesting that for the average treated household, residing in a community with an internet café results in 3.34, 3.64 and 5.61 units higher of vitamin A-, protein-, and iron-rich foods intake, respectively, whiles residing in a community with an ICT centre results in 3.27, 3.84 and 6.63 units of vitamin A-, protein-, and iron-rich foods intake, respectively. Similarly, for the average treated household, residing in a community with community radio is associated 3.20, 3.23 and 5.24-units higher intake of vitamin A-, protein-, and iron-rich foods, respectively.

The ATE is (weakly) statistically significant for protein in the case of internet cafés. Whereas the ATE and ATU are generally significant at the 1% for all nutritious diet outcomes in the case of ICT centre, for community radio, the ATE is at least weakly significant for all the outcomes and only significant for protein and iron in the ATU. Specifically, the ATE results show that for a household randomly selected from the population of households, having an internet café in the community results in 1.42 units higher intake of protein rich foods whiles having ICT centre in the community results in 5.81, 6.74- and 4.67-units higher consumption of vitamin A-, protein-, and iron-rich foods. Also, residing in a community with a community radio results in 3.05, 3.97- and 5.06-units higher intake of vitamin A-, protein-, and iron-rich foods for a household picked randomly from a population of households. The ATU on the other hand implies that for the average untreated household, being in a community with an ICT centre increases vitamin A-, protein-, and iron-rich foods intake by 6.09, 7.06 and 4.45 units, respectively. Similarly, being in a community with a community radio increases the intake of protein and iron by 4.50 and 5.04 units, respectively, for the average untreated household.

When the impacts are compared across information infrastructure, the effect of internet cafés on nutritious diets appears not to be substantial on the average household and the average untreated household if they were to reside in a community with the information infrastructure. However, a critical examination of the responses by the nutrition experts seems to throw some light on this situation. A nutrition expert in the middle zone stated that:

> When it comes to the internet, information about nutrition is normally published by organisations such as the Ghana Health Service and the World Health Organisation regularly. And it is usually people who can access this information that can make use of the services of the internet (Key Informant, Kintampo).

Also, a nutrition expert in the Ga West Municipal for instance has specifically indicated her involvement in a programme on Sunny FM geared towards sharing her expert views with the public on the need to take nutritious diets and avoid certain foods. But she also indicated that:

> Information on the internet is not very common to the general public and even those on social media platforms or online portals such as YouTube need some additional commitment in terms of ability and cost to be able to access them (Key Informant, Oduman)

This could partly explain why we see significant effect of the internet café on households who are more likely to use it but not on the average household or those who are less likely to use the internet café. Further discussions with the nutrition experts revealed that the effect of information infrastructure, especially through the services they provide, goes beyond availability of and access to nutritious diets to even touch on safety issues. It was revealed that: "*Government agencies such as the Food and Drugs Authority also use community radio to sensitise people about the need to buy FDA authorised food*" (Key Informant, Walewale). In Offinso in the middle belt, for instance, Life and Time Radio gave out a slot to educate people on the issues of safety and hygiene in food intake.

The key informant further indicated that "*... even the disclaimer about the need to buy FDA authorised products that comes with advertisement creates awareness about safety and hygiene issues for the general public*" (Key Informant, Offinso).

When these summary treatment effect measures are considered together, they give an indication of the pattern of selection on gains from the information infrastructure. For instance, we observe that the ATT is greater than the ATE which is also greater than the ATU in the case of internet cafés. This relationship is suggestive of positive selection on gains, which implies that households which are more likely to reside in communities with internet cafés tend to benefit more from living in a community with internet cafés. However, the pattern of selection observed for ICT centre and community radio is not uniform but differs across the nutritious diet indicators. The summary estimates show reverse selection on gains for vitamin A and protein in the case of ICT centre, and for protein in the case of community radio. However, they show positive selection on gains for iron in ICT centre and vitamin A and iron in community radio. The reverse selection on gains implies that households which are less likely to reside in communities with ICT centre (community radio) benefit more in terms of vitamin A and protein (protein) rich foods intake. This is suggesting the need for selective targeting in promoting the role of information infrastructure on various nutritious outcomes.

Treatment effects heterogeneities in observed characteristics

We present treatment effect heterogeneities in household farm status, household expenditure and the community price index in Panel C of Table 3 (see Tables A8 to A10 for complete results). Our interest is in the household farm status because this will show the impact of information infrastructure on nutritious diet intake between farm and nonfarm households in the data. At the untreated state, farm households are observed to be consuming significantly lower vitamin A-, protein-, and iron-rich foods compared to nonfarm households. Specifically, farm households were significantly consuming 0.21, 0.08 and 0.14 lower units of vitamin A, protein and iron compared to nonfarm households in the untreated case for internet cafés (Panel B of Table 3). Similarly, farm households were consuming 0.19, 0.05, 0.18 less vitamin A, protein, and iron, respectively, than nonfarm households for ICT centre, although not statistically significant in protein. Also, the differences in consumption frequency of vitamin A, protein and iron between farm and nonfarm households are 0.29, 0.17 and 0.25 units lower for farm households for community radio.

Interestingly, farm households tend to more than catch-up with nonfarm households in terms of consumption of these nutrients when they have the information infrastructure. These are represented in Panel C (Table 3) which presents the difference-in-difference estimates of the effects of the infrastructure across the observed characteristics (eq. 3). The estimates show that the treatment effects on nutritious diet intake between farm and nonfarm households are statistically significantly higher for farm households. Specifically, the treatment effect of internet cafés on vitamin A-, protein-, and iron-rich foods consumption is about 1.76, 1.34 and 1.98 units, respectively, higher for farm households than that of nonfarm households. A similar pattern, and in fact higher magnitudes, are observed for ICT centre and community radio. The treatment effect of ICT centre on the intake of vitamin A-, protein-, and iron-rich foods is 2.20, 1.54 and 3.74 units, respectively, higher for farm households than their nonfarm households. In the case of community radio, the treatment effect is about 2.94, 2.35 and 3.34 units higher for farm households than that of nonfarm households in the intake of vitamin A-, protein-, and iron-rich foods, respectively.

These observations imply that the physical presence of the information infrastructure in a community helps farm households to fully and even more than catch up with nonfarm households in terms of nutritious diet intake. This observation was to a greater extent confirmed by the findings from the qualitative interviews. In fact, it was said in six (6) out of the 7 focus group discussions (FGD) that information infrastructure has greatly improved the conditions of farming at the communities.

Table 3. Marginal treatment effect estimates of information infrastructure on nutritious diet intake.

	Internet			ICT centre			Community radio		
	VitaminA	**Protein**	**Iron**	**VitaminA**	**Protein**	**Iron**	**VitaminA**	**Protein**	**Iron**
Panel A: Impacts									
ATT	3.344***	3.642***	5.607***	3.272***	3.839***	6.634***	3.203***	3.234***	5.235***
	(0.250)	(0.232)	(0.266)	(0.362)	(0.349)	(0.429)	(0.398)	(0.384)	(0.483)
ATE	0.941	1.417*	-0.206	5.813***	6.736***	4.668***	3.047*	3.973*	5.062**
	(0.489)	(0.579)	(0.572)	(0.895)	(0.976)	(1.078)	(1.528)	(1.604)	(1.904)
ATU	0.537	1.043	-1.188	6.091***	7.055***	4.454***	3.047	4.051*	5.043*
	(0.567)	(0.675)	(0.669)	(0.996)	(1.075)	(1.189)	(1.651)	(1.728)	(2.056)
Panel B: ρ_0									
HHFarm	-0.208***	-0.078**	-0.141***	-0.188***	-0.049	-0.180***	-0.289***	-0.166***	-0.252***
	(0.036)	(0.029)	(0.029)	(0.046)	(0.029)	(0.031)	(0.043)	(0.036)	(0.040)
HHExpenditure	2.110***	1.445***	2.067***	1.703***	1.126***	1.483***	1.158***	0.739***	1.192***
	(0.377)	(0.278)	(0.348)	(0.284)	(0.169)	(0.196)	(0.308)	(0.167)	(0.186)
PriceIndex	-0.024***	-0.002	-0.015***	-0.023***	2.5E-04	-0.011**	-0.027***	0.005	-0.005
	(0.005)	(0.004)	(0.004)	(0.005)	(0.003)	(0.004)	(0.005)	(0.003)	(0.002)
Panel C: $(\rho_1 - \rho_0)$									
HHFarm	1.763***	1.336***	1.975***	2.195***	1.536***	3.737***	2.935***	2.351***	3.338***
	(0.267)	(0.211)	(0.384)	(0.572)	(0.427)	(0.608)	(0.333)	(0.287)	(0.637)
HHExpenditure	-1.932***	-1.048*	-1.856*	-0.152	0.590	0.446	1.697	2.048*	7.158***
	(0.554)	(0.529)	(0.790)	(0.676)	(0.667)	(0.814)	(1.119)	(0.893)	(1.441)
PriceIndex	0.027	-0.035	0.104	0.002	-0.194	-0.002	0.199**	-0.072	0.072
	(0.064)	(0.046)	(0.069)	(0.101)	(0.100)	(0.101)	(0.074)	(0.063)	(0.092)
p-value Obs. Het.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value Ess. Het.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
N	19650	19650	19650	19340	19340	19340	19650	19650	19650

Notes: Standard error in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The participants have unanimously agreed that the improvements in farming and other related economic activities have been much better when they compare the situation with the information infrastructure to the situation without it in the past. The reason provided was that more people now have access to extension services and information about inputs which make them knowledgeable about best farming techniques and nutritious diet intake. This is also in line with what a key informant in the middle zone said:

> … government organisations like the District Ministry of Food and Agriculture (MoFA) officers do educate farmers on radio and at durbars, at the community information centres on the availability of extension services, how to apply fertilisers or even planting time, which help in increasing farmers' productivity and eventually translating into higher incomes and spending on nutritious diet/food (Key Informant, Offinso).

This finding and the theory of change (in section 1.3) highlight that the ultimate means by which information infrastructure could affect household consumption of nutrients rich foods are through households' incomes and prices in the form of market margins. To shed light on some of the underlying reasons why the treatment effects of the information infrastructure are higher for farm households than nonfarm households, we present the effects of household expenditure and community price index in the untreated state in Panel B and the treatment effects of these in Panel C of Table 3. As expected, a cedi increase in household total expenditure increases nutritious diet intake by about 0.74 units of protein rich foods for community radio to as high as about 2.11 units of vitamin A rich foods in the untreated state. Conversely, an increase in the community price index generally deceases the consumption of nutritious diets. In particular, the consumption of vitamin A and iron rich foods significantly decreases by 0.02 and 0.02 units, respectively for internet cafés, and 0.02 and 0.01 units respectively for ICT centre when local price level of goods and services increases by 1 cedi. We observe similar pattern in the consumption of vitamin A rich foods in the case of community radio where the frequency of consumption significantly decreases by 0.03 when local price index increases by a cedi.

However, the significant advantage associated with household expenditure in nutritious diets significantly narrows for internet cafés and disappears for ICT centres. Except for community radio where its presence in a community tends to benefit high expenditure households in nutritious diet intake, the results show that the impact of having an internet café in a community on household intake of vitamin A, protein and iron is significantly higher by 1.93, 1.05 and 1.86, respectively, for households with lower income. The treatment effects also show that the significant advantage in nutritious diet intake associated with increased household expenditure disappears with the presence of ICT centre in the community. Similarly, the significant decrease in nutritious diet intake associated with an increase in the local price index disappears and, for community radio, this leads to increase in the intake of vitamin A rich foods by households in community with high price index. This implies that the information infrastructure helps to decrease the consumption gap between high and low expenditure households and contributes to reducing the dreaded effect of inflation on nutritious diet intake. In sum, in the untreated state, farm households and low expenditure households are disadvantaged in terms of nutritious diet intake. However, this disadvantage generally disappears and the catch-up is larger for farm households.

Marginal treatment effects (MTE)

To investigate the pattern of selection further and the distribution of unobserved returns from the information infrastructure, we present the marginal treatment effect (MTE) curves for each information infrastructure across the outcomes in Figure 2. The test of essential heterogeneity shows there is statistically significant unobserved heterogeneity among households in returns to the information infrastructure across all the nutritious diets outcomes (Table 3). The figures on the internet café present

evidence of positive selection on unobserved gains for all the nutritious diets outcomes. The MTE is higher with lower resistance to the information infrastructure and decreases with increasing resistance up to the point where the unobserved resistance to treatment (URT) (i.e., resistance to residing in a community with an internet café) is about 60% ($URT = 0.6$) and begins to increase with increasing resistance to treatment, generally mimicking the pattern of positive selection on gains. This implies that households which are more likely to reside in communities with an internet café appear to benefit the most from having an internet café, a pattern of heterogeneity (i.e., the MTE curve slope) that is statistically significant at the 1% level ($p < 0.000$ for test of essential heterogeneity in Table 3).

Specifically, for the 20% of households ($URT < 0.2$) which are more likely to be found in communities with an internet café (i.e., with the lowest resistance to treatment), having an internet café in the community (statistically) significantly increases vitamin A-, protein-, and iron-rich foods consumption than the average households (i.e., the dashed lines). Also, the highest treatment effect is found in this segment. In contrast, the returns to the internet café are lower than the returns to the average household for the households with 30% to 74% (i.e., $0.3 < URT < 0.74$) resistance to having an internet café in the community in the intake of vitamin A and protein rich foods, and this is (statistically) significantly different from zero. Similarly, for the households with 45% to 85% (i.e., $0.45 < URT < 0.85$) resistance to having internet cafés, being in communities with internet cafés is associated with lower consumption of iron rich foods than that of the average household, which is also significantly different from zero.

We next consider the MTE for ICT centre. The pattern of selection on unobserved gains shows a reverse selection on gains in the intake of vitamin A and protein rich foods and somewhat positive selection on unobserved gains in the consumption of iron rich foods. The MTE curve is (statistically) significantly higher for at least the households with the lowest ($URT < 0.22$ for vitamin A, $URT < 0.27$ for protein and iron) and those with the highest ($URT > 0.64$ for vitamin A, $URT > 0.62$ for protein and $URT > 0.75$ for iron) resistance to having ICT centre in the community. For vitamin A, the MTE curve is (statistically) significantly higher at least for the households with the lowest ($URT < 0.22$) and those with the highest ($URT > 0.64$) resistance to having ICT centre in the community. Also, the treatment effect is at the highest for households with the highest resistance to having ICT centre in the community ($URT > 0.9$). In fact, the MTE is significantly higher, than the returns to the average household, for the 25% of households with highest ($URT > 0.75$) resistance to ICT centre compared to only 10% of households with the least ($URT < 0.1$) resistance which have their treatment effects significantly higher than the average household.

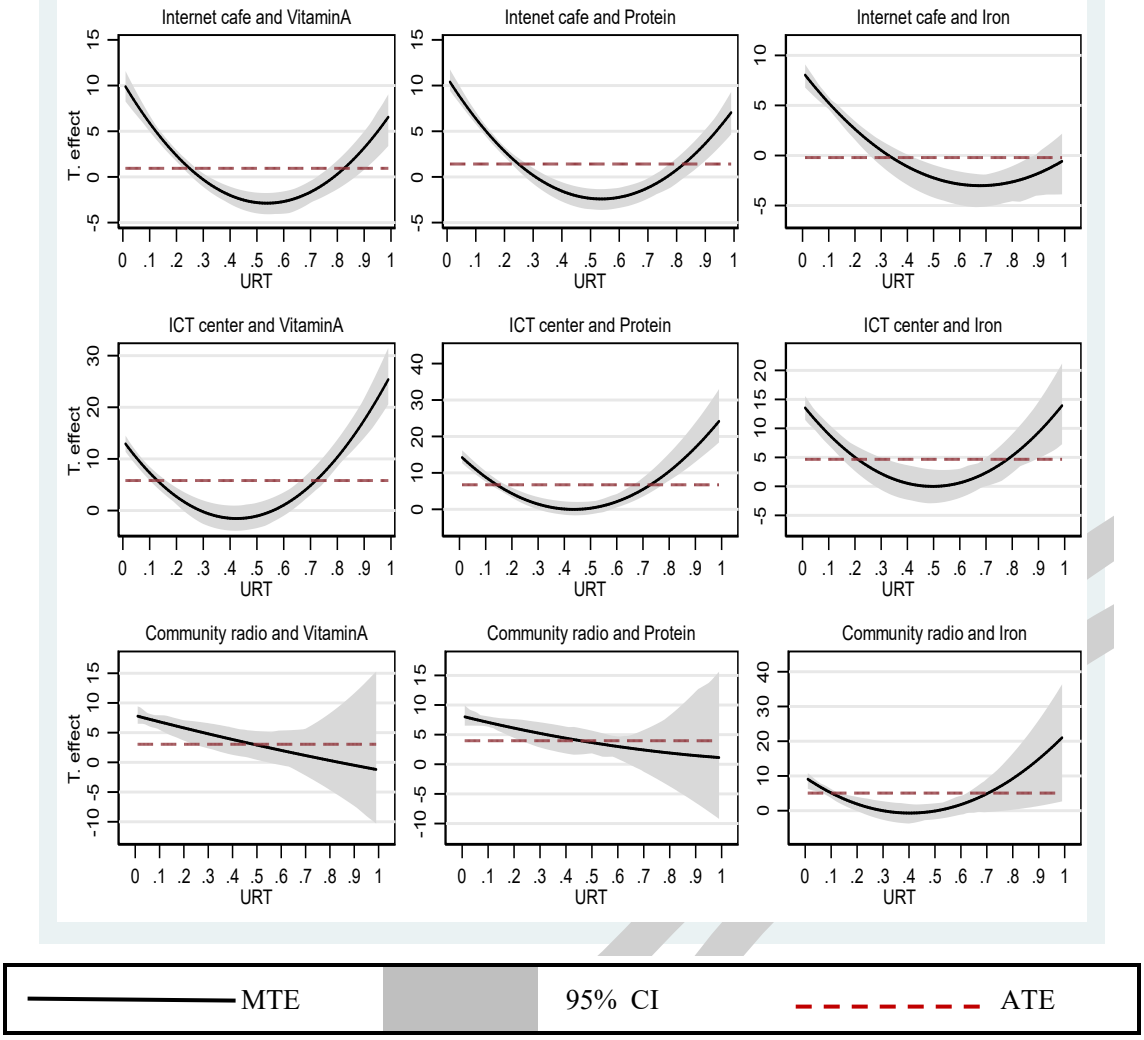

Figure 2. Marginal treatment effect estimates of nutritious diets.

Similarly, for protein foods intake the returns to ICT centre are at the highest for households with the highest resistance to ICT centre in the community (URT >0.9), and the treatment effect is significantly higher for the 22% of the households with highest (URT >0.78) resistance to ICT centre than the average household (dashed line). Comparatively, the percentage of households with significantly more than average treatment effects for those with the highest resistance (22%) is greater than the 10% of the households with the least resistance to ICT centre which have their treatment effects significantly greater than the average household. Conversely, the treatment effects are significantly higher for households with lowest and highest resistance (URT <0.25 and URT >0.25, respectively) in the case of iron. But, whereas about 10% (URT <0.11) of the households with the lowest resistance to treatment have significantly higher treatment effects than the average household in iron rich food consumption (dashed line), not more than 5% (0.93< URT <0.97) of households with the highest resistance to treatment have their treatment effects significantly greater than the average household. Thus, based on the unobserved characteristics, households which are most (least) likely to live in communities with ICT centre appear to benefit the least (most) from having an ICT centre in the community in terms of vitamin A and protein (iron) rich foods consumption, which are suggestive of reverse (positive) selection on unobserved gains.

Finally, we consider the MTE for community radio where the slopes of the curves show statistically significant heterogeneities in unobserved gains (p <0.003 for the test of essential heterogeneity) among households. Whereas the slope is statistically significant for the 50% (URT <0.50) and 65% (URT <0.65) of households with lowest resistance to having community radio for vitamin A and protein, respectively, it is statistically significant for the 17% (URT <0.17) with the lowest resistance and 17% (URT >0.17) with the highest resistance in the case of iron. Relative to an average household, residing in a community with community radio results in significantly higher consumption of vitamin A and protein for the 19% (URT <0.19) and 19% (URT <0.19) of households with the lowest resistance to having community radio, respectively. In the case of iron, the figure shows that only 4% (URT <0.04) of households with the lowest resistance to having community radio have significantly higher iron rich foods consumption than an average household whereas households with resistance between 18% and 57% (i.e., 0.18< URT <0.57) have significantly lower iron rich foods consumption than the average household. The pattern of slopes of the curves suggests positive selection on unobserved gains where the returns to community radio in terms of nutritious diet intake significantly decrease with increasing resistance to community radio.

Impact mechanisms: production support

Our theory of change discussed in section 1.3 argues that information infrastructure could affect nutritious diets either through production support systems or market support system or both. To investigate this, we present estimates of impact mechanisms associated with the production support system in Table 4 and the market support system in Table 5.

The production support systems investigate the impact of the information infrastructure on nutritious diet intake through 1) direct information about diets (i.e., types, preparation and handling) measured as consumption of own food produced by the household (HHOwnFood); 2) extension access, farm outputs, and farm income (CExtAgent, FarmOutput and FarmRevenue); and 3) storage, own food produce consumption, processing and farm income (FarmStored, HHOwnFood, FarmProcessed and FarmRevenue). We see that the impact mechanisms differ depending on the information infrastructure. The first immediate mechanism of the effect of information infrastructure through the production support on vitamin A, protein and iron is *own food produce consumption*. The estimates, respectively, show 0.17, 0.24 and 0.17 for internet cafés, 0.46, 0.39 and 0.44 for ICT centre and 0.41, 0.42 and 0.42 for community radio. These effects are statistically significant for ICT centre and community radio. This suggests that 0.46, 0.39 and 0.44 of the effects of ICT centre on vitamin A and protein, respectively, and 0.41, 0.42 and 0.42 of the effects of community radio on vitamin A, protein, and iron, respectively, can potentially be attributed to households' consumption of own food produce.

The other two immediate mechanisms of the production support system are through *extension access* and *storage of own produce*. When these are compared to the household consumption of own produce, the *extension access* is the most prominent immediate impact mechanism. In particular, except for internet cafés where *storage* significantly serves as the means through which the internet café affects vitamin A and protein intake, this does not appear to be a significant route by which any of the information infrastructure affects the nutritious outcomes.

Table 4. Weighted-least square estimates of impact mechanisms: production support system.

	(1) Vitamin A	(2) Protein	(3) Iron		(4) Vitamin A	(5) Protein	(6) Iron
Internet cafe							
HHOwnFood	0.167	0.237	0.172				
	(0.140)	(0.143)	(0.175)				
CExtAgent	1.056***	0.992***	0.727***	FarmOutput	1.020***	1.123***	0.463***
	(0.104)	(0.108)	(0.140)		(0.038)	(0.035)	(0.071)
				FarmRevenue	0.667***	0.730***	0.563***
					(0.032)	(0.031)	(0.059)
FarmStored	0.418**	0.342**	0.225	HHOwnFood	-0.003	0.001	0.005
	(0.156)	(0.157)	(0.214)		(0.046)	(0.047)	(0.062)
				FarmProcessed	0.292***	0.251***	0.232**
					(0.051)	(0.051)	(0.071)
				FarmRevenue	0.223**	0.179**	0.428***
					(0.086)	(0.098)	(0.096)
ICT center							
HHOwnFood	0.462**	0.393*	0.440**				
	(0.204)	(0.207)	(0.215)				
CExtAgent	0.993***	0.979***	0.485**	FarmOutput	0.264	1.225***	0.315***
	(0.189)	(0.183)	(0.201)		(0.219)	(0.195)	(0.133)
				FarmRevenue	0.400**	0.605***	0.523***
					(0.163)	(0.178)	(0.123)
FarmStored	0.434	0.487	0.150	HHOwnFood	0.065	0.182	0.093
	(0.271)	(0.561)	(0.305)		(0.093)	(0.163)	(0.098)
				FarmProcessed	0.324*	0.308	0.055
					(0.160)	(0.407)	(0.123)
				FarmRevenue	0.201	0.367*	0.104
					(0.168)	(0.200)	(0.172)
Community radio							
HHOwnFood	0.407**	0.416**	0.416**				
	(0.141)	(0.143)	(0.184)				
CExtAgent	2.156***	2.228***	1.356***	FarmOutput	2.801***	0.939***	0.315***
	(0.252)	(0.236)	(0.317)		(0.116)	(0.108)	(0.101)
				FarmRevenue	0.132	0.042	0.183
					(0.130)	(0.133)	(0.158)
FarmStored	0.194	0.191	0.223	HHOwnFood	0.047	0.025	0.055
	(0.167)	(0.159)	(0.228)		(0.040)	(0.038)	(0.054)
				FarmProcessed	0.069	0.078	0.143*
					(0.059)	(0.055)	(0.078)
				FarmRevenue	0.459**	0.270*	0.364*
					(0.145)	(0.140)	(0.208)

Notes: Standard error in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

However, the estimates show the impact of *extension access* is statistically significant for all the nutritious outcomes and for all the information infrastructure. In fact, for internet cafés, the estimates show that 1.06, 0.99 and 0.73 of the effects of internet cafés on vitamin A, protein, and iron, respectively, are potentially through extension information. Similarly, the estimates show that about 0.99, 0.98 and 0.49 of the effect of ICT centre and 2.16, 2.23 and 1.36 of the effects of community radio on vitamin A-, protein-, and iron-rich foods intake can potentially be attributed to households' access to extension services. In fact, four (4) out of the 6 nutrition experts interviewed attributed the impact of the

information infrastructure as being through extension access. They indicated they were very much aware of the information infrastructure increasing access to extension services, increasing input use efficiency, increasing productivity, increasing income, and spending on nutritious diets.

We next consider the intermediate mechanisms which are through *extension contact* and *storage* in columns 4-6. The estimates further show interesting results about the effects of *extension access* through *farm output* and *farm revenue*. Having an internet café in the community results in extension access significantly contributing 1.02, 1.12 and 0.46 to vitamin A-, protein-, and iron-rich foods intake, respectively, through farm output, whiles significantly contributing 0.67, 0.73 and 0.56 to vitamin A-, protein-, and iron-rich foods intake, respectively, through farm revenue. Similarly, the results show that farm output and farm revenue are potential mechanisms by which ICT centre affects nutritious diet intake through access to extension. Specifically, the estimates show that about 0.26, 1.23 and 0.33, and 0.40, 0.61 and 0.52 of the effects of ICT centre on vitamin A-, protein-, and iron-rich foods intake, respectively, can possibly be due to enhanced farm output and farm revenue respectively, through extension access, *albeit* not statistically significant in vitamin A intake in the case of farm output. Regarding community radio, the estimates show that only farm output serves as the intermediate mechanism through which the availability of this information infrastructure affects nutritious diet intake through extension access. The results in columns 4-6 show that about 2.80, 0.94 and 0.32 of the effects of community radio on these outcomes can be attributed to farm output through access to extension.

The other branch of the intermediate effects is through *storage*. Columns 4 and 5 under the internet café show that storage accounts for about 0.42 and 0.34 of the effect of internet cafés on vitamin A and protein, respectively. However, storage does not significantly mediate the effects of ICT centre and community radio on these outcomes. We next examine the intermediate effects of storage (i.e., through own produce consumption, processing and farm revenue) on the nutritious diets' intake. Just as observed in the immediate case, *own produce consumption* does not appear to be an important intermediate mechanism by which any of the information infrastructure affects nutritious diet intake through storage. The second intermediate mechanism examined through storage is *processing* (i.e., whether any of the farm produce was processed). The estimates in column 4-6 also show that this mechanism is only statistically significant for internet cafés. In fact, up to 0.29, 0.25 and 0.23 of the effects of internet cafés on nutritious diet intake can perhaps be attributed to processing of stored produce. However, this appears not to have any statistical significance in ICT centre and community radio, an observation that is not surprising given that storage as an immediate mechanism is only significant for the internet café but not for ICT centre and community radio.

Similarly, the results of the effects of the infrastructure through *storage* and *farm revenue* are statistically significant for all the nutritious diet intake for internet cafés and community radios, and only statistically significant for protein in the case of ICT centre. However, the significance of *farm revenue* through storage observed particularly for community radio, even though storage itself is not statistically significant in this case, can partly be explained by the possible externalities in market factors (such as price margins). This second mechanism route also suggests that the internet café is the most important information infrastructure in impacting nutritious diet intake through storage.

Impact mechanisms: market support

The other major immediate mechanism discussed in the theory of change as means by which information infrastructure affects nutritious diets is market support. We present estimates of the immediate mechanisms for the market support system in columns 1-3 and intermediate mechanisms (which is through the immediate) in column 4-6 of Table 5. Given the role of information in breaking information asymmetry and in enhancing market access (Key et al. 2000), we first examine the effect of the information infrastructure on nutritious diet intake through market access. The estimates show that market access is only an important immediate mechanism through which the internet café affects vitamin A and protein rich foods intake. In particular, the estimates in columns 1-3 show that about 0.46, 0.40

and 0.26 of the effects of internet cafés are potentially due to enhanced market access, *albeit* not significant for iron.

However, we see that market access is generally not an important mechanism by which ICT centre and community radio affect nutritious diet intake. It is only in the case of iron where community radio has a marginal significance and negative effect on iron rich foods intake through community market access, which is suggestive of a relationship of substitutability between community radio and market access. This is not surprising especially when, in their quest to beat down transaction costs, market agents rely on services provided by information infrastructure to first enquire about market availability and conditions before getting to the market (Jensen 2007; Ingram 2011). In such situations, it is possible to see the effect of the information infrastructure affecting the outcomes through market access either positively (when the enquiries lead to agents immediate participating and selling in the markets) or negatively (when such enquiries lead to deferred participation or selling in search of favourable market conditions). Either of these situations will then mean that favourable prices are the most important motivation of farmers' use of the information infrastructure, and subsequent engagement with the market, which we investigate next.

Table 5. Weighted-least square estimates of impact mechanisms: marketing support system.

	(1)	(2)	(3)		(4)	(5)	(6)
	VitaminA	**Protein**	**Iron**		**VitaminA**	**Protein**	**Iron**
Internet cafe							
Com market	0.462***	0.401***	0.260				
	(0.142)	(0.141)	(0.168)				
PriceMarket	0.327***	0.327***	0.701***				
	(0.037)	(0.038)	(0.045)				
CropStored				PriceMarket	0.176***	0.146**	0.386***
					(0.054)	(0.055)	(0.074)
ICT center							
Com market	0.162	0.052	-0.231				
	(0.137)	(0.142)	(0.164)				
PriceMarket	0.853***	0.807***	0.924***				
	(0.132)	(0.114)	(0.097)				
CropStored				PriceMarket	0.229**	0.069	0.287**
					(0.095)	(0.161)	(0.129)
Community radio							
Com market	-0.144	-0.082	-0.466*				
	(0.203)	(0.193)	(0.246)				
PriceMarket	0.285***	0.277***	0.278***				
	(0.058)	(0.058)	(0.070)				
CropStored				PriceMarket	0.208***	0.183***	0.462***
					(0.062)	(0.060)	(0.082)

Notes: Standard error in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Interestingly, Table 5 shows that market price is a statistically significant immediate market mechanism by which the information infrastructure affects nutritious diet intake. In particular, the estimates show that 0.33, 0.33 and 0.70 of the effect of internet cafés on nutritious diet intake can be attributed to favourable selling prices of produce received by farmers, whiles about 0.85, 0.81 and 0.92 of the effects of ICT centre can be attributed to selling prices of farm produce. Furthermore, the estimates show that about 0.29, 0.28 and 0.28 of the effects of community radio on nutritious diet intake can possibly be attributed to favourable selling price of farm produce received by farmers. This buttresses our argument

about favourable prices and the use of information technology and services, as we see in this case that the effect of the information infrastructure through market prices are highly significant in almost all cases. This also partly reinforces the significance of farm revenue in improving household nutritious diet intake given that price was one of the arguments in explaining farm income.

We next consider market prices of farm produce as an intermediate effect resulting from possible sale of stored produce. The estimates show market price as persisting in its role as an impact mechanism. Specifically, the results show that about 0.18, 0.15 and 0.39, and 0.23, 0.07 and 0.29 of the effects of internet cafés and ICT centres on vitamin A, protein, and iron, respectively, can potentially be ascribed to favourable market price from sale of stored farm produce, although not statistically significant for protein in the case of ICT centre. We also observe statistically significant effects and similar pattern of estimates in the instance of community radio where about 0.21, 0.18 and 0.46 of the effects of community radio on these nutritious diets' outcomes are possibly through favourable market prices from sale of stored farm produce. As stated earlier, this perhaps explains why the effects of farm revenue through storage under the production support system was significant for some of the outcomes where storage itself was not statistically significant. This implies that part of the effects of the information infrastructure on the outcomes through farm revenue observed under production support could be due to favourable market price received from speculative market behaviour by farmers, and reduced transactions cost of market participation (Key et al. 2000).

Furthermore, it was revealed at some of the FGDs that they often get weekly market prices on food stuff across the various markets in the districts through phone calls and some radio programmes, which make them to know the price difference across the various markets and the price margins. Also, participants in the FGDs in the northern zone indicated that contribution of the information infrastructure to enhancing price information is much better now than when they did not have them in the past. They agreed that the information infrastructure has now given them the opportunity to compare prices across markets because of the information available. This gives them the opportunity to go in for markets with favourable prices. Specifically, in discussing the role of infrastructure in enhancing nutrition and women's empowerment among women in the Upper West Region, a participant had this to say:

> I went to a fertiliser depot and the prices and quantity were not so favourable for me, instantly a woman farmer from behind, picked her phone and inquired from several other places I had never known. She was so helpful to me that day, and it is all because of the existence of information infrastructure and ability to individually take decisions around her work (an FGD discussant at Zongo, Wa).

3.4 Impact of Information Infrastructure on Women's empowerment Outcomes

Aggregate treatment effect measures

Table 6 also presents estimates of the treatment effects of the information infrastructure on women's economic empowerment outcomes in Panel A, the effects of household farm status, household expenditure and price index at levels in Panel B, and the treatment effect heterogeneities in these observed characteristics (see columns 4-6 of Table A8-A10 in appendix for complete estimates) in Panel C. In Panel A, the average treatment effect on the treated (ATT) suggests that for an average woman in a household residing in a community with internet cafés, having internet cafés results in 0.33, 0.05 and 0.20 higher average empowerment index, gender parity index and women's economic empowerment index, respectively. The average treatment effect (ATE) indicates that for a woman picked at random from the population of women, having an internet café in the community raises the average empowerment index, gender parity index and women's economic empowerment index by 0.54, 0.17 and 0.30, respectively. Additionally, the average treatment effect on the untreated (ATU) implies that residing in a community with internet cafés raises average empowerment index, gender parity index and the women's economic empowerment index by 0.57, 0.24 and 0.38 for the average untreated woman.

We see similar pattern of treatment effects for ICT centre and community radio with estimates slightly

higher in magnitudes. In the case of ICT centre, the ATT suggests that living in a community with an ICT centre significantly increases women's economic empowerment indices by 0.43, 0.15 and 0.11 for the average woman residing in a community with an ICT centre. Also, the ATE implies that for an average woman picked at a random from a population of women, residing in a community with an ICT centre increases average empowerment, gender parity and women's economic empowerment indices by 0.82, 0.56 and 0.40, respectively. For the untreated average woman, residing in a community with an ICT centre increases the average empowerment by 0.86, gender parity by 0.70 and women's economic empowerment by 0.53.

Also, the seemingly higher magnitudes of the treatment effects of ICT centre and community radio over internet café can still be attributed to the constraint in the use of internet. In fact, a key informant of the Information Services Department at the Ga West Municipality said this about the role of ICT centre and internet café:

> Most of our communities are such that members will only hear about certain important things only if the Information Services Department delivers it through the vans. The people are mostly not apt with smart phones, internet and social media (Key Informant, Amasaman).

We next consider the average treatment effect measures of community radio where the impact of community radio is estimated to have positive and statistically significant effect on the women's economic empowerment outcomes. In particular, the estimates show that, for the average treated woman, being in a community with community radio increases the average empowerment, gender parity and women's economic empowerment indices by 0.69, 0.10 and 0.29, respectively. Similarly, residing is a community with community radio results in 0.80, 0.33 and 0.33 increase in average empowerment, gender parity and women's economic empowerment, respectively, for a woman picked at random from the population of women. In contrast to the ATT, the ATU shows that, for the average untreated woman, living in a community with community radio increases these women's economic empowerment indices by 0.81, 0.39 and 0.34.

The discussions with the key informants suggest that information centres and community radio play crucial roles in increasing women's access to credit and transfer payments in the southern and middle zones. For instance, in the southern zone, a women's empowerment expert mentioned that:

> … women beneficiaries of micro credit facilities in the Ga West area are usually taken through economic empowerment programmes where they learn some skills in soap making and other businesses. The community information centres in the area are the media for mobilising women's groups, and the trainings always take place in these information centres. I am aware of women being trained at the information centres by some "credit houses" on how, where and requirements to meet to obtain credit. As such, women now obtain loans from banks because of the education they have received through the information infrastructure (Key Informant, Amasaman).

Also, a key informant at an organisation in the middle zone said:

> The department use the information centres and radio stations to inform beneficiaries of the Livelihood Empowerment Against Poverty (LEAP) about their money when it is ready. And since women and children dominate the list of beneficiaries in the area, the use of these affects access to productive capital of women if the beneficiaries form part of those investing their benefits into some income generating activities (production and selling of kenkey, charcoal etc.) (Key Informant, Offinso).

Unlike the case of nutritious diet intake where the pattern of selection differed among the information infrastructure and across the outcomes, we see a uniform pattern of selection, which is a reverse selection, on gains in the indicators for women's economic empowerment. When the magnitudes of the summary treatment effect measures are compared, we see that the ATU>ATE>ATT, which is

suggestive of reverse selection on gains. This implies that women in communities that are least likely to have the information infrastructure tend to benefit more from having the infrastructure. This corroborates the argument by Ufuoma (2012) that community information infrastructure such as radio has become the alternative media for the empowerment of marginalised public or communities. However, such reverse selection on gains is often associated to bottlenecks that are outside the capabilities of these women or their communities at large. Some of these can be due to infrastructural bottlenecks such as electricity access and availability, availability of specific information infrastructure support services and networks (such as accessing radio frequencies, national satellites etc.), as well as policy and regulatory requirements that may restrict the speed at which the infrastructure can be established in a community. Existing evidence show inadequate national physical assets and prohibitive costs in providing these infrastructures (ILO 2019), and complex legal and regulatory mechanisms (Ufuoma 2012; Nyarko et al. 2018) that have made the establishment of these information infrastructures, particularly community radio, very difficult in Ghana.

Treatment effects heterogeneities in observed characteristics

Panel C presents estimates of the treatment effects heterogeneities in observed characteristics. The results indicate equalising effects of information infrastructure on women's economic empowerment outcomes with different observed characteristics, and the tests of observable heterogeneity indicate that these households differ in their observed characteristics. Most notably, in the untreated state for internet café, women in farm households have 0.24, 0.25 and 0.26 lower average empowerment index (E_Index), gender parity index (GPI) and women's economic empowerment index (WEEI) than women in non-farm households (Panel B). Similar pattern of estimates is observed in the cases of ICT centre and community radio, where women in farm households have 0.23, 0.23 and 0.25, and 0.22, 0.22 and 0.24, respectively, lower average empowerment, gender parity and women's economic empowerment indices than women in non-farm households in the untreated state.

However, the treatment effects of the information infrastructure show otherwise, with clear evidence of more than catching up effects on women in farm households in Panel C. Specifically, the treatment effects of internet café on average empowerment index, gender parity index and women's economic empowerment index of women in farm households are 0.44, 0.42 and 0.35 higher than women of non-farm households. Similarly, whereas the treatment effects of ICT centre on these women's economic empowerment indices of women in farm households are 0.52, 0.15 and 0.48 higher than women in non-farm households, the treatment effects of having community radio on these empowerment indices of women in farm households are 0.38, 0.47 and 0.39 higher than that of women of non-farm households.

In sum, these estimates suggest that women in farm households tend to benefit more from the availability of these information infrastructures than their counterparts in non-farm households. This observation could be attributed to the fact that women in farm households are much deprived than their counterparts in non-farm households in the untreated state or benefit more with availability of the information infrastructure or both. In whichever case, it will lead to women of farm households having significantly higher treatment effects of these information infrastructures on their empowerment than women of non-farm households. Further investigation suggests that women in farm households are significantly less likely to have post-secondary education, have low household expenditure, and mostly rural than their non-farm household counterparts irrespective of the treatment status. However, the conditions of women appear to be much improved for all groups of women in the treated. This partly explains why the treatment effects of the information infrastructure for both groups are higher for women in farm households than those of non-farm households.

In line with this, we also presented the effects of household expenditure and price index as well as their treatment effects in Table 6. The estimates show that a cedi increase in household expenditure is

significantly associated with an increase in average empowerment (E_Index) in the untreated state by 0.08 for internet café, 0.06 for ICT centre and 0.05 for community radio. At the same time, the treatment effects show that having internet café or ICT centre in a community significantly increases the average empowerment of women in households with low expenditure than women in households with high expenditure. Thus, this implies that women in households with lower household expenditure benefit more in average empowerment in their households than women in higher expenditure households, which reinforces the earlier case about the equalising effects of information infrastructure on women's economic empowerment indices. Similar pattern is observed for price index, where an increase in the community price index significantly decreases most of the women's economic empowerment indices in the untreated state. However, the treatment effects show that the effects are also that of levelling for most of the empowerment outcomes where households in communities with high community price index significantly benefit from the infrastructure.

Table 6. Marginal treatment effect estimates of information infrastructure on women's economic empowerment.

	Internet café			ICT centre			Community radio		
	E_Index	**GPI**	**WEEI**	**E_Index**	**GPI**	**WEEI**	**E_Index**	**GPI**	**WEEI**
Panel A: Impact									
ATT	0.331***	0.051	0.200***	0.434***	0.148***	0.110***	0.685***	0.104***	0.287***
	(0.021)	(0.037)	(0.037)	(0.027)	(0.050)	(0.041)	(0.042)	(0.035)	(0.033)
ATE	0.536***	0.173***	0.300***	0.817***	0.557***	0.399***	0.798***	0.330***	0.326***
	(0.058)	(0.039)	(0.025)	(0.072)	(0.090)	(0.045)	(0.154)	(0.069)	(0.048)
ATU	0.571***	0.244***	0.381***	0.860***	0.695***	0.531***	0.808***	0.389***	0.340***
	(0.069)	(0.063)	(0.048)	(0.079)	(0.118)	(0.064)	(0.134)	(0.086)	(0.058)
Panel B: ρ_0									
HHFarm	-0.241***	-0.248***	-0.262***	-0.232***	-0.234***	-0.253***	-0.223***	-0.219**	-0.235***
	(0.003)	(0.005)	(0.009)	(0.003)	(0.006)	(0.003)	(0.003)	(0.007)	(0.008)
HHExpenditure	0.077**	-0.052	0.111	0.059***	-0.075	-0.035	0.052***	-0.032	-0.007
	(0.024)	(0.063)	(0.076)	(0.017)	(0.045)	(0.036)	(0.014)	(0.035)	(0.028)
PriceIndex	-0.001***	-0.002**	-0.002**	-0.002***	-0.002**	-0.002**	-0.002**	-0.001	-0.001
	(3.9E-04)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Panel C: $(\rho_1 - \rho_0)$									
HHFarm	0.440***	0.418***	0.351***	0.516***	0.150**	0.479***	0.378***	0.466***	0.394***
	(0.026)	(0.017)	(0.017)	(0.048)	(0.056)	(0.045)	(0.043)	(0.027)	(0.020)
HHExpenditure	-0.082**	0.052	-0.105	-0.176**	0.112	0.042	0.157	0.071	0.005
	(0.029)	(0.070)	(0.079)	(0.058)	(0.087)	(0.064)	(0.084)	(0.101)	(0.074)
PriceIndex	0.001	0.032***	-0.009	-0.002	0.017*	-0.019**	0.028**	0.015*	-0.009
	(0.010)	(0.006)	(0.007)	(0.016)	(0.007)	(0.007)	(0.010)	(0.007)	(0.005)
p-value Obs. Het.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
p-value Ess. Het.	0.064	0.000	0.152	0.606	0.000	0.375	0.000	0.000	0.000
N	15211	4833	3786	14965	4626	3598	15211	4833	3786

Notes: Standard error in parenthesis. ** $p < 0.05$, *** $p < 0.0$

In fact, evidence from the qualitative interviews lend support to these findings. Discussion with the women's economic empowerment experts and FGD participants (who specifically mentioned Maranatha Information Centre, Osonoba Information Centre, Eye Clear Information Centre in the southern zone, Time and Cristo Adom FM in the middle zone, and Might FM, and Yelvieni Internet café in the northern zone, among others) show that the presence of these information infrastructures has boosted the confidence of women to go into farming. One of the women's economic empowerment experts in the Kintampo area stated that "*... the District MoFA Office has a programme on some radio stations to educate women on agriculture*" (Key Informant, Kintampo). The discussion further revealed that unlike the past when women were relegated to only domestic chores and the lower level of the value chain, such programmes have currently led to women getting involved in the various value chains. Also, discussion with an empowerment expert in the northern zone showed an NGO has a women's economic empowerment programme on radio, which educates women on how to adopt innovative ways of processing shea butter in northern Ghana and with a similar programme in the southern Ghana where women are taught innovative ways of processing cocoa beans. Furthermore, discussions with the women groups show that the District Agriculture officials come to the information centres to educate and encourage women not to be left out when it comes to farming. The women revealed they are encouraged and sensitised to go into farming not just to feed the family but also to consider it as business or to commercialise it. Some other participants also indicated that, the acquisition and distribution of farm inputs like seeds and equipment (cutlasses) are mostly done at such meetings and at the premises of the information centres within their communities.

Marginal treatment effects

We examine the distribution of unobserved gains from the information infrastructure in Figure 3. For internet café, the MTE slopes are conventionally significantly different from zero but significantly different from the returns to an average woman only in the case of gender parity index (GPI). Also, the nature of the MTE slope differs across the women's economic empowerment outcomes. Still for internet café, whereas the highest unobserved gains are within the regions of $0.40 < URT <0.55$ for the average empowerment index and $0.15< URT <0.37$ for the WEEI, this is highest for those with resistance in the region of $URT >0.98$ for the gender parity index. Also, the figure for internet café and average empowerment index (E_Index) shows that only women in households with the lowest resistance ($URT < 0.10$) to having internet café have significantly lower average empowerment than the average woman. However, we see that the GPI is significantly higher than that of the average woman for women in households with the lowest resistance ($URT <0.15$) and those with the highest resistance ($URT > 0.85$) to having internet café in the community but lower for the women with intermediate resistance.

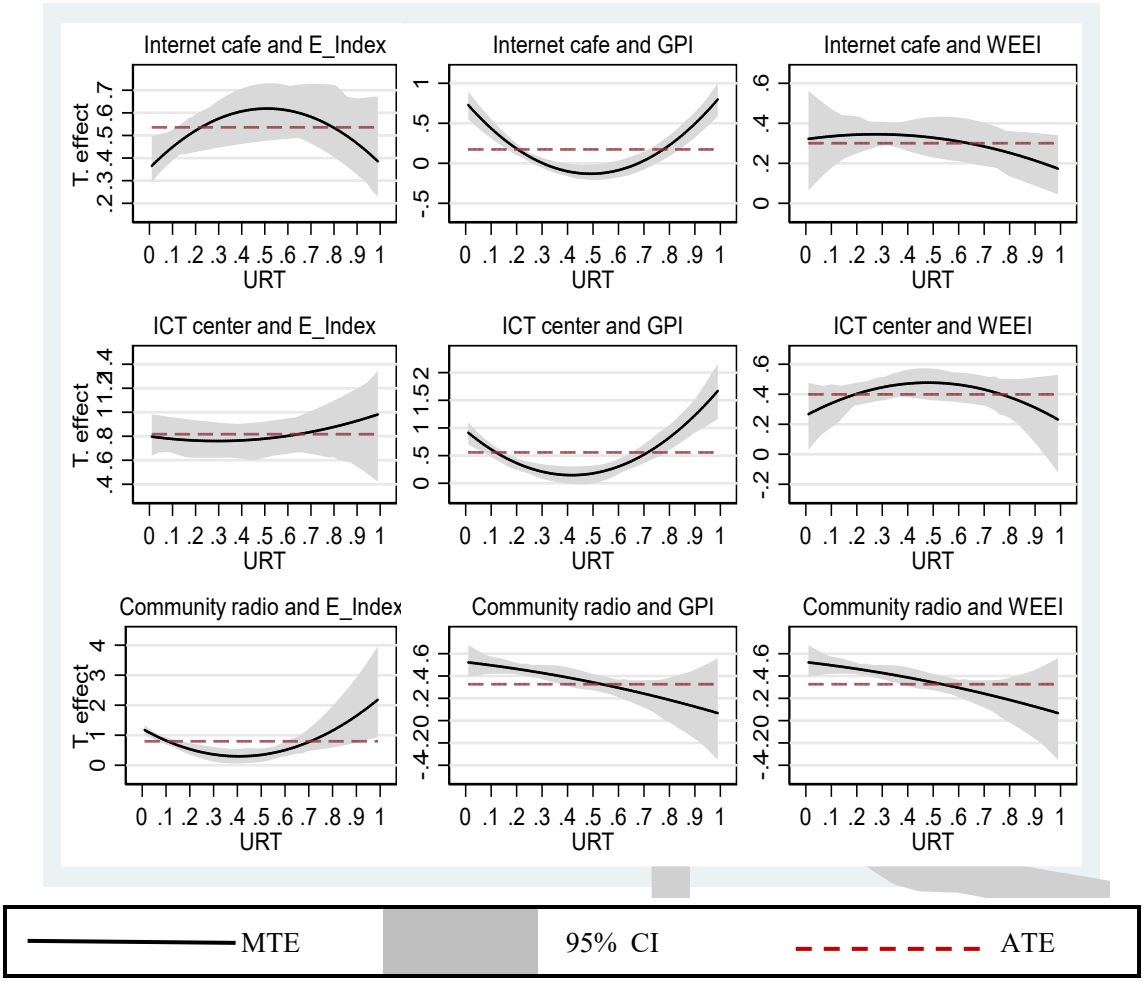

Figure 3. Marginal treatment effect estimates of women's economic empowerment.

The second panel presents the MTEs for ICT centre across the three women's economic empowerment outcomes. As observed in the case of internet café, the MTE slope is significantly different from the returns to an average woman in the GPI case (p-value of the essential heterogeneity is 0.000 in Table 6). Although, the unobserved gains in GPI are significantly higher for women in households with the lowest resistance (URT <0.05) and those with the highest resistance (URT >0.80), the segment is large for those with higher resistance than those with the lowest resistance. Similarly, the unobserved returns to ICT centre in terms of the GPI are significantly lower than the GPI of an average woman for those with resistance between 0.18< URT <0.63. Interestingly, the MTE slope for community radio appears to be statistically significantly different from zero, and that of the average gains in empowerment. The curves show significantly decreasing slope across the empowerment outcomes, suggesting that the unobserved gains to women's economic empowerment are significantly higher for women in households with the lowest resistance to having community radio. Specifically, the figures show that returns to community radio in terms of unobserved gains decrease with increasing resistance up to URT < 0.5 for E_Index, and for the entire distribution for GPI and WEEI. This implies a positive selection on unobserved gains where women in households who are more likely to reside in communities with community radio benefits more in terms of empowerment than women in households with the highest resistance.

The results imply significant heterogeneities exist in returns to internet café and ICT centre in terms of GPI, and in returns to community radio in respect of all the women's economic empowerment outcomes. This also adds to the observation in the summary treatment effects that there is the need for selective

intervention in promoting women's economic empowerment at the household levels through investment in information infrastructure. The significant slope and heterogeneities in unobserved gains in gender parity for internet café and ICT centre could possibly be because access to this infrastructure requires some form of extra motivation and commitment in terms of effort, finance, and time to access. Unlike community radio where its services can mostly be accessed without much commitment of resources and time as well as with low levels of education, access, and use of services of internet café and ICT centre by women and households require some levels of significant investment and education. For instance, it was expressed by an information expert, during an interview, that "*... bad network and high data charges/costs make the use of internet difficult. One must spend at least GHS 50 just for an hour of browsing or streaming*" (Key Informant, Tamale). Thus, it is not surprising to see the positive selection on unobserved gains to community radio, and both positive and reverse selection on unobserved gains to internet café and ICT centre.

Impact mechanisms

Given the noticeable impact of the information infrastructure on increasing women's economic empowerment of farm households and other households in general (as in the ATT, ATE and ATU), as well as the heterogeneous returns to the information infrastructure, we investigate the impact mechanisms by which the information infrastructure affects women's economic empowerment. The theory of change in section 2 argues that information infrastructure delivers services that support women who engage in agriculture and other trades by introducing them to new practices in production and marketing, which will lead to increased women income and command of resources. To investigate the impact mechanisms, we considered four mechanisms. These are women participation in productive ventures such as farm and non-farm businesses (WomenProduce), average hours women work in productive work (WorkHrs), number of town level meetings attended by women in the household (CMeetings), and whether women have been denied participation in community meetings because of their gender (NotAllowed).

Women participating in production is an important mechanism by which the information infrastructure affects the empowerment outcomes. This is statistically significant in the case of average empowerment (E_Index) for all the information infrastructure considered in this study, GPI for ICT centre and community radio, and WEEI for ICT centre (Table 7). The estimates imply that about 0.17, 0.02 and 0.03 of the effect of internet café on average empowerment index (E_Index), gender parity index (GPI) and women's economic empowerment index (WEEI) can be attributed to women's engagement in production, although this is significant only for the E_Index.

Also, we find that this mechanism is statistically significant for all the empowerment indices for ICT centre. The estimates show that about 0.12, 0.16 and 0.11 of the effects of ICT centre on E_index, GPI and WEEI can potentially be attributed to women's engagement in production activities, whiles up to 0.13 and 0.16 of the effects of community radio on E_index and GPI can be attributed to women's participation in production activities. Relatedly, we consider the hours worked by women in production. Although hours worked may appear like whether a woman participates in production activities or not, the former is richer as a measure of women's engagement in economic activities, and includes the hours worked in all productive ventures including formal wage employment.

Table 7. Weighted-least square estimates of impact mechanisms: inclusiveness and equity.

	(1)	(2)	(3)	(4)
	NotAllowed= 1	**E_Index**	**GPI**	**WEEI**
Internet cafe				
WomenProduce		0.173***	0.018	0.034
		(0.065)	(0.131)	(0.078)
WorkHrs		0.008***	0.012***	0.008***
		(0.002)	(0.004)	(0.002)
CMeetings		0.034***	0.005	0.024*
		(0.007)	(0.012)	(0.012)
Internet café=1	-0.530***			
	(0.024)			
NotAllowed		-0.060	-0.328	-1.320
		(0.045)	(0.532)	(0.749)
ICT center				
WomenProduce		0.124***	0.156***	0.109***
		(0.018)	(0.059)	(0.018)
WorkHrs		0.002	0.007	0.004
		(0.003)	(0.009)	(0.004)
CMeetings		0.058	0.159***	0.115
		(0.056)	(0.052)	(0.105)
ICT center=1	-0.449***			
	(0.031)			
NotAllowed		0.031	0.101	-0.137
		(0.034)	(0.073)	(0.124)
Community radio				
WomenProduce		0.132***	0.161*	-0.002
		(0.032)	(0.084)	(0.032)
WorkHrs		0.006***	0.012***	0.009***
		(0.002)	(0.003)	(0.002)
CMeetings		0.036	0.013	0.002
		(0.227)	(0.024)	(0.033)
Com radio=1	-0.452***			
	(0.030)			
NotAllowed		-0.092***	-0.004	-0.017
		(0.013)	(0.035)	(0.113)

Notes: Standard error in parenthesis. * $p < 0.1$, *** $p < 0.01$

The estimates show that changes in the hours worked by women are important mechanism in explaining the effect of internet café and community radio on all the empowerment outcomes. Increased working hours of women is estimated to account for 0.01, 0.01, and 0.01 of the effect of internet café, and 0.01, 0.01 and 0.01 of the effect of community radio on average empowerment, GPI and WEEI, respectively.

Interestingly, discussions with the women's empowerment experts throw more light on the impact of the information infrastructure through productive ventures and hours of work. A WIAD officer in the northern zone indicated that:

> … the information infrastructure has empowered women a lot because of the use of radio stations and community information centres by Agric Officers to educate farmers on where to

> get production inputs like seeds, the types of crops to grow, management of the farm, and marketing (Key Informant, Tamale).

In respect of time allocation, the two empowerment experts interviewed at the Kintampo and Ga West Department of Social Welfare indicated that the issue of time management is an essential component of their sensitisation programmes on radio and at the community information centres. It was argued that women now know how well to balance their time at work and in the home, and that women are also now gainfully employed than before, which increase their abilities to work to support basic needs at home. An empowerment expert at the middle zone stated that "*... the information people receive through the information infrastructure has made women realise that time lost cannot be gained. So, they spent a lot of time at their farms*" (Key Informant, Kintampo). Furthermore, regarding the role of internet café in women's economic empowerment, a key informant in the southern zone stated that:

> Today we have a lot of women learning things on the internet to better themselves, i.e., they are acquiring skills relevant for their personal development. People even learn trade online these days and can use that to support themselves and their families. On the various social media platforms, a lot of people including women have created accounts which sometimes fetch them some income. Even though there are negative aspects of these infrastructuress available to us, overall, I think the good outweighs the bad (Key Informant, Accra).

Table 7 further shows that increased attendance of community meetings potentially accounts for 0.03 and 0.02 of the effect of internet café on average empowerment index and WEEI, and about 0.16 of the effects of ICT centre on GPI. Indeed, it was revealed at the discussions with the KIIs that there were instances where leaders of women's groups in communities go to information centres to discuss important issues on women's welfare and advocate for inclusion of women in decision-making process. Further, a key informant at the Department of Social Welfare and Community Development stated that "*... they also encourage open forum discussions and everybody, including women, is free to share their opinions on matters of concern* (Key Informant, Kintampo).

Quite unexpectedly, whereas having internet café, ICT centre or community radio in a community is significantly associated with lower probabilities (0.53, 0.45 and 0.45, respectively) of women being denied participation in community meetings for gender reasons than women in communities without the information infrastructure, this mechanism does not appear to be critical in mediating the effect of the infrastructure on the women's economic empowerment outcomes. Except for average empowerment index where about 0.09 of the effect of community radio can be attributed to this, it is not statistically significant in all the empowerment outcomes across the information infrastructure.

When these mechanisms are taken together, the results suggest that engagement in production in terms of participation and hours worked are the prominent mechanisms by which information infrastructure affects women's economic empowerment. This is highlighting the importance of the information infrastructure in enhancing access to productive ventures and resources. These findings also suggest that community meetings and reduced gender stereotyping and discrimination are potential means by which information infrastructure affects women's economic empowerment although the effects of these appear not to be very strong. A possible explanation of the weak link of community meetings as an impact mechanism is that the participation in community level meetings in several settings in Ghana are largely in name, and not much is achieved in terms of women's contributions during meetings and in making decisions. We also observed during the FGDs that there were some customs and values observed in some of the communities that limited the contribution of younger women in the midst of older women in discussions. In fact, a young lady came to the team after one of the FGDs in the Kintampo area to confide in us that she had something to say but she dared not speak when her elders were speaking. Under such customs and practices, it is possible to observe substantial micro effect of information infrastructure on women at the production level but not much effect in terms of their influence at the community level or meetings. Hence, it is not surprising to find that productive capacity is a strong and

ubiquitous mechanism through which information infrastructure affects women's economic empowerment than attendance or participation in community meetings.

3.5 Policy Simulation

The analyses show that having the information infrastructure substantially contributes to household nutritious diet intake and women's economic empowerment, and that the returns to the infrastructure affect agents differently as shown by the MTE. This implies that policies that support or provide the needed conditions for the establishment of the information infrastructure will be rewarding. In this section, we quantify the returns to a policy that increases electricity access by computing the policy-relevant treatment effects (PRTE) as the weighted average over the MTE curve where the weight shows the households shifted by the policy (equation 10). We specifically simulate the policy that provides electricity to 10% (the instrument) of the households in communities without electricity. The results are presented in Table 8 where columns (1-2) show the baseline and policy induced propensities of having the information infrastructure for the entire sample, and columns (3-4) show the baseline and policy induced propensities of having the infrastructure for farm households. Columns 5-7 show the PRTE on the nutritious diets' outcomes, whiles columns 8-10 show the PRTE on the women's economic empowerment outcomes.

The results show that the policy shifts households and women with high treatment effects from unobserved characteristics into treatment, thereby increasing household nutritious diet intake and women's economic empowerment. In respect of the baseline and policy propensities of having the infrastructure, the expansion of electricity to the communities increases the likelihood of the communities having internet café, ICT centre and community radio by 39.02%, 28.71% and 41.56%, respectively, and the likelihood of farm communities having internet café, ICT centre and community radio by 84.91%, 72.73% and 58.70%, respectively. This suggests that although the expansion of electricity coverage increases the likelihood of having the information infrastructure, the induced changes are substantial on farm households which experience notably large improvements in nutritious diet intake and women's economic empowerment.

We attribute this strikingly high effects on farm households to the deprivation of farming communities in terms of access to electricity and other infrastructure such as roads and well-functioning markets. These findings suggest that establishing the information infrastructure requires access to electricity, which partly explains why some ICT centres which were established in communities without electricity were mostly not in use during our visits to the communities.

We now consider the PRTE in columns (5-10). The 10% expansion in electricity increases vitamin A-, protein-, and iron-rich foods intake by 7.59, 8.01 and 6.95 units for internet café, 10.31, 11.39 and 10.83 units for ICT centre and 9.00, 8.86 and 6.59 units for community radio, respectively, per household shifted. These are all statistically significant at the 1% level. Also, the results show that a 10% expansion in electricity coverage significantly increases average women's empowerment (E_index), gender parity index (GPI) and women's economic empowerment index (WEEI) by 0.97, 0.06 and 0.18 for ICT centre, per woman shift. However, the effect of this policy is estimated to significantly increase women's average empowerment index and women's economic empowerment index by 0.54 and 0.21 for internet café and 1.10 and 0.30 for community radio, per woman shift. These findings generally suggest that the mere provision of the infrastructure in a place is not enough to see to its functioning and yielding the needed outcomes. There is the need for creating the enabling environment by policy, especially in the aspect of technical support infrastructure and services, as this is crucial in having the information infrastructure operational in a place and in engendering the needed impact. Hence this emphasises the policy objective and advocacy of the Government of Ghana that the expansion of village information and communication infrastructure, and the development and modernisation of the national information

and communication infrastructure require rapid enabling physical infrastructure development (GoG 2003).

3.6 Interpretation and Discussions

In this section, we attempt to understand the sources of the pattern of unobserved gains from the information infrastructure. Our results generally show that returns to the infrastructure are heterogeneous, characterized by positive selection, reverse selection and in some cases both patterns of selection. Specifically, we examine the sources of the unobserved gains that gave rise to the nature of the MTE slope by investigating whether the gains from the information infrastructure by resistance to treatment $[E(U_1 - U_0|U_E = u_E)]$ are due to differences in the nutritious diets and women's economic empowerment outcomes in the untreated state $[E(U_0|U_E = u_E)]$, treated state $[E(U_1|U_E = u_E)]$ or both. In Figures 4 and 5, we present plots of the curves for U_1 and U_0, and the patterns are revealing. Figure 4 presents the plot of the gains from nutritious diet intake by resistance to treatment. The curves in the untreated state (dashed-black line) are generally concave or quasi-concave showing worse nutritious diet intake in the untreated state for households with lowest (highest) resistance to treatment in all the nutritious diets outcomes (vitamin A and protein), and for those with highest resistance to having community radio for iron.

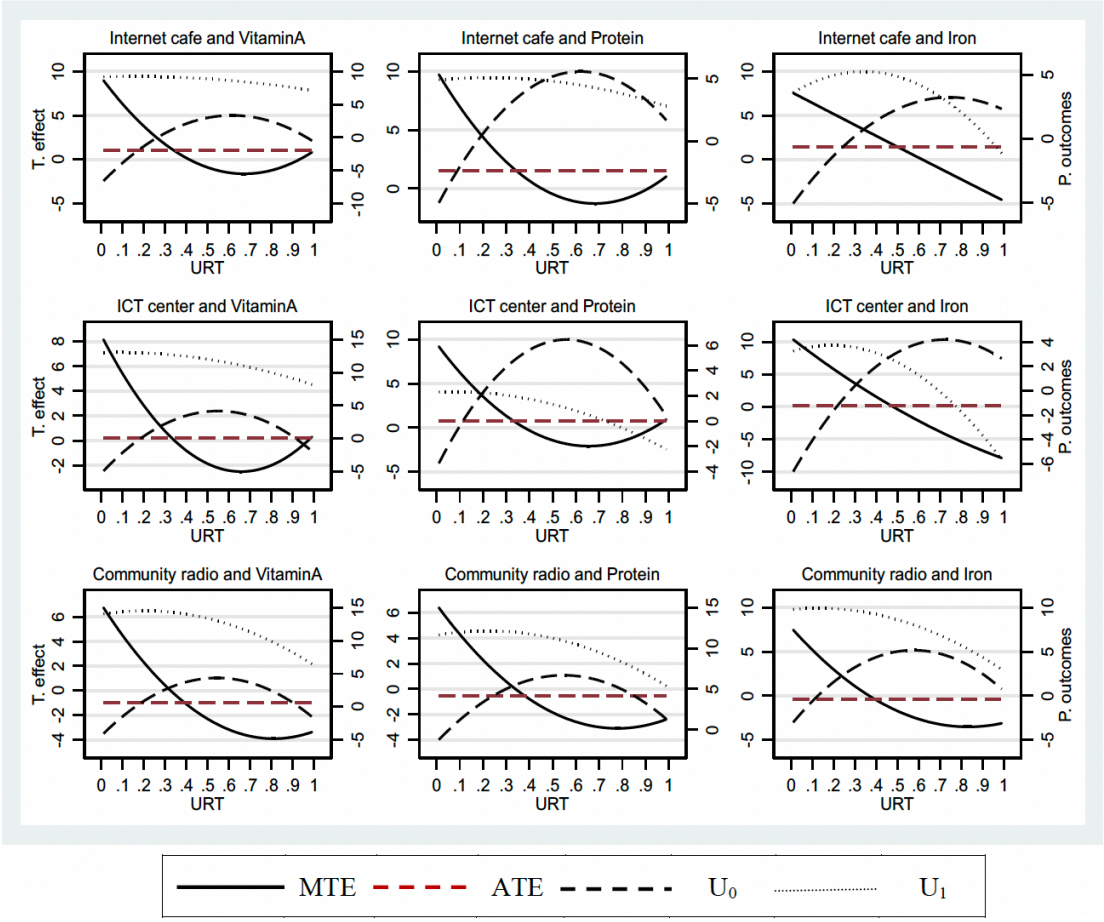

Figure 4 Reason for pattern of selection: Nutrition

However, the curves become relatively flat especially for the vitamin A and protein rich foods intake in the treated state, and even in cases where the flattening is not obvious (such as iron foods intake for internet café and ICT centre) the patterns still show that households which are worse-off in the untreated state appear to benefit more from the information infrastructure. Hence, this pattern suggests that larger treatment effects on nutritious diet intake between low and high resistance households can largely be explained by the lower nutritious diets' intake of the former in the untreated state (rising U_0). It also implies that having the information infrastructure in a community helps as an equaliser that largely removes the nutritious diet intake differences among households.

Figure 5 plots the returns on women's economic empowerment by the resistance to treatment, where the curves present patterns that are like that observed in the case of nutritious diet intake. In the untreated state, the curves are mostly (quasi) concave and alluding to the case where those with lower resistance to treatment having worse women's economic empowerment in this state. Also, even in the few instances such as the effect of internet café and ICT centre on average empowerment (E_Index) where the curves are somewhat convex and linear sloped, respectively, the patterns suggest that households with higher resistance to treatment have better women's economic empowerment than those with lower resistance to treatment. Strikingly, the curves appear flatter for all the infrastructure across all the empowerment outcomes in the treated state. This also implies that having the information infrastructure tends to benefit lower resistance households more than higher resistance households, and in that regard serving as an equaliser that mostly removes the intergroup economic empowerment differences between lower and higher-resistance groups.

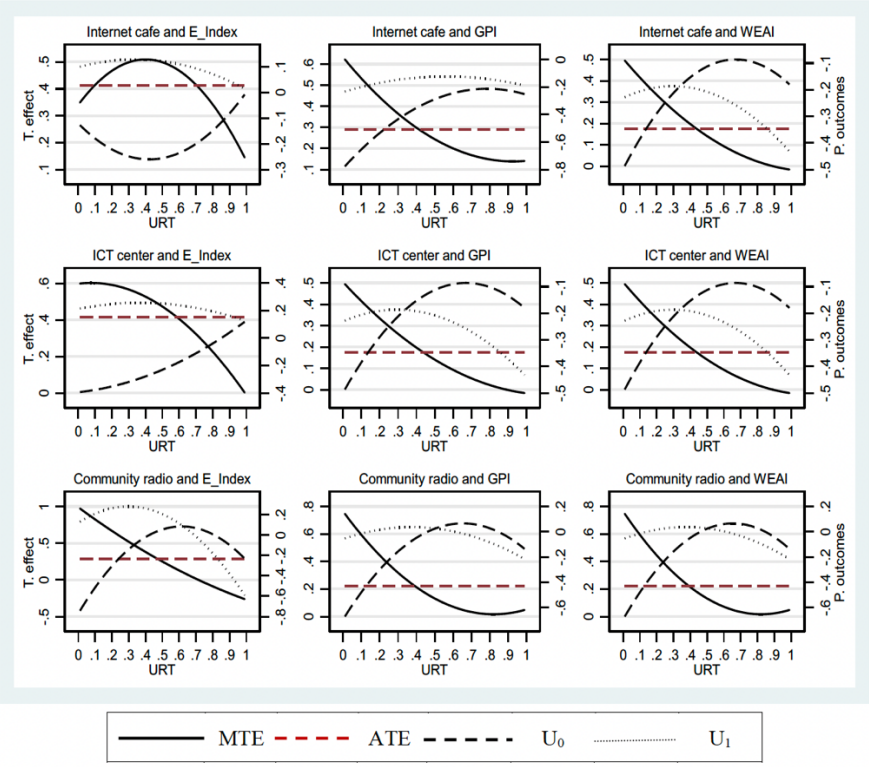

Figure 4. Reason for pattern of selection: Women's empowerment

Table 8. Policy relevant treatment estimates (PRTE)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Baseline	**Policy**	**Baseline**	**Policy**	**VitaminA**	**Protein**	**Iron**	**E_Index**	**GPI**	**WEEI**
Internet cafe										
Pscore	0.123	0.171	0.053	0.098						
PRTE					7.586***	8.007***	6.946***	0.537***	-0.031	0.211***
					(0.427)	(0.403)	(0.446)	(0.050)	(0.024)	(0.023)
ICT center										
Pscore	0.101	0.130	0.033	0.057						
PRTE					10.310***	11.390***	10.830***	0.972***	0.063*	0.183***
					(0.719)	(0.835)	(0.751)	(0.113)	(0.032)	(0.028)
Community radio										
Pscore	0.077	0.109	0.046	0.073						
PRTE					9.000***	8.863***	6.585***	1.103***	0.035	0.295***
					(0.638)	(0.667)	(0.689)	(0.083)	(0.025)	(0.026)

Standard errors in parentheses
* $p < 0.1$, *** $p < 0.01$

These observations bring to bear concerns about what could have accounted for such catching-up between the two groups of lower and higher-resistance to treatment in the presence of the information infrastructure. To probe this, we compiled data on household ownership of computers, mobile phone and radio, as well as the use of internet and internet from café/ICT centres from the GLSS datasets in Panel A of Table 9. We present the mean of these variables between the two groups: untreated (not having any of the infrastructure) and treated (i.e., having the information infrastructure) across the two survey periods. The table shows that more treated households across the two rounds of the survey appear to own computers, mobile phones and use internet than untreated households, whereas untreated households had more ownership of radio than the treated households. Interestingly, the table further reveals that the use of internet is generally higher for the treated than the untreated in all the rounds, and the same is the case when we consider internet use at internet café and ICT centres.

Hence, the observation that treated households largely own computers, mobile phones and use internet than untreated whereas the untreated appear to own radios slightly more than the treated households are pointing to the differences in essence and reach of specific information infrastructure for different groups and households in these communities. Precisely, these differences in ownership and use between the two groups could reflect some sort of comparative advantages in the use of the services of specific infrastructure. For instance, this could explain why we have complete positive selection and reverse selection on nutritious diet intake for internet café and ICT centre, whiles having somewhat mixed pattern of selection across the nutritious outcomes for community radio. Also, the equalising effects observed for the information infrastructure despite this seeming bias in use between treated and untreated households (in Table 9) could be suggestive of the comparative advantages associated with the use of each information infrastructure. This implies that policies meant to promote the information infrastructure need to consider not only the returns to the infrastructure, but also the comparative access and ease of use of the services of the infrastructure by various groups.

In addition, the argument above makes us wonder what type of households and communities access the information infrastructure as well as use the services of the infrastructure. Another feature of our results, especially those on women's economic empowerment in Table 6, is that of reverse selection on gains from the infrastructure as shown from the summary treated effect measures. This scenario is also the case for all the nutritious diets outcomes for ICT centre and protein for community radio in Table 3. This latter issue gives rise to the question that, why are households and women in communities which would have benefited more from the information infrastructure having higher resistance? One important reason may be that of endowments constraint on the part of households and communities that limit their ability to provide or access the infrastructure for their communities. To investigate this, we present data on household education and expenditure for untreated and treated households across survey rounds in Panel B of Table 9.

Table 9. Household use of information devices and services and selected household and community characteristics by round and treatment status

	2012/2013		2017/2018	
	Untreated	**Treated**	**Untreated**	**Treated**
Panel A				
Computer ownership	0.036	0.125	0.073	0.184
Mobile phone ownership	0.759	0.833	0.815	0.933
Internet use	0.031	0.208	0.216	0.469
Internet use in café/youth and ICT centres	n.a.	n.a.	0.017	0.022
Functioning radio ownership	0.569	0.556	0.414	0.366
Dysfunctional radio ownership	0.052	0.014	0.046	0.034
Panel B				
Primary education	0.239	0.208	0.037	0.045
Secondary education	0.236	0.292	0.194	0.335
Post-secondary education	0.147	0.222	0.077	0.145
Household expenditure	0.064	0.123	0.270	0.464
Motorable road	0.862	0.819	0.879	0.964
Community market	0.252	0.208	0.237	0.712
Urban	0.059	0.403	0.196	0.969

The table shows that the proportions of treated households with secondary and post-secondary education are higher than that for untreated households across the survey rounds. It is only in the case of primary education that the proportion of untreated is higher than treated, suggesting that treated households are (on average) more likely to attain higher education than untreated households. We also examine households' expenditure as a proxy of the household income and wealth. The results in Table 9 re-enforce this endowment argument. In fact, household expenditure has witnessed an increase between the survey rounds, but the average expenditure of the treated households is consistently higher than that of the untreated households in both survey rounds.

We also decided to scale up the endowment argument to check community level characteristics. We consider whether the community is motorable, whether it has a market and whether it is an urban or a rural community. The reason is that the provision of some of the information infrastructure considered in this study (such as internet café and community radios) are sometimes demand driven where providers will consider the endowment of the place in terms of market, road network and population. Our discussions with information infrastructure and services experts during the KIIs affirm this argument. In fact, the experts on this interviewed held that availability of electricity, markets, and good road network system; population size and availability of skilled labour; as well as other support services such as schools, reliable and favourable government policies are the factors they consider in siting a particular information infrastructure. In this case, we will expect communities that are accessible, have market potentials and populations (as in urban areas) to be able to attract more of the information infrastructure.

Reassuringly, the table shows that whiles the differences between treated and untreated groups in terms of motorable road and community across the survey rounds are mixed, more treated communities appear to have community markets than untreated communities in the latest round. Also, the data show that the proportion of treated communities that are urban are more than that of untreated communities in both survey rounds. These discussions, therefore, have two implications. First is that, although the provision of some of the information infrastructure such as the ICT centres can be said to be policy-driven that is provided by the government[13] they are not entirely exogenously determined as providers including

[13] ICT centres are largely provided by the National Communications Authority in Ghana.

private sector actors do consider the conditions of the communities. Secondly, the provision of these correlates with households' and communities' endowments, and that households and women with high resistance to having the information infrastructure are from less endowed backgrounds and communities.

Finally, the findings on the policy relevant treatment effects (PRTE) generally highlight the policy relevance of electricity access and connectivity to the information infrastructure and the outcomes. Reliable electricity access and supply contributes to lowering investment and operational costs of information infrastructure. In fact, it has been argued that even entities that are not connected to the electricity grid and are operating using stand-alone generators or batteries as primary source of energy are running on very high costs (GoG 2014), which will be prohibitively high for many internet cafes, ICT centres and community radio stations to operate. This critical importance of electricity access and connection was observed by the research team during our visit to some selected information infrastructure sites. All internet cafes, community radio stations and majority of the ICT centres visited were connected to the electricity grid, whiles the ICT centres in communities without electricity were mainly used as community durbar platforms and meeting grounds. In addition, connection to electricity encourages the use of information and communication technology such as cell phone, internet, radio devices and television services among others. Since these services provide households with a variety of leisure and access to information, it is not surprising that the availability of the infrastructure and use of these devices and services have increased between the rounds (see Tables 2 and 9, respectively), and with the expansion of electricity connection in Ghana (see, also Adu et al. 2018). Thus, given that the information on nutritious diets and women's empowerment that can be attributed to these information infrastructures are accessed through these devices and services, then policies, such as electricity coverage expansion, that provide the necessary condition for the operation of the information infrastructure will indirectly stimulate the access and use of the outputs of the information infrastructure which will ultimately affect agents decisions and welfare outcomes (GoG 2014; Adu et al. 2018).

4.Summary, Conclusions and Policy Implications

4.1 Summary of Results

This study investigated the impacts of internet café, ICT centre and community radio on household nutritious diet intake and women's economic empowerment using the marginal treatment effects (MTE) framework. Basically, we considered the impact of the information infrastructure on farm households, and on the entire sample of the Ghana Living Standards Survey datasets (i.e., rounds 6 and 7). The study revealed that in the untreated state, farm households were observed to be consuming significantly lower vitamin A-, protein-, and iron-rich foods compared to nonfarm households. However, the presence of the information infrastructure makes farm households to at least catch-up in nutritious diet intake with the nonfarm households. Farm households tend to have substantially higher vitamin A-, protein-, and iron-rich foods intake than nonfarm households when they have the information infrastructure. This catching-up of the farm households was due to poor nutritious diet intake without the information infrastructure.

The results show significant ATT, ATE and ATU across the nutritious diets indicators. The ATT (ATU) suggest that for the average treated (untreated) household, residing in a community with internet café, ICT centre and community radio results in higher vitamin A-, protein-, and iron-rich foods intake, respectively, whiles the ATE indicates that residing in a community with ICT centre and community radio significantly results in increased vitamin A-, protein-, and iron-rich foods intake for a household selected at random from the population of households. However, when the impacts are compared across information infrastructure, the effect of internet café on nutritious diet intake appears to be not substantial on the average household and the average untreated household if they were to reside in a

community with the information infrastructure, and lower in magnitudes compared to the treatment effects of the other information infrastructure.

When these summary treatment effect measures are considered together in addition to the slopes of the MTE curves, they show a positive selection on gains for internet café implying that households which are more likely to reside in communities with internet café tend to benefit more from living in a community with internet café. However, the pattern of selection observed for ICT centre and community radio is not uniform but differs across the nutritious diets' indicators. In the instance of ICT centre, the results revealed reverse selection on gains for vitamin A and protein, and same for protein in the case of community radio. This reverse selection on gains shows that households which are less likely to reside in communities with ICT centre or community radio benefit more in terms of vitamin A and protein or protein rich foods intake. However, the pattern of selection on gains were positive selection for iron in ICT centre, and for vitamin A and iron in community radio.

Further investigations show that extension access and market prices are the important immediate mechanisms through which the information infrastructure affects nutritious diet intake. Also, having the information infrastructure in a community that results in extension access significantly contributes to increase nutritious diet intake through farm output and farm revenue, which shows that farm output and farm revenue are intermediate impact mechanisms by which the infrastructure affects nutritious diet intake through access to extension. In respect of the market support system, whereas market access appears to be an important immediate mechanism through which internet café affects vitamin A and protein rich foods intake, market price appears to be important immediate market mechanism by which the information infrastructure affects all the nutritious diets outcomes.

Regarding women's economic empowerment, the results also show that, in the untreated state, women in farm households have lower average empowerment index (E_Index), gender parity index (GPI) and women's economic empowerment index (WEEI) than women in nonfarm households. However, the treatment effects of the information infrastructure show that the average empowerment index, gender parity index and economic empowerment index of women in farm households are higher than women of nonfarm households. These estimates across the women's economic empowerment outcomes show that women in farm households tend to benefit more from the availability of these information infrastructures than their counterparts in nonfarm households largely due to worse economic empowerment conditions of women in farm households in the untreated state.

For the summary treatment effects, the results show that for an average treated (untreated) woman living in a community with an information infrastructure significantly increases women's economic empowerment indices. Similarly, the ATE shows that having an information infrastructure in a community significantly increases women's economic empowerment for a woman picked at random from a population of women. Comparatively, the results appear to show slightly higher magnitudes of the impacts of ICT centre and community radio than impacts of internet café. Also, when we consider the heterogeneities in the treatment effects, the results show a uniform pattern of selection, which is a reverse selection, on gains, indicating that women in communities that are least likely to have the information infrastructure tend to benefit more from having the infrastructure in terms of economic empowerment. The results further revealed that engagement in production, hours worked, and attendance of town meetings are potential impact mechanisms through which the information infrastructure affects women's economic empowerment. However, engagement in productive ventures and hours worked are the prominent mechanisms, highlighting the importance of the information infrastructure in enhancing access to productive ventures and resources.

Finally, the policy relevant treatment effects (PRTE) show that when electricity is expanded to 10% of communities without electricity in the sample, this increases the likelihood of the communities having internet café, ICT centre and community radio, and the magnitudes in increased likelihood of getting

the information infrastructure are even higher for farm communities. In terms of the net effect, the PRTE results show that a 10% expansion in electricity increases vitamin A-, protein-, and iron-rich foods intake associated with all the information infrastructure, per household shifted. Also, the results on the women's economic empowerment show that a 10% expansion in electricity coverage significantly increases the impact of the information infrastructure on average women's empowerment index (E_index), gender parity index (GPI) and women's economic empowerment index (WEEI), per woman shifted.

4.2 Conclusions

The above discussions suggest several conclusions that we present in this section. Firstly, the more than catching-up effects of the information infrastructure on nutritious diet intake and women's economic empowerment between farm and nonfarm households imply that the physical presence of the information infrastructure in a community helps farm households to fully and even more than catch up with nonfarm households in terms of nutritious diet intake and economic empowerment. Thus, the presence of these information infrastructures can be viewed as not only beneficial to farm households and farmers in terms of access to information about production and marketing thereby closing the digital and information gap, but also as a means by which the gaps in nutritious diet intake and women's empowerment between farm (who are generally deprived in these indicators in Ghana) and nonfarm households can be narrowed.

Returns to the information infrastructure in terms of nutritious diet intake depend on the infrastructure and vary based on the nutritious diets' outcome. In the case of internet café, this is beneficial for households which are capable of its use and can afford the associated cost making its impact quite favourable for these group of people. Conversely, the presence of ICT centres and, to some extent, community radio tends to benefit households which are marginalised in terms of access, affordability, and ability to use some of the information infrastructure themselves because the mode of services rendered through the ICT centres and radio programmes are open to all participants and audience. Hence, there is some form of comparative advantage in having the infrastructure where the ICT centre and community radio are more favourable in improving nutritious diet intake of disadvantaged and marginalised households than internet café which favours more of advantaged households.

Information infrastructure serves as conduits of access to information about innovative ways of production and market intelligence since the infrastructure improves household nutrition mainly through household income from production and selling prices. This implies that the information infrastructure serves to complement farm and household productivity by increasing access to information and public learning (from extension agents) about innovations, input use and access to credit, and increase households access to market information, which delivers favourable input and output prices. All these account for the improved household nutrients rich foods consumption through increased incomes. This further implies that much of the improvements in nutritious diet intake by households associated with the information infrastructure are through household expenditure on nutritious food items and not direct consumption of own produce. This confirms the existing literature on income and nutrition that whereas increases in income correlate with reduction in the proportion of income spent on food, the proportion of income spent on nutritious food items such as meat, fish, eggs, and dairy products increases (Colen et al. 2018), especially among deprived households (WFP & GSS 2012).

Returns to women's economic empowerment associated with this infrastructure are higher for women in farm households, which is pointing to deprivation differences between women in farm households and those in nonfarm households. This is buttressed by the summary treatment effects measures that show that deprived households (i.e., households which are less likely to be able to have the information infrastructure) have higher returns in empowerment from the information infrastructure. Thus, there exists some challenges or bottlenecks (including infrastructure and regulations) that confront women in

households or communities with less likelihood of accessing or having the information infrastructure, even though they eventually benefit more in terms of women's empowerment when they have the information infrastructure.

There is the possibility of the existence of some customs and values that seem not to support the participation of all categories of women in town meetings, and so appear to focus the impact of the information infrastructure on women's productive ventures and hours worked. This came up during our engagement in a community in the middle zone. This could be the reason why the engagement in production in terms of participation and hours worked are the prominent mechanisms by which information infrastructure affects women's economic empowerment, compared to through women's participation in community meetings. This also means that much of the engagement of women through the information infrastructure is in the form of promotion of empowerment in economic activities. Education and household expenditure are necessary conditions for access and use of the information infrastructure, especially internet café, as the proportion of households with secondary and post-secondary education and those with higher expenditure appear to have more access to all the information infrastructure and the returns to internet café largely depending on these. Much of those without access to the information infrastructure in their communities are those either without education or mostly with primary education.

Although support services yield substantial access to the information infrastructure across all households, the effects of such policies, specifically electricity coverage, on farm and deprived communities in terms of access to the information infrastructure are very large. The positive and significant effect of the expansion of electricity coverage on both access and the outcomes, implies that it is possible to significantly increase farm households and women's access to information infrastructure, and improve their nutritious diet intake and women's empowerment by investing in just electricity coverage in these deprived areas. The policy relevant effect of electricity also suggests that the mere provision or presence of the infrastructure in a place is not enough to see to its functioning and yielding the needed outcomes if it is not backed by the needed infrastructure.

4.3 Challenges and Lessons Learnt

In this section, we present the challenges and lessons learnt from this project. The challenges we faced are largely issues related to the data access and collection. Below are the challenges and some of the lessons learnt:

1. The first challenge we encountered was in accessing data on telecom masts' locations in Ghana. At the proposal development stage, we had made contacts with the National Communications Authority about the locations of the telecom masts. Subsequently, we were told by the National Communications Authority that these masts are not owned and managed by the Authority and so they cannot share that information with us for proprietary and security reasons. They indicated these were the reasons why they took the report on the masts down from their website. Consequently, the Authority referred us to the authorised companies in-charge (i.e., American Tower Company; Ghana Eaton Towers Ghana Limited and Helios Tower Ghana Managed Services Limited) which we made several contacts and follow-ups to get the needed information. Unfortunately, all the efforts in this respect yielded no results and our persistence got to a point where we were told by the NCA that it will be impossible for them to give us this information. These notwithstanding, we do not expect the absence of this to affect out results since the impacts of the information infrastructure were independently examined. Also, the fact that the operations of some of the infrastructure, especially internet café, we have considered in this study highly correlate with the availability of the masts in a place, the effects of internet café should at least

give an indication of what the effects of the telecom masts would have been if we had the information on the locations.

2. The consideration of more than one information infrastructure, although it makes the work longer and challenging in terms of timelines, the subtle differences in the findings and patterns of selection between the information infrastructure observed has paid off. The peculiarities of the various outcomes across the infrastructure and the varying importance of the impact mechanisms by infrastructure and the outcomes make the consideration of the multiple information infrastructure important and worthwhile task. This implies that in examining the impact of related infrastructure, it will be beneficial to consider a collection of these as they introduce multidimensionality and nuances to the analysis, results and implications drawn from the exercise.

3. Linkages from information infrastructure to the outcomes are quite staggered and hence the triangulation in the qualitative data collection used was very helpful. The link from information infrastructure to nutritious diets and women's economic empowerment involves intermediaries that are associated with the services of the infrastructure on one hand and intermediaries from the outcomes side on the other. This made it difficult for a person with knowledge on one aspect of the study theses, such as nutrition, to effectively talk about how information infrastructure affects nutritious diet intake taking into consideration the information services intermediaries. Thus, our triangulation where we interviewed experts of information infrastructure, nutrition and women's economic empowerment was very useful in this course.

4. Organising Focus Group Discussions (FGDs) along gender and other demographic lines (such as age) is rewarding in terms of enhancing participants' contributions. We observed during some of the FGDs that, despite the organisation of these discussions along gender lines, some of the younger women complained to us of their inability to respond to some of questions due the presence of the older women they respect so much. One of them stated that "*... answering a question an elderly person does not know in front of strangers is a sign of disrespect ...*".

5. Respondent fatigue and expectation gap are on the increase, and hence the need for an innovative and convincing way of introducing rationales of data collection to these communities. We faced some challenges in conducting interviews in some communities due to unfulfilled promises of past researchers. Some community leaders claimed that we take information from them and use that information to source money for ourselves without giving them the needed support to address their problems. Relatedly, some of the key informants requested that we pay them before they would respond to our questions. In one instance, a key informant told us that if the interview lasts longer, we will have to pay him before he continues.

6. Using formal protocol and informal means (such as reaching out to the respondent directly instead of through the organisation) to contact respondents of key informant interviews are efficient in helping to circumvent some of the difficulties associated with the institutional protocols. In particular, we faced challenges in getting nutrition officers in public hospitals because they demanded that approval must be sought from the Regional Health Directorates before such interviews could be conducted. The introductory and request letters were sent and were kept in some cases for up to a week, without approval in the end.

7. The final lesson from this research is that backup plan is very critical in all respects, especially when dealing with electronics. We recorded interviews using the audio recorders and complemented that with our notes and phone recordings. These were very helpful when we

encountered some challenges in accessing the recordings of one of the audios. Fortunately, we got an IT expert to retrieve them for us.

4.4 Policy Implications

The equalising effects of the information infrastructure between farm and nonfarm households imply that policies that increase the provision of these infrastructures or support the improvement of the existing ones will increase farmers' access to information about production and market and subsequently increase nutritious diet intake and women's empowerment. This is also in line with government's ICT policy strategy of improving rural information infrastructure development in farming communities to promote farming, agro-industry, and marketing.

Secondly, heterogeneities in returns from the infrastructure suggest the need for selective targeting in promoting the role of information infrastructure on various nutritious outcomes. This is because a jack horse policy or intervention which treats the information infrastructure considered as if they have same effects or similar pattern of impact may not yield the desired outcomes. Thus, policies meant to promote the information infrastructure need to consider not only the returns to the infrastructure, but also the comparative access and ease of use of the services of the infrastructure by various groups. Thus, policies and interventions need to consider investment in internet café and similar infrastructure when the community or households are better-off in terms of education, incomes and other conditions that enable better use of internet services and focus on ICT centres and community radio when considering less literate, low income, deprived and marginalised communities and households.

To harness the substantial benefits from the infrastructure in respect of empowering underprivileged women and communities, there is the need to invest in overcoming bottlenecks that challenge and limit the capabilities of these women or their communities in having the information infrastructure. Thus, it is important to provide some of the infrastructural base such as electricity, and other specific information infrastructure support services and networks, as well as review and update policy and regulatory requirements to ensure sound regulations without compromising the establishment and operations of these information infrastructures.

Given limited effect of women's participation in town meetings in enhancing their empowerment, it is recommended that policymakers and promoters of ICT for development need to increase engagement with managers of ICT centres and community radio stations to increase education and sensitisation on the need to completely break gender and demographic stereotyping (where the young women appear not to be interested in contributing to discussions during older women). This will help reduce the impact of subtle customs and traditions that still appear to disadvantage some women from making contributions at meetings, especially at the community level.

There is also the need to promote education and adult literacy in these areas. This will engender access to and the use of the information infrastructure by households and women. It will also empower them to engage with the internet to explore its services and to engage well with it in learning and in doing commerce. This will also impact the income generation ability of the household and enhance their ability to afford the services of internet café. With respect to community radio, education and literacy will also improve the ability of households and women to participate in radio programmes and not just to serve as audience. Finally, it is recommended that policymakers and actors in the area to create enabling environment, especially in the aspect of technical support infrastructure and services, for the establishment and sustainability of the information infrastructure. This is important for the operations and functioning of the information infrastructure. To this end, this reinforces the policy objectives of the Government of Ghana to expand village information and communication infrastructure, and to develop and modernise the national information and communication infrastructure through enabling physical infrastructural development (GoG 2003).

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