Working paper GHA-23058

April 2024

The welfare implication of reversing Ghana's electricity tariff structure

Evidence from residential and non-residential customers

Amin Karimu
Jabir Ibrahim Mohammed
Eric Kofi Obutey
Eric Kyem

IGC

DIRECTED BY LSE UNIVERSITY OF OXFORD

FUNDED BY UKaid from the British people

The Welfare Implication of Reversing Ghana's Electricity Tariff Structure: Evidence from residential and non-residential customers

By

Amin Karimu

School of Economics & Environmental policy research unit, University of Cape Town, South Africa and a Visiting Professor at Birmingham Business School, UK

Jabir Ibrahim Mohammed

University of Ghana Business School, University of Ghana

Eric Kofi Obutey

Public Utilities Regulatory Commission (PURC)

Eric Kyem

Public Utilities Regulatory Commission (PURC)

Abstract

A cross-subsidisation tariff structure has been the practice in Ghana for its electricity sector, where non-residential customers pay a higher rate, which a portion is used to subsidise the tariffs for the residential customers. Such tariff structure is not only unfair to businesses but also detrimental to the competitiveness of business due to the high cost of electricity. It also creates inefficiencies in the utilisation of electricity by the residential sector. Using survey data for both non-residential customers (firms) and residential customers (households), and a two-step estimation approach via an EASI demand system and Cost of living index, we assess the welfare implication of the partial reversal of the cross-subsidisation policy implemented by the Public Utilities Regulatory Commission (PURC) of Ghana. Findings indicates a loss in welfare for both groups of customers under the partial reversal policy. However, scaling the reversal rate to 70% and 100% result in higher welfare gains for firms at magnitudes that can overcompensate the welfare loss from residential customers. Findings also reveals heterogeneity in welfare across firm's groups and household groups.

1. Introduction

After emerging from a recent three-year power crisis, Ghana is keen on reforming its power sector. Key among these reforms, is a regime shift towards tariffs that are more cost reflective, but less detrimental to businesses, especially Micro-Small-Scale Enterprises (MSMEs). Over the years, the practice has been for non-residential customers to cross-subsidize tariffs for the residential class. This tariff structure implies that, MSMEs and other businesses tend to pay more per kWh of electricity, relative to similar bands from the residential segment, thereby further increasing the cost of doing business in Ghana. In August 2022, the economic regulator, Public Utilities Regulatory Commission (PURC), which oversees the regulation of the quality of service and tariffs for both electricity and water sectors, took a policy decision to partially reverse the cross-subsidization in electricity consumption from non-residential customers to residential customers by removing close to 36% of cross-subsidies from the non-residential class and allowing the residential class to absorb this, which was implemented in September 22.

The aim of this project, therefore, is to evaluate this policy reversal of the electricity tariff structure on the welfare of both non-residential and residential customers. Additionally, the study will generate some simulations based on the welfare effects on scaling-up to 70% and 100% on the subsidy reversal and to provide guidelines on such a policy reversal on the electricity tariff structure in Ghana. Furthermore, the study will touch on the distributional implications of such a policy change, utilizing income levels for residential customers and firm size for non-residential customers.

In Ghana, even though prices of electricity have surged significantly in recent times, power producers argue that the current tariffs are still not cost reflective. Cross-subsidization is an important component of electricity tariffs in Ghana, with high tariffs imposed on industry and heavy or large customers of electricity. A consequence of this cross-subsidization is the demand side inefficiencies at the residential level. In recent times, rising electricity tariffs for the industrial class has been met with strong resistance from industry players, who argue that the practice hinders growth of the industrial sector through an ever-increasing production cost (Acheampong & Ankrah, 2014; AGI, 2019).

There has been calls for full cost-reflective electricity pricing in Ghana to enable utilities providers operate efficiently and to improve on the quality of supply. Similarly, the recent power crises experienced in the country has ignited calls for policy reforms in the electricity sector to engender the reliable supply of electricity to end-users. Given the relatively low-income levels of most households, coupled with the political economy implications of high electricity tariffs, policy makers are caught in a dilemma between “cost recovery and affordability”. Nevertheless, there is growing optimism among policy makers that a regime change in electricity pricing in favour of cost reflective tariffs is imminent or at least a tariff structure that does not overly burden the non-residential sector to cross subsidise the residential sector. Such a shift in tariff structure may create some positive and negative welfare implications and may hinder the success of the policy depending on the size of the welfare loses relative to the gains. There is therefore the need for sufficient understanding of consumer (residential and non-residential) welfare of the partial reversal of cross-subsidisation of electricity tariffs in Ghana and to assess such a policy change on the welfare of customers. The objective of this study is in four-folds. We assess the welfare implications of the partial reversal of the September 2022 cross-subsidisation of the electricity tariff policy on both residential and non-residential customers in Ghana and the size of the welfare. Second, we determine the customers who are most affected by the electricity tariff policy change. Thirdly, the study also explores the welfare implication of scaling-up the reversal rate to 70% and 100% to inform policy makers on the implication of various reversal rates on welfare and to advise the course of action regarding the policy.

In achieving these objectives, the study relies on a survey data and employ a two-phase method of analysis, this involves, first, estimating a structural demand system via a two-stage budgeting system with particular interest on electricity to obtain the parameter estimates for the demand model for the two groups of customers (residential and non-residential). Based on the estimated parameter estimates, a welfare analysis of the tariff reversal is computed and analyzed.

Electric Utilities play a vital role in modern production and consumption activities across the globe. Despite its importance, the power sector in many developing countries, especially Sub-Saharan Africa (SSA) is characterized by many challenges such as low access rate, unreliable supply, inefficiencies in generation and distribution, pricing schemes that may not be reflective of true cost of supply among others, which Ghana is not an exception. Some of the reasons for the unreliability of electricity in Ghana is the demand-supply gap, nature of the tariff structure and political interference in pricing of these services, making the sector unattractive to the private sector due to the huge risk.

The structure of the paper is as follows. The next section presents a review of the literature. Followed by the demand system framework as the conceptual approach for the study (section 3). The data and the results are discussed in the next two sections. And the final section presents the main conclusions.

2. Literature Review

This section discusses the implication of energy prices on welfare of both household and firms. The studies reviewed provide the basis for the understanding of prior ideas on the relationship between price reversals or tariffs of electricity on welfare implications of both residential and non-residential customers.

2.1 Electricity Tariffs Reforms and Welfare Implications for Customers

There have been several empirical discussions on the relationship between electricity tariffs reforms and household welfare. For instance, Pacudan and Hamdan (2019) study the impact of tariffs reforms on welfare and electricity expenditure and how the price structure reforms shielded the low-income household on the adverse effect of potential subsidy removal. They find that there is a high welfare loss when price structure changes from declining bulk tariff (DBT) to increasing bulk tariff (IBT). They noted that when demand for electricity is inelastic, there is higher welfare losses due to an increased in electricity expenditure. Despite this effect, their study concluded that household expenditure is still below 5% of their income. In a related study, Gassmann, (2014) analyse the impact of higher energy tariffs on household welfare in Kyrgyz using micro-level data from Kyrgyz Integrated Household Survey 2009. Using an OLS model, the study finds that richer households in urban areas are affected due to increasing tariffs for thermal power used for central heating and hot water. He notes that reducing implicit electricity subsidy affects the entire population because of countrywide coverage of the subsidy. The study also finds that both lifeline tariffs and direct cash transfer could mitigate the effect of higher electricity tariffs at lower costs and then any universal subsidy. when tariffs transfer is rather made for lifeline and direct cash transfers has a higher mitigating effect on. The study recommends that different mitigating measures could soften the increasing impact of energy tariffs and protect the energy consumption of the poor and vulnerable households such as direct cash transfer allocated to households with children.

Furthermore, Supriadi, et al. (2019) examine the impact of a subsidised electricity tariff, increase on subsidised household welfare. They find that the lower expenditure group's subsidy allocation rose to 34.16% while the top 20% expenditure group decreased to 20.4%. In effect, the increase in tariffs causes the welfare of a subsidised household to decline. The policy inclination is that, subsidised electricity tariff reduces the consumption of electricity to help with the redistribution of the subsidy allocation from the top 20% spending group to the lowest 40% expenditure group. Also, Chian, (2014) evaluates the welfare implication of new electricity tariffs in Brunei. The study also looks at the implication of subsidy on the consumer. The study finds that the new electricity tariffs benefit 80% of households, with the poor households having higher benefits in the new tariffs as compared with the old tariffs. Relatively, the study finds that total electricity subsidies remain unchanged with the poor household continue to enjoy substantial benefits of the subsidy. Their policy implication is to call for addressing the high fiscal costs associated with subsidies and the problem of redistribution distortions.

In a related study, Romero-Jordán, et al. (2016) document the responsiveness of household electricity demand and welfare effects in Spain between the period 2006 and 2012. They find that medium-high income households are more responsive to electricity price changes while the medium low-income households are more responsive to changes in income. This finding leads to lower U-shape price elasticities of demand and higher N-shape income elasticities of demand. In low-income households, the joint impact of these two-effects is higher on their welfare than other income groups. Additionally, Ansarin, et al., (2020) highlights on the impact of distributed renewable energy sources (D-RES) on electricity tariffs on welfare. The study finds that a large welfare transfers to D-RES owners from non-owners in a traditional tariffs design. Their study documents the importance of demand elasticity in analysing cross-subsidisation and its effects on different tariffs. This suggests that the acceptability of traditional tariff designs may no longer be applicable with the addition of D-RES.

In another study on electricity subsidy, Wang, & Lin, (2017) find that residential subsidy amounted to 467.17 billion CNY in 2010 accounting for 1.17% of GDP in that year. The study employs a compensating variation (CV) measurement and find that if residential electricity prices changes, by different percentages, the corresponding CV should by 288.5, 394.2, 451.1 and 467.2 billion CNY respectively. The authors' noted that there is electricity rebound effect of 20% on electricity consumption. The study concludes that the electricity subsidy has a greater welfare effect on residential users of electricity. Also, Berkouwer, et al. (2022) evaluate the Ghana electricity subsidy programme during the COVID-19 period which promised monthly subsidy transfer of 50kwh (worth 3.50 USD) for the April-June 2020 to “lifeline” customers (for those who use less than 50kWh per month at baseline), a monthly transfer of 50% baseline usage for all residential customers. The study finds that over 45% of the household surveyed value the electricity transfer than if they were given cash. Again, the study finds that only 46% of the household received the transfer after the first month of the program while one-third of the household did not.

Hancevic et al. (2016) propose a model to explain a class of subsidised energy prices. Their model applies a median household preference for receiving transfer gains and followed by future transfer losses. Using empirical data, they find that the subsidy cycles have larger welfare instability for the poor than those in the middle- and higher-income households. In a related study in Argentina, Giuliano, et al. (2020) use household surveys and administrative data to establish that social tariff is relatively pro-poor and this is significantly higher among the poorest households. Again, the study finds that monthly electricity subsidy has increased from 1.1% of total household income to 3.4%. Similarly, Horowitz, and Lave (2014) use a flat rate electricity tariff from 1260 Commonwealth Edison residential hourly load data for the period 2007 to 2008. They find that only 35% of the customers save money while the rest of the 65% loss using a real-time pricing.

Furthermore, Karimu et al. (2022) estimate the welfare and emission implication of moving to a mandatory dynamic pricing scheme in Sweden. They use the flexible Exact Affine Stone Index (EASI) demand system model to accommodate for both unobserved and heterogeneity in preferences. Their findings indicate a corresponding reduction in welfare and carbon emission is small by less than one percent. Specifically, they noted a welfare reducing of less than 0.2 percent. Similarly, Gambardella, et al. (2020) analyse the gross welfare gain from real-time pricing in retail electricity market by inducing carbon taxation using stylized numerical electricity model. Their study finds a U-shaped relationship between carbon taxation and gross welfare gains.

In summary, the avalanche of empirical studies discussed here focused on electricity subsidies and its implications on welfare. Others try to examine real-time electricity prices on welfare. Some of the studies look at distributional renewable energy and welfare implications on residential customers. In terms of methodology the they have often look at the direct effect of subsidies on welfare without highlighting on its implicit effects. This study further honed that in a new contribution, by further discussing electricity tariff reversal from non-residential customers to residential customers different from the usual subsidy given by government to customers directly in the form of either tariff price reduction or additional kilowatt of electricity directly credited to customers. An example is Ghana’s COVID-19 direct tariffs subsidy to lifeline customers who consume below 50kilowatt. Also, the study considers real-time pricing of electricity since it takes into consideration pricing structures. Finally, unlike other studies, this study looks at scaling-up tariffs reversal from the initial rate that was implemented to full scale reversal which is distinct from existing studies.

3 Demand and System Framework

3.1 Conceptual Approach

This study builds on the previous literature on demand systems and welfare computation from such systems by using residential (household) and non-residential (firm) data to evaluate the effect of electricity subsidy reversal in Ghana. In this study, we treat monthly (m) demand for electricity as being driven by the demand for an underlying service it provides. The monthly utility is derived from the consumption of electricity in that month while the daily consumption of utility is derived from the aggregation of utility over the hours consumed in a day (Karimu et al. 2022).

To achieve objectives of the project, the researcher relies on micro data on households and industry which is obtained from a survey of seven (7) administrative regions in Ghana. The survey consists of two main parts. In the first part, the researcher collects data on industry and households' socio-economic and demographic characteristics, monthly consumption expenditures, and prices of goods and services consumed, including electricity. This data is used to conduct welfare analysis of the effects of the 2022 tariff reversal structure on electricity consumers (residential and non-residential). By assuming a two-stage budgeting framework, a representative household, in the first stage, allocates its income between expenditure on utilities and other products, while in the second stage, the utility expenditure is spent on traditional means of electricity consumption, and alternative energy use. Such as process also applies to the non-residential customers with different derivers of their utility function and budgeting items.

In applying the expenditure shares on electricity consumption, a structural demand system, is estimated to derive the price and income elasticities for electricity. Given the non-linear relationship between electricity demand and income levels (Brännlund & Ghalwash, 2008), the Exact Affine Stone Index (EASI) Implicit Marshallian Demand system will be used (Lewbel & Pendakur,2009). A similar approach described above will also be implemented with the non-residential sector. EASI has a peculiar advantage over the traditional Almost Ideal Demand System (AIDS) in terms of having a flexible functional form that allows Engel curves to be polynomials or splines of any order in real expenditures.

Utilizing the EASI demand estimates, we will undertake welfare analysis of consumers through a consumer surplus measure, where we will assess the change in cost of consuming the same bundle of goods when prices change from an initial price vector $\mathbf{p_0}$ to a new price vector $\mathbf{p_1}$, while keeping utility constant. In this case, the initial price vector, is the previous prices with the cross-subsidization, whereas the new price vector will be prices with the partial reversal introduced in September 2022. This is basically a cost-of-living index (Karimu et al., 2022). Note that the cost-of-living index for the welfare analysis from the EASI model is made of two parts, a part that reflects changes caused by a change in price and the other part, which explicitly, captures the substitution effect of a price change. Furthermore, the cost-of-living index is at the individual customer level in the case of the residential class and at individual firm level in the case of the non-residential class. Consequently, we will be able to assess the distribution of welfare in terms of those who gain a positive welfare, those whose welfare has not changed and those who experience a loss in welfare. From this, we can assess those that are most affected by the policy change (positively and negatively). Moreover, we can undertake simulation on the reversal from the current percentage to 70% and 100% and assess which of the percentage reversals produces the most positive welfare for the two types of customers.

3.2 The EASI demand system

To overcome the problem of unobserved household heterogeneity, Lewbel and Pendakur (2009) developed the EASI demand system. This study chooses the EASI function over the existing demand systems such the popular Almost Ideal Demand System (AIDS) and Quadratic Almost Ideal Demand System (QAIDS) because these earlier models are not able to accommodate unobserved heterogeneity. In the EASI system, Marshallian demand functions are considered as implicit, with budget shares being expressed as implicit functions of prices, expenditure and other observable characteristics of household and firms. Again, the EASI demand functions are more flexible than the QAIDS, in terms of its Gorman rank restrictions. However, the QAIDS preserves its key convenience, which is linearity in parameters (Karimu et al. 2022). The EASI demand function allows for non-linear Engle curves and does not restrict preferences to depend upon observable factors. Furthermore, to account for price heterogeneity in estimating the demand model, the Stone-Lewbel (SL) prices are adopted (this approach is explained under the sub-heading "Construction of Price Index").

Th EASI demand system is derived from consumer cost function on goods and services. This is done by considering the cost for a good or service as the minimum expenditure required to meet a certain utility (u) level from consuming that good, conditional on demographic characteristics z, unobserved preferences and the logarithm of the price (p) faced by the consumer (residential and non-residential customers in this case). Shepard's, lemma is applied to the cost function to obtain the Hicksian budget shares. Lewbel and Pendakur (2009) argue that replacing the u with the Stone index-transformed log-real total expenditure (y) leads to an implicit Marshallian demand system, which in this study, the implicit Marshallian demand system for a consumer (residential or non-residential) is defined as:

$$w^m = \sum_{r=0}^{R} b_r^m y^r + \sum_{l=1}^{L} (C_l^m Z_l + D_l^m Z_l y) + \sum_{l=0}^{L} \sum_{k=1}^{M} \alpha_l^{mk} Z_l logP^k + \sum_{k=1}^{M} \beta_k^m logP^k y + \varepsilon^m \qquad (1)$$

Where, w^m is the budget share of electricity for monthly m, m=1,…, M, r=1,2, …, R is the degree of the polynomial in y, the real total expenditure, $logP^k$ is the log price of good k, Z_l denotes the $l^{th}, l = 1, 2, \dots, L,$ demographic characteristics, $ylogP^k, Z_l y \; and \; Z_l logP^k$ are the interaction terms, $\boldsymbol{\varepsilon^m}$ is an unobserved preference heterogeneity parameter, and the coefficients $b_r^m, C_l^m, D_l^m, \alpha_l^{mk}$ and β_k^m are parameters to be estimated. Equation (1) is estimated separately for residential customers and for non-residential customers with different budget shares. In the case of residential customers, the budget items are food, non-food, electricity and rent, whereas in the case of non-residential customers, the items are wages, non-wage items excluding electricity and rent, electricity and rent.

Castellón et al., (2015) and Lewbel and Pendakur, (2009) employ an approximation for the measure of real expenditure, which is express

$$\bar{y} = log_X - \sum_{m=1}^{M} w^m logP^m \quad (2)$$

We estimate equation (1) and (2) using the Generalized Methods of Moments (GMM) approach by imposing adding-up, homogeneity and symmetric conditions. The choice of the GMM estimating is due to the need to control for potential endogeneity problem introduced by the expression of the real expenditure (y) in equation 2 which is a function of the budget shares (w^m).

The use of the EASI demand systems is more flexible and better able to deal with both observed and unobserved heterogeneity than for instance AIDS or QAIDS. The interaction between price and expenditure in the demand function yields greater flexibility in accommodating observed heterogeneity. Whereas the budget share errors are used to account for unobserved heterogeneity.

3.3 Welfare Computations

Welfare analysis is carried out by considering a consumer surplus measure-thus, a change in the cost of consuming the same bundle of goods when prices change from an initial price vector $\mathbf{p_0}$ to a new price vector $\mathbf{p_1}$, while keeping utility constant. The welfare measure under the EASI system, which is a cost-of-living index (Lewbel and Pendakur, 2009) is expressed as:

$$ln\left[\frac{C(\mathrm{p}_1, u, z, \varepsilon)}{C(\mathrm{p}_0, u, z, \varepsilon)}\right] = \sum_{m=1}^{M} w_o^m (logp_1^m - logp_0^m) + \frac{1}{2}\sum_{m=1}^{M}\sum_{k=1}^{M}\left(\sum_{l=0}^{L} \alpha_l^{mk} z_l + \beta_k^m y\right) \times \ (logp_1^m - logp_0^m)^2 \quad (3)$$

Where, $C(\mathbf{p_0}, \boldsymbol{u}, \boldsymbol{z}, \boldsymbol{\varepsilon})$ is the cost function, w_o^m is the budget share of the month *m*, $logp_1^m$ is the new log price faced by the consumer in month *m*, $logp_0^m$ is the month-m baseline price, α_l^{mk} are the price parameters, which depend on prices and on household characteristics for the residential model, and on prices and firm characteristics for the non-residential model. β_k^m is the parameter associated with the price-income interaction term in eq. (1). The expression in eq. (3) is made up of two terms; the first term reflects changes in the Stone-price-index caused by a change in price, while the second term explicitly captures, the substitution effect of a price change.

3.4 Construction of the price index

In the survey, the responses to the question on electricity prices and consumption in KwH is very low for residential and non-residential customers. They can provide information on expenditures on electricity and not the price or the KwH of electricity purchased. The study therefore relied on the official tariffs approved by PURC before the introduction of the partial reversal, and those with the partial reversal in 2022 across the various bands for the two types of customers, excluding the fixed service charges for both customers. The average across the various tariff bands for each of the types of customers is calculated for the prices before the tariff reversal and prices with the tariff reversals. These prices are averages for the types of customers and therefore does not vary within customer group. To induce such a variation within customer groups, Stone-Lewbel (SL) price indices are constructed for the prices before the introduction of the tariff reversals and prices with the tariff reversal for both groups of customers. Details on the SL price and its computation is in Lewbel (1989). The SL price approach utilizes the variation in customer characteristics to identify within group-specific "price indices". Such a price index approach allows for a theory-consistent modeling of heterogeneity across households and firms (Karimu et al., 2022), which leads to a more efficient demand estimates due to the resulting increase in price variation (Castellón et al., 2015). There are many applications of this approach in the empirical literature, where there is limited price variation (Castellón et al., 2015; Hoderlein & Mihaleva, 2008). Others include studies by Schulte and Heindl (2017), Lewbel and Pendakur (2017) and Böhringer et al. (2017) for an application to aggregate energy demand.

4 Data Source

To achieve objectives of this project, the researchers rely on a survey from a nationwide representative sample of residential and non-residential customers of electricity in Ghana. Data was collected from seven (7) regions out of the sixteen (16) administrative regions of Ghana from both Electricity Company of Ghana (ECG) operating area and Northern Electricity Development Corporation (NeDCo) area. The ECG operating regions are Greater Accra Region, Ashanti Region, Central Region, Western Region and Volta Region. That of NeDCo operating area regions are Northern Region and Bono East Region. We collected data on demographic variables of the household, household use of appliances, the electricity tariff reversals, the kilowatt per hour, monthly consumption of electricity, tariffs reversal and welfare implications. Similarly, for the non-residential customers data on their business characteristics were collected, tariff reversal, electricity consumption and business welfare.

4.1 Sampling Design

The survey was undertaken using questionnaire and visual aids through face-to-face interviews. The researchers utilized the sampling approach used by the Ghana Statistical Service (GSS) in the recent population census. In this light, the researchers requested for a sample of Ghanaians (residential and non-residential customers) for 63 enumeration areas (EAs) for seven major regions in Ghana. The Ghana Statistical Service uses a two-staged stratified sampling approach, where they have geo data on sampled households. It consisted of 25 rural EAs and 38 urban EAs from the 261 administrative districts and 272 statistical districts.

This research provides information to the Ghana Statistical Service about the study's target sample size of 1500 for the seven administrative regions from which the sample should be derived, where 600 was allocated to non-residential customers and 900 to residential customers. Furthermore, the researchers allocated the 63 based on the proportion of population in rural areas (25 EAs) versus those in urban areas (38 EAs) in the seven administrative regions to enable analysis along rural-urban heterogeneity if there is any, for the research questions the researchers may provide answers to.

Based on this, the Ghana Statistical Service, undertook the sampling and provided us with the geo reference code for the team to utilize in the field survey. Ghana Statistical Service uses the current population survey to provide such sampling services for researchers based on an official request, therefore issues such as sampling frame and unit, stratification and sample size allocation were resolved by the Ghana Statistical Service with input from the research team. The Table 1.1 and Table 1.2 below presents the sampling for the residential and non-residential customers. The data collected was done using the weighted average of the population taken into consideration the population of each region and the number of firms that exist in the region.

Table 1.1 Residential Sampling (Household Level)

Region	Proposed Household	Cluster	Adj Clusters	Urban	Rural	Adj Households@15	Replacement	Total
Western	88	5.9	6	3	3	90	30	**120**
Central	123	8.2	9	4	5	135	45	**180**
Greater Accra	234	15.6	16	15	1	240	80	**320**
Volta	71	4.7	5	2	3	75	25	**100**
Ashanti	233	15.5	16	10	6	240	80	**320**
Bono Esat	52	3.5	4	1	3	60	20	**80**
Northern	99	6.6	7	3	4	105	35	**140**
Total	**900**	**60**	**63**	**38**	**25**	**945**	**315**	**1,260**

In Table 1.1 above, proposed residential customers were classified into clusters for both rural and urban categories. Each cluster has a minimum of 15 households and with at least 5 households for replacement. With the adjusted clustering, the total sample size became 945 household which is 45 more than the proposed number of households. With replacement, the sample size for each cluster moved to 20 households and therefore, total sampling size for the residential than becomes 1,260 instead of the 945 with the adjustment. This increases the original sample by 40%. Overall, the researchers went to the field to survey 1260 household instead of the proposed 900 household after sampling design. In all, we were able to elicit a response of 1035 household representing a response rate of 82.14% for the residential customers.

Table 1.2 Non-Residential Sampling (Firm Level)

Region	No. of Firm	Sample size	Replacement	Total
Western	1,181	73	5	**78**
Central	2,020	92	5	**97**
Greater Accra	2,733	142	5	**147**

Volta	1,099	31	5	**36**
Ashanti	3,555	215	5	**220**
Bono Esat	461	19	5	**24**
Northern	930	28	5	**33**
Total	**11,979**	**600**	**35**	**635**

Table 1.2 shows the non-residential customer (firms), overall, we obtained 11,979 firms from the seven administrative regions of Ghana. Based on the weighted average of the non-residential customers we sampled 600 customers with a replacement of 5 non-residential customers for each region. This brings it to a total of 635 non-residential customers. Overall, our field officers were able to elicit a response of 520 non-residential customers. This represents a response rate of 82%. Therefore, this response rate was akin to that of the residential customers response rate of 82.14%. This is more adequate for such an important analysis on welfare given that obtaining responses from humans can be at times too difficult based on behavioral tendencies.

4.2 Descriptive Statistics

The summary statistics for the key variables for study for both groups of customers are presented Table 1.3, which reveals an average monthly budget for the non-residential customers to be about GH¢ 7,044.14 relative to GH¢ 1,932.60 for residential customer, both standard deviations are higher than their respective means, suggesting high variation of both residential and non-residential monthly budgets. The average monthly wage bill account for about 41% of monthly total budget for non-residential customers, whereas non-wage bills excluding electricity and rent account for 30 percent of the monthly budget. Average electricity expenses per moth is about 18% of the monthly non-residential customers total budget and rent contributes the least, about 11%. For residential customers, expenses on food accounts for the largest share of the monthly budget, with an average percentage share of about 60%, followed by non-food budget share of 25%, electricity share of 11% and rent share of 3%. The average electricity bill's share of monthly budget is higher for the non-residential class of customers relative to that of residential customer highlighting the contribution of the cost of electricity to the cost of doing business in Ghana, especially for micro and small businesses.

The average price of electricity with the partial cross-subsidy reversal based on the SL price index construction range from GH¢ 1.01 to GH¢ 13.45 for the non-residential customers compared to GH¢ 0.65 to GH¢1.24 per KwH. The mean price for non-residential customers (GH¢1.85 per KwH) is about 1.9 times higher than that of residential customer (GH¢0.97). Other firm's related variables with high variability are number of employees (mean is about 4 employees), number of days in the last six months there was delays in the payment of wages (mean of 120.96 days) for the non-residential sector. These variables have their respective standard deviation higher than their respective means.The average age of the heads of households is about 49 years.

Table 1.3 summary statistics

Non-residential customers

Variables	Mean	SD	Observations
Total monthly budget	7044.14	45785.47	504
Wage expenses	2231.21	5297.62	504
Non-wage expenses	3965.33	43285	504
Electricity expenses	362.28	519.53	504
Rent expenses	485.33	1572.1	504
Wage budget share	0.41	0.27	504
Non-wage budget share	0.3	0.23	504
Electricity budget share	0.18	0.17	504
Rent budget share	0.11	0.14	504
sl_price(electricity)	1.85	1.73	503
Firm size	1.17	0.44	506
Number of employees	3.72	9.24	506
Number of days there was delay in payment of wages	120.96	459.14	506
Number of days when there is a cut in non-wage expenditure	2	0.13	506
Number of days which there was a challenge in the payment of staff bonuses	10.71	7.26	506
Number of days in which there was a challenge in payment of staff work-related hospital bills	1.56	0.5	506

Residential customers

Variable	Mean	SD	Observation
Total monthly budget	1932.60	1892.93	1024.00
Food expenses	1116.63	993.17	1024.00
Non-food expenses	549.10	717.48	1024.00
Electricity expenses	175.36	253.68	1024.00
Rent expenses	91.50	555.24	1024.00
Food budget share	0.60	0.18	1021.00
Non-food budget share	0.25	0.15	1021.00
Electricity budget share	0.11	0.13	1021.00
Rent budget share	0.03	0.08	1021.00
sl_price (electricity)	0.97	0.07	985.00
Age of household head	49.40	13.37	1043.00

How often do you cut the size of meals due to financial challenges (in days)	4.15	1.07	1024.00
How often has a member of the family not eaten due to lack for funds (in days)	4.45	0.86	1024.00
How often has any student in the household skip school due to financial challenges (in days)	4.62	1.13	1024.00
How often has any student in the household skip hospital due to financial challenges (in days)	4.12	1.11	1024.00
Income groups	1.91	0.85	1043.00

5. Analysis and Discussion

The EASI demand model, which is presented under the methodology section was applied to the data, and the summarised results with respect to the diagnostics of the model is reported in Table 1.4 and the parameter estimates for the demand system for the two groups of customers is presented in the appendix (A1). The application of the EASI demand model to the data is to help achieve the key research objectives presented in the introduction section. Thus, to assess the welfare implication of the cross-subsidy tariff reversal and the implication of scaling-up the reversal from the initial 36% in September 2022 to 70% and further to 100% on both customers (residential and non-residential). Before presenting the key results and discussing them, it is important to assess the estimated EASI demand model for both residential and non-residential customers of the Electricity Company of Ghana (ECG) and Northern Electricity Development Company (NeDCo).

5.1 Estimated EASI model

The estimated model for residential customers (households) is made up of four equations each for the four items (food, non-food, electricity and rent) in the budget of the residential customers. Likewise, the estimated model for non-residential customers is also made up of four equations denoting each of the budget items (wage, non-wage, electricity and rent) in the non-residential group. The summarised results in Table1.4 indicate that most of the parameters are precisely estimated. The summary provides information on the variables in the model, the number of parameters estimated, hypothesis test on various restriction on the polynomial terms of the expenditure variable, demographic and price variables and whether they are jointly insignificant. It also provides information on model specification via the Hansen J-test.

The results reported in Table 1.4 indicates that fourth order polynomial for the expenditure variable is appropriate. This is because the Wald test for the individual exclusion of the first, second, third and fourth order polynomial terms in the expenditure variable are all rejected at any of the conventional significance level, likewise the combined exclusion is also rejected. Furthermore, the test also reveals that both the demographic/firm and household characteristic and price variables are significant at the conventional significance level. The Hansen J-test of over-identification restriction could not be rejected at the 5% significance level for the residential and non-residential model, leading to the conclusion of a good fit for both models.

Table 1.4: Summary of model diagnostics for both Residential and Non-residential customers

Residential model

Specification	Null hypothesis	df	Test statistics	P-value
Log expenditure				
y	$b1j = 0$ for all j	4	28.53	0.000
$y2$	$b2j = 0$ for all j	4	45.28	0.000
$y3$	$b3j = 0$ for all j	4	112.36	0.000
$y4$	$b4j = 0$ for all j	4	114.36	0.000
y,$y2$,$y3$,$y4$	$b1j = b2j = b3j = b4j = 0$, for all j	12	403.41	0.000
Demographic effect	D=0	15	28.68	0.018
Demographic and y interaction	C=0	15	44.41	0.000
Price and y interaction effect	B=0	6	2534.32	0.000
J-Test	system over-identification	145	332	0.968
Variables in the model				
Expenditure on food				
Expenditure on non-food				
Expenditure on electricity				
Expenditure on rent				
Age				
Cuts in household' meal size				
Member of the family not eaten in a day due to lack for funds				
How often has any student in the household skip school due to financial challenges				
Prices				
Number of equations				
Number of equations	4			
Number of parameters	87			

Non-residential model

Specification	Null hypothesis	df	Test statistics	P-value
Log expenditure				
y	$b1j = 0$ for all j	4	33.69	0.000

*y*2	*b*2*j* = 0 for all j	4	18.68	0.000
*y*3	*b*3*j* = 0 for all j	4	102.18	0.000
y,*y*2,*y*3	*b*1*j* = *b*2*j* = *b*3*j* = 0, for all *j*	12	2102.90	0.000
Demographic effect	D=0	15	57.96	0.000
Demographic and y interaction	C=0	15	36.05	0.002
Price and y interaction effect	B=0	6	484.78	0.000
J-Test	system over-identification	135	232	0.935
Variables in the model				
Expenditure on wages				
Expenditure on non-wages				
Expenditure on electricity				
Expenditure on rent				
Number of employees				
Delays in payment of wages				
Cuts in non-wage expenditure due to income challenges				
Challenges in payment of staff bonuses				
Challenges in the payments of staff work-related hospital bills				
How often has any student in the household skip school due to financial challenges				
How often has any student in the household skip hospital due to financial challenges				
Prices				
Number of equations				
Number of equations		4		
Number of parameters		81		

5.1 Welfare Analysis

Next, we turn to evaluating the welfare effects of introducing the tariff reversal of the cross subsidy policy, the potential heterogeneity of the welfare effects across both customer groups (residential and non-residential), and the likely welfare consequences of scaling-up the reversal from the initial 36% to 70% and further to 100% to understand the potential likely welfare implication of such a policy of reversing non-residential customers cross-subsidising residential customer on electricity consumption in Ghana.

Furthermore, as indicated in the methodology section, the welfare analysis is carried out using the cost-of-living index (CLI) as done by (Lewbel & Pendakur, 2009: Karimu et al., 2022) by using the parameter estimates from estimated demand models for each of the two groups (residential and non-residential) as described in equation (3) in the methodology. The computed CLI is in Ghana cedi per month for both customers under the initial 36% tariff reversal is presented in figure 1.1. Boxplot is utilized to present the CLI as it can show the distribution of welfare for the tariff reversals. The figure reveals a loss in welfare for both customers, about GH¢4 per month on average for residential customers (2.3 % of average electricity monthly budget) and about GH¢0.845 per month on average for non-residential customers (0.13 % of average electricity monthly budget). This finding supports the work of Pacudan and Hamdan (2019) who noted a welfare loss for residential customers because of a subsidy removal.

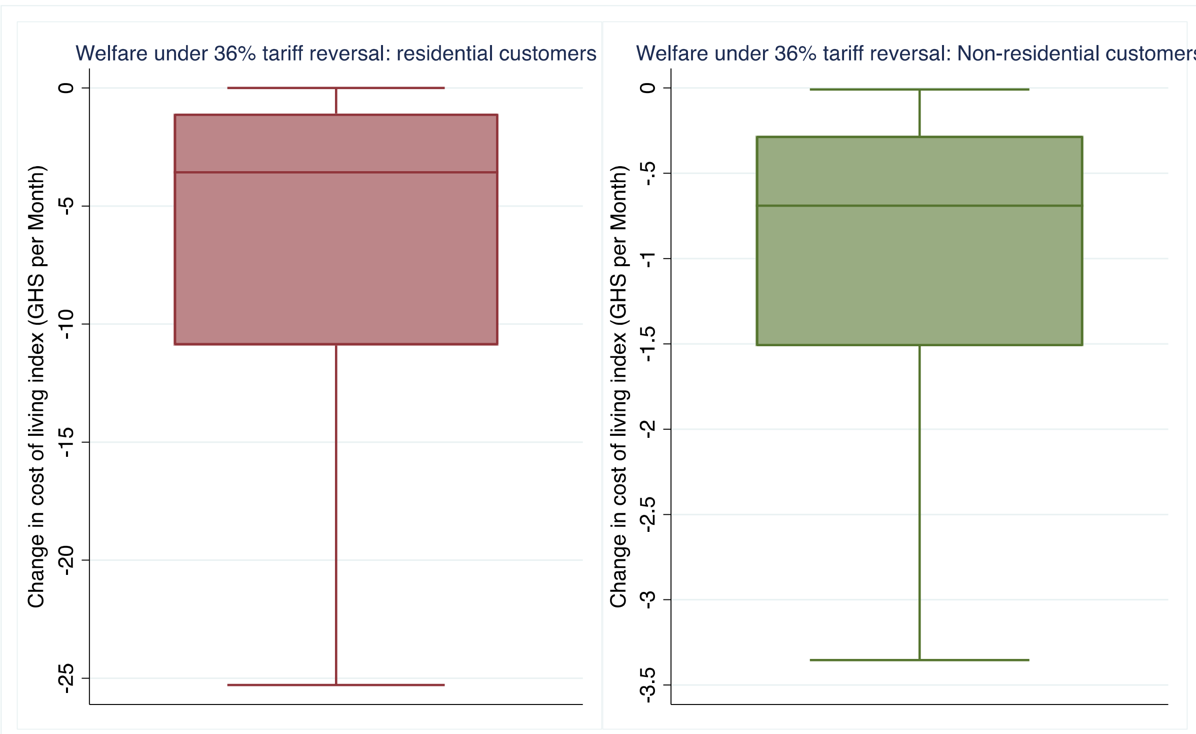

Figure 1.1: Welfare under 36% cross-subsidy reversal for residential and non-residential customers

This suggest that on the average the loss in welfare (GH¢4) is higher among the residential customers relative to non-residential customers (GH¢0.845). The higher loss in welfare for residential customers relative to non-residential customers is due to the partial reduction in the subsidy from non-residential to the residential group of customers. This means that electricity tariffs for residential customers increased than they would have if the reversal policy have not come into effect.

Heterogeneity of welfare under 36% cross-subsidy reversal for electricity tariffs across groups in residential and non-residential customer

To understand potential heterogeneity of the welfare implication of the partial tariff reversal, further analysis is done by assessing welfare across firm groups based on size (micro, small and medium size) and household groups based on income level (low, middle, and high income). The results are reported in figure1.2 reveals welfare losses vary across firm groups and across household's groups. Specifically, the welfare loss for the residential customers is largest for the high-income households with an average loss of GH¢6.3 per month, whereas the low-income households on the average experience the least loss in welfare (GH¢2 per month). To put these values in perspective, they translate to about 2.6% and 1.6% of the monthly electricity budget for the high-income households and low-income households respectively (table5).

Similar analysis for the non-residential customers also indicates heterogeneity in welfare, with micro size firms experiencing the largest monthly average loss (0.3% of monthly electricity budget) as reported in Table1.5. This is followed by small size firms (0.2% of monthly electricity budget) and medium size firms experiencing the least (0.04% of monthly electricity budget). This finding supports the study by Supriadi, et al. (2019) who find that, for the lower expenditure group, subsidy allocation to rose to 34.16% while for the top 20% expenditure group, it decreased to 20.4%. Thus, an increase in tariffs causes subsidised household welfare to decline. Similarly, our study also confirms the finding of Chian (2014) who noted that electricity subsidy in Brunei benefits 80% of poor household as compared with wealthier household.

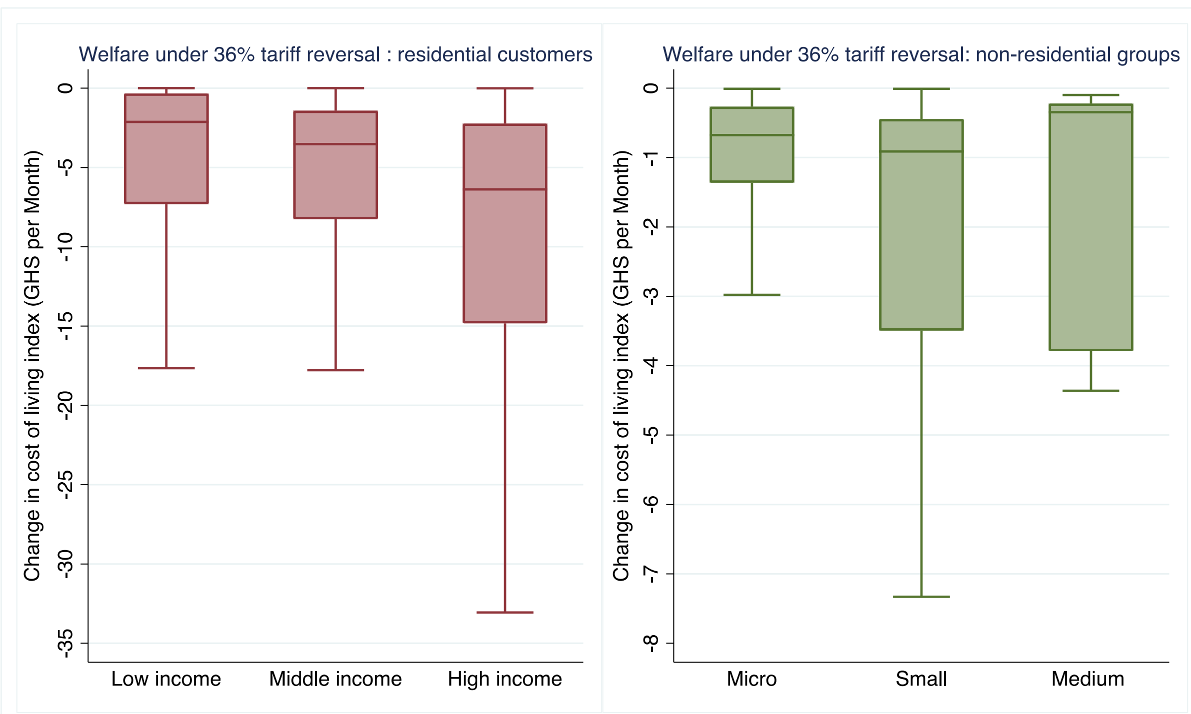

Figure 1.2: Welfare for firm and household groups under 36% cross-subsidy reversal

The second scenario is to assess the potential welfare implication of scaling-up the tariff reversal to 70% for both customers. The result for this as shown in figure1.3 indicates a loss in average welfare which varies from GH¢0.004 per month to GH¢56 per month for residential customers with an average loss of about GH¢9 per month. Non-residential customer on the other hand experienced an improvement in welfare from about GH¢0.157 per month to about GH¢ 58 per month with an average monthly welfare improvement of about GH¢13 per month. Similar reason for a higher loss in welfare for residential customers relative to non-residential customers when faced with the 36% of electricity cross subsidy reversal applies here as well, with much higher effects due to higher reversal that translates to much higher electricity prices for residential customers and much lower prices for non-residential customer relative to the status quo (no reversal of the cross subsidy by non-residential customers to residential customers).

Table 1.5: Welfare reversal and percentage share of monthly budget for customer groups: 36% reversal

Change in Welfare (GH¢ per month)		
Firm groups	**36% tariff reversal**	**% of electric budget**
Micro	GH¢0.756 (loss)	0.3%
Small	GH¢0.924 (loss)	0.2%
Medium	GH¢0.384 (loss)	0.04%
Household groups	**36% tariff reversal**	**% of electric budget**
Low income	GH¢2 (loss)	1.6%
Middle income	GH¢3.8 (loss)	2.2%
High income	GH¢6.3 (loss)	2.6%

Welfare under 70% and 100% electricity tariff reversal

The third scenario is a full reversal of the cross-subsidy (100% electricity cross-subsidy tariff reversal), which the analysis indicates that for residential customers, 100% tariff reversal will lead to higher welfare loss, which ranges from GH¢0.004 per month for some households to GH¢82 per month other households. The average loss in welfare for residential customers from such a tariff reversal in terms of cross-subsidy from non-residential customers to residential customers is about GH¢13 per month, which amounts to GH¢156 per year. Welfare improves for the non-residential class of customers range from GH¢0.461 per month to GH¢160 per month. The average improvement in welfare measured by the CLI for the non-residential class of customers is about GH¢35 per month, which translate to GH¢496.6 per year.

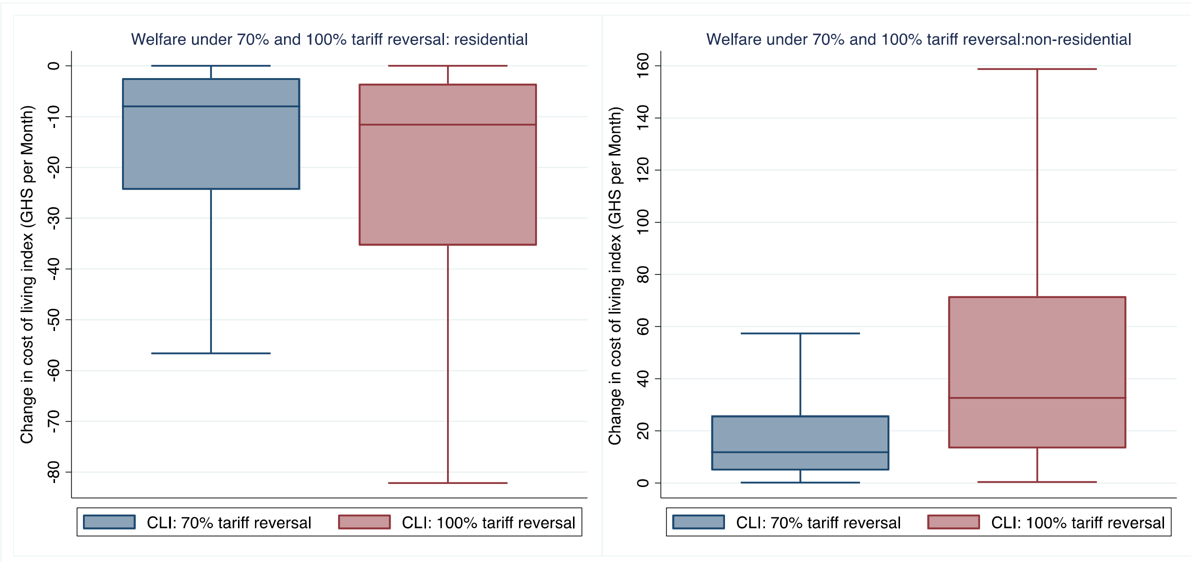

Figure 1.3: Welfare under 70% and 100% reversal for residential and non-residential customers

Heterogeneity of welfare under 70% and 100% cross-subsidy reversal for electricity tariffs across groups in residential and non-residential customers

Next, the potential heterogeneity of the estimated welfare from the two scenarios (70% and 100%) of the cross-subsidy electricity tariff reversal is analysed. In the case of the residential customers, the monthly income is used to create groups households. Those with monthly income below the mean income in the sample is classified as low-income group, those with income above the mean and below 75th percentile is classified as medium income group, and those with income above the 75th percentile is classified as high-income households in the sample. In the non-residential sample, the firms are classified into micro, small and medium size firms. Results for both residential and non-residential customers is presented figure1.4. Results for the non-residential customers show a positive welfare gain across the different groups of firms for both the 70% and 100 % reversals, though with much higher gains under the 100% reversal relative to the 70% reversal. Specifically, the welfare gains for micro firms under the 70% reversal range from GH¢0.521 per month to GH¢50 per month. For small firms, it ranges from GH¢0.209 per month to GH¢135 per month. Whereas it ranges from GH¢1.664 per month to GH¢78 per month for medium firms.

The specific welfare gains under 100% reversal ranges from GH¢1.443 per month to GH¢ 145 per month for micro firms, from GH¢0.580 per month to GH¢350 per month for small firms, and from GH¢4.606 per month to GH¢210 per month for medium size firms. Though figure 1.4 also presented the mean values of welfare for the various groups of firms for both tariff reversal scenarios, they are masked by the large ranges. Table 1.6 contain a clearer presentation of the mean values in Ghana cedi per month, which clearly indicates on the average, micro firms benefitted the most from both cross-subsidy reversals when expressed as percentage of monthly electricity budget, followed by small firms and the least being medium size firms.

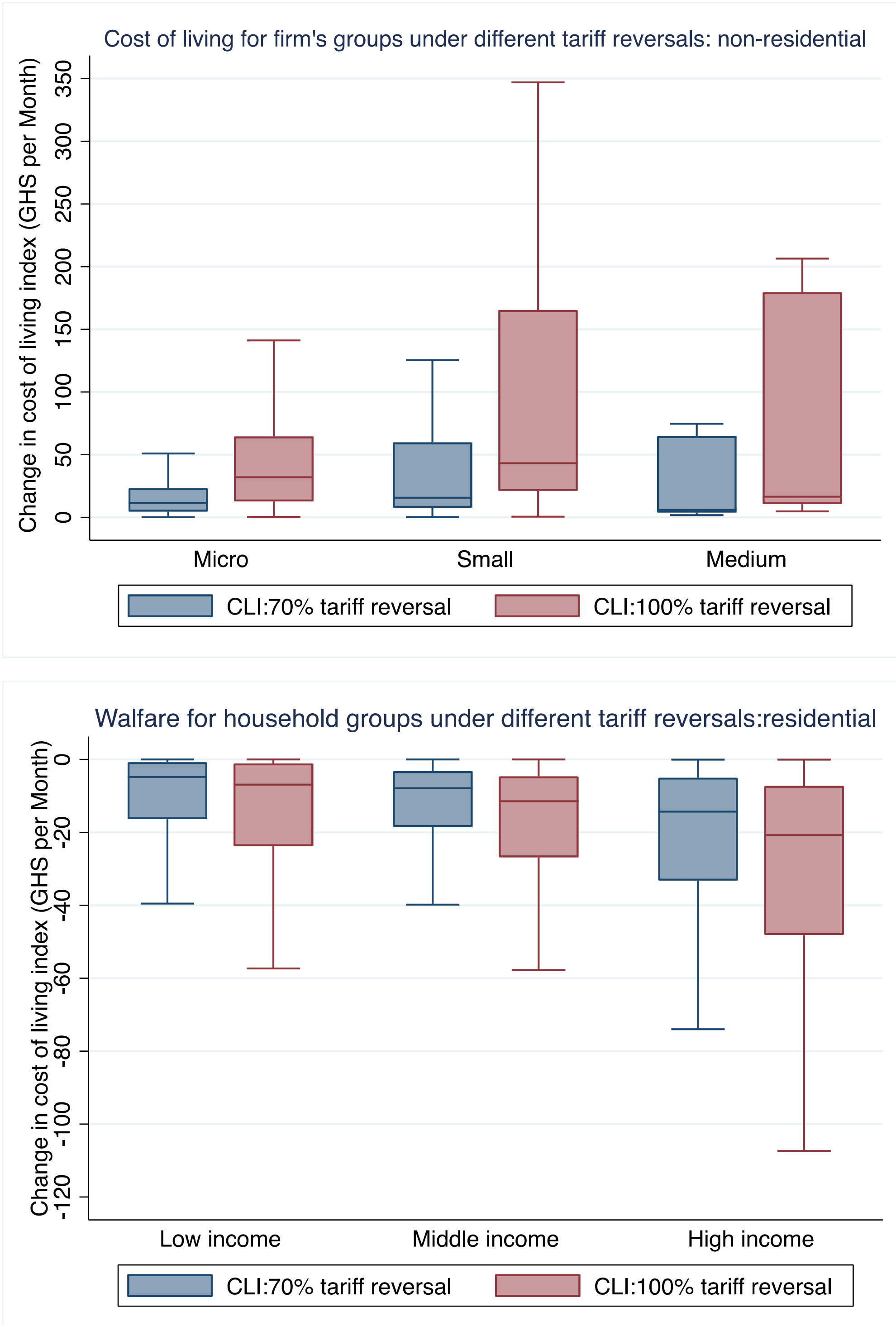

Figure 1.4: Welfare for firm and household groups under 70% and 100% cross-subsidy reversal.

Table 1.6: Average monthly welfare under 70% and 100% tariff reversal for residential and non-residential groups.

	Change in Welfare (GH¢ per month)			
Size of firm	**70% tariff reversal**	**% of electric budget**	**100% tariff reversal**	**% of electric budget**
Micro	GH¢11(gain)	3.7%	GH¢33(gain)	10.7%
Small	GH¢18(gain)	2.6%	GH¢48(gain)	7.7%
Medium	GH¢6(gain)	0.6%	GH¢19(gain)	1.8%
Total gains	GH¢35		GH¢100	
Income group - household				
Low income	GH¢5(loss)	4.1%	GH¢6.5(loss)	5.3%
Middle income	GH¢8(loss)	4.6%	GH¢12.5(loss)	7.2%
High income	GH¢14(loss)	5.7%	GH¢21(loss)	8.6%
Total loss	GH¢27		GH¢40	
	Net average total welfare per month			
70%	GH¢8			
100%	GH¢60			

Considering the heterogeneity of welfare from the 70% and 100% reversal for the residential group based on income level as reported in figure 1.4, all household groups experience a loss in welfare at larger magnitudes relative to the case of the 36% tariff reversal, highlighting the rising cost per KwH of electricity due to the reversal on cost of living for households. The welfare losses under the 70% reversal are lower for all the household's income groups relative to those under the 100% reversal. Specifically, the welfare loss under the 70% reversal ranged from GH¢0.023 per month to GH¢78 per month for the high-income group, from GH¢0.006 per month to GH¢40.5 per month for the middle-income group, and from GH¢0.001 per month to GH¢40 per month for low-income households. The ranges of welfare loss under the 100% reversal are much larger as shown in figure 1.4.

Table 1.6 also present the mean values of welfare loss and the associated share of the monthly electricity budget to put the average loss in perspective. For instance, under the 70% reversal, the high-income households experience the largest average loss in welfare (GH¢14 per month), followed by middle-income households (GH¢8 per month) and the low-income households the least loss (GH¢ 5 per month). The loss in welfare from the high-, middle- and low-income groups correspond to 5.7%, 4.6% and 4.1% of average monthly budget respectively. Our findings also align with the work of Ansarin, et al., (2020), who find a larger welfare transfer from distributed renewable energy sources (D-RES) from owners to non-owners in a traditional tariffs design. Their study equally documents the importance of demand elasticity in analysing cross-subsidisation and its effects on different tariffs. Similarly, the high-income group experience the largest average loss in welfare per month (GH¢21 per month) under the 100% reversal, followed by the middle-income households (GH¢ 12.5 per month) and the low-income households are with the least loss (GH¢6.5 per month). These losses correspond to 8.6%, 7.2% and 5.3% of the monthly budget share respectively.

6. Conclusion

Ghana is keen to reform its power sector in ways that help reduce inefficiencies in the sector, transition to a cost reflective tariff system, promote an effective distribution segment of the power sector and promote reliable generation and distribution of power by attracting private investments to modernize its power systems and in the long run reduce government interference. A key contribution to the recurrent power crisis in Ghana, especially in recent times is financial challenges faced by the sector in paying various players in the power sector including payments to generators and upgrading transformers, network systems and the procurement of quality electricity meters. The financial challenges of the power sector are compounded by the inability of the main distributor (ECG) to reduce commercial loses for each kWh of electricity distributed to the final consumers due to inefficiencies in the revenue collection approach, high illegal electricity connection among others. Furthermore, prior to September 2022, the electricity tariff structure was based on a practice where non-residential customers cross-subsidies tariffs for the residential class. Which implies that, SMEs and other businesses tend to pay more per kWh of electricity, relative to similar bands from the residential segment, thereby further increasing the cost of doing business in Ghana.

The aim of this study is to investigate the welfare implication of the partial reversal (36%) of the cross-subsidy policy that was implemented in September 2022 on both residential and non-residential customers. The goal is to assess the welfare associated with such a tariff structure that reduces the burden on businesses by the removal of some or all the additional cost that businesses incur in term of subsidising the cost of electricity for residential customers.

the reversal to 70% and 100% for both customers to inform the review process on whether to further scale- up the reversal to 70% or to a full reversal (100%) or it is better to keep it the current 36% or even reverse to the status quo of cross-subsidy. Specifically, we are interested in assessing the welfare of residential customers if less than half, more than half or all the subsidy they are enjoying form non-residential customers is taken away and whether the welfare varies across different groups of residential customers based on income level compared to that of non-residential group of customers.

Using a demand system approach, specifically the EASI demand system approach on a survey data for selected regions in Ghana based on the number of registered SMEs, combine with a cost-of-living index approach, we estimate the demand for each of the key budget items for both customers, thus, food, non-food, electricity and rent for residential customers and wage, non-wage, electricity and rent for non-residential customers. Focusing on the estimates for the electricity demand for both customers, the cost-of-living index is computed, which is multiplied by the monthly budget to convert it to a cost of living per month (welfare measure).

Several interesting findings emerge. First, both customers experienced a loss in welfare under the 36% partial reversal relative to the status quo (no reversal), though the loss is relatively higher for the residential relative to the non-residential. The loses in general are marginal about 2.3% and 0.13% loss of the average electricity monthly budgets for residential and non-residential customers, respectively.

Second, welfare varies across income groups for the residential customers and across firm size for the non-residential customers. In the case of the residential customers, the high-income households experience the largest loss in welfare, whilst the low-income households experience the least in loss in welfare. The loss in welfare is highest for small size firms followed by micro-size firms, with medium-size firms experiencing the least loss in welfare.

Third, there is evidence of a reversal for welfare loss to gains for the non-residential customers when the percentage reversal is scale-up to 70% and further to 100%. Whereas residential customers continue to experience a loss in welfare at higher magnitudes relative to the initial 36% reversal. There is also evidence of welfare heterogeneity for both customers at both the 70% and 100% reversals, where the low-income households and the high-income households consistently experience the lowest and highest loss in welfare, respectively. In the case of non-residential customers, small-size firm consistently experience the best welfare gains for both the 70% and 100% reversal, whereas the medium-size firms experience the least gains in welfare.

Our results have important policy implications, at least for the review of the partial cross-subsidy reversal by the Public Utilities Regulatory Commission (PURC). The partial reversal may not have resulted in leading to a total welfare gains as both customers experience a loss in welfare. This may be due to a general rise in cost of living at rates that are par or even higher than the reversal rate, nullifying the potentials gains from the reversal for at least the non-residential customers. This is backed by the positive gains when the percentage reversal rates increased to the top end, 70% and 100%. The evidence also showed that the average gain in welfare per month for both the 70% and 100% reversals are much higher than the losses in welfare for the residential customers for these reversal rates. Suggesting a positive net gains in welfare for the society, though marginal as the highest average welfare gain is only about 10.7% of the monthly electricity budget for micro-size firms. Despite the marginal nature of the benefits, 10.7% reduction in the monthly cost of electricity is still significant and it is recommended that the policy be scaled-up to 100% reversal since the highest loss in welfare is only about 5.8% of the monthly electricity budget for the high-income households. This should be done in phases, where the next face after the review of the policy, the reversal rate should be scale-up to 70% with further education provided to at least the residential customer on the differences between reversal and tariff increases and why it is important to do this. Then after the review on the 70% reversal, the policy maker can proceed to the next phase by scaling it to 100 %.

References

Acheampong, T., & Ankrah, F. (2014). Pricing and deregulation of the energy sector in Ghana: challenges and prospects. *Ghana Energy Situation Report, Q1 2014*.

Allcott, H. (2011). Rethinking real-time electricity pricing. *Resource and energy economics*, *33*(4), 820-842.

Ansarin, M., Ghiassi-Farrokhfal, Y., Ketter, W., & Collins, J. (2020). The economic consequences of electricity tariff design in a renewable energy era. *Applied Energy*, *275*, 115317.

Association of Ghana Industries (AGI), 2019, The AGI Business Barometer 2nd Quarter 2019: Summary Report, Accra.

Berkouwer, S. B., Biscaye, P. E., Puller, S., & Wolfram, C. D. (2022). Disbursing emergency relief through utilities: Evidence from Ghana. *Journal of Development Economics*, *156*, 102826.

Böhringer, C., Landis, F., & Reanos, M. A. T. (2017). Economic impacts of renewable energy promotion in Germany. *The Energy Journal*, *38*(1_suppl), 189-210.

Brännlund, R., & Ghalwash, T. (2008). The income–pollution relationship and the role of income distribution: An analysis of Swedish household data. *Resource and Energy Economics*, *30*(3), 369-387.

Castellón, C. E., Boonsaeng, T., & Carpio, C. E. (2015). Demand system estimation in the absence of price data: an application of Stone-Lewbel price indices. *Applied Economics*, *47*(6), 553-568.

Chian, K. W. (2014). A new electricity tariff in Brunei Darussalam: welfare implications for households. *Journal of Southeast Asian Economies*, 276-291.

Filippini, M. (1995). Swiss residential demand for electricity by time-of-use. *Resource and Energy Economics*, *17*(3), 281-290.

Gambardella, C., Pahle, M., & Schill, W. P. (2020). Do benefits from dynamic tariffing rise? Welfare effects of real-time retail pricing under carbon taxation and variable renewable electricity supply. *Environmental and Resource Economics*, *75*, 183-213.

Gassmann, F. (2014). Switching the lights off: The impact of energy tariff increases on households in the Kyrgyz Republic. *Journal of Comparative Economics*, *42*(3), 755-769.

Giuliano, F., Lugo, M. A., Masut, A., & Puig, J. (2020). Distributional effects of reducing energy subsidies: Evidence from recent policy reform in Argentina. *Energy Economics*, *92*, 104980.

Hancevic, P., Cont, W., & Navajas, F. (2016). Energy populism and household welfare. *Energy Economics*, *56*, 464-474.

Hoderlein, S., & Mihaleva, S. (2008). Increasing the price variation in a repeated cross section. *Journal of Econometrics*, *147*(2), 316-325.

Horowitz, S., & Lave, L. (2014). Equity in residential electricity pricing. *The Energy Journal*, *35*(2), 1-24.

Karimu, A., Krishnamurthy, C. K. B., & Vesterberg, M. (2022). Understanding hourly electricity demand: implications for load, welfare and emissions. *The Energy Journal*, *43*(1), 161-190.

Lewbel, A., & Pendakur, K. (2009). Tricks with Hicks: The EASI demand system. *American Economic Review*, *99*(3), 827-863.

Lewbel, A., & Pendakur, K. (2017). Unobserved preference heterogeneity in demand using generalized random coefficients. *Journal of Political Economy*, *125*(4), 1100-1148.

Pacudan, R., & Hamdan, M. (2019). Electricity tariff reforms, welfare impacts, and energy poverty implications. *Energy Policy*, *132*, 332-343.

Romero-Jordán, D., Del Río, P., & Peñasco, C. (2016). An analysis of the welfare and distributive implications of factors influencing household electricity consumption. *Energy Policy*, *88*, 361-370.

Schulte, I., & Heindl, P. (2017). Price and income elasticities of residential energy demand in Germany. *Energy Policy*, *102*, 512-528.

Supriadi, A. Y., Ikhsan, M., Mahi, B. R., & Girianna, M. (2019). Impact of changes to subsidized electricity tariffs on the welfare of households. *Etikonomi: Jurnal Ekonomi*, *18*(2), 169-184.

Wang, X., & Lin, B. (2017). Impacts of residential electricity subsidy reform in China. *Energy Efficiency*, *10*, 499-511.

Appendix: Number of employees

A1

Variable	(Non-residential demand estimates)
Expenditure (Y)	
b10	0.676***
	(5.19)
b11	-0.183***
	(-5.32)
b12	0.014***
	(3.67)
b20	0.621***
	(3.25)
b21	-0.054
	(-0.99)
b22	-0.003
	(-0.60)
b30	-0.315
	(-1.50)
b31	0.218***
	(3.85)
b32	-0.009*
	(-1.72)
Firm characteristics (C)	
C11	-0.002
	(-0.57)
C12	0.041

	(1.26)
C13	-0.085**
	(-2.48)
C14	0.024
	(0.97)
C15	0.005
	(0.17)
C21	0.009
	(1.49)
C22	0.115**
	(2.38)
C23	-0.148**
	(-1.99)
C24	-0.099**
	(-2.32)
C25	0.132**
	(2.40)
C31	-0.007
	(-1.13)
C32	-0.111**
	(-2.37)
C33	0.190***
	(2.87)
C34	0.062*
	(1.72)
C35	-0.119**

	(-2.42)
Interaction between firm characteristics and expenditures (D)	
D11	-0.001
	(-1.01)
D12	-0.007
	(-1.57)
D13	0.015***
	(2.87)
D14	-0.004
	(-1.24)
D15	0.004
	(0.96)
D21	-0.003***
	(-3.04)
D22	-0.022***
	(-3.21)
D23	0.0221*
	(1.92)
D24	0.013*
	(1.91)
D25	-0.015*
	(-1.69)
D31	0.003**
	(2.17)
D32	0.022***
	(3.28)
D33	-0.032***

	(-3.07)
D34	-0.00581
	(-1.04)
D35	0.008
	(1.03)
Interaction between prices and firm characteristics (A)	
A11_0	0.273***
	(7.34)
A11_1	0.002
	(1.35)
A11_2	0.001
	(0.15)
A11_3	-0.004
	(-0.91)
A11_4	
	-0.002
	(-0.66)
A11_5	-0.010***
	(-2.63)
A12_0	-0.066***
	(-3.07)
A12_1	0.001
	(1.46)
A12_2	
	-0.001
	(-0.50)
A12_3	0.003

	(1.14)
A12_4	0.005**
	(2.52)
A12_5	-0.004*
	(-1.67)
A13_0	-0.180***
	(-4.03)
A13_1	-0.002
	(-1.48)
A13_2	0.0002
	(0.04)
A13_3	0.002
	(0.36)
A13_4	-0.004
	(-1.04)
A13_5	0.014***
	(2.81)
A22_0	-0.085***
	(-4.89)
A22_1	0.005
	(1.30)
A22_2	0.0161***
	(3.57)
A22_3	0.0004
	(0.08)
A22_4	0.006
	(1.29)
A22_5	-0.020***

	(-3.64)
A23_0	0.132***
	(5.99)
A23_1	-0.006
	(-1.62)
A23_2	-0.015***
	(-3.51)
A23_3	-0.002
	(-0.28)
A23_4	-0.010**
	(-2.26)
A23_5	0.021***
	(3.44)
A33_0	0.301***
	(4.75)
A33_1	0.009*
	(1.71)
A33_2	0.016
	(1.42)
A33_3	-0.005
	(-0.35)
A33_4	0.016**
	(2.14)
A33_5	-0.037***
	(-3.12)
Interaction between prices and expenditures (B)	
B11	-0.019***

	(-4.33)
B12	0.005
	(1.42)
B13	0.012**
	(2.02)
B22	0.032***
	(14.04)
B23	-0.033***
	(-15.77)
B33	0.0001
	(0.02)
N	286

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

	(Residential)
Expenditure (Y)	
b10	0.805***
	(3.08)
b11	-0.108
	(-1.46)
b12	0.00526
	(0.53)
b13	-0.00004
	(-0.74)
b14	0.00001
	(0.71)
b20	-0.888
	(-1.35)

b21	0.488**
	(2.04)
b22	-0.0777**
	(-2.34)
b23	0.00404*
	(1.82)
b24	-0.0001
	(-1.27)
b30	-0.0249
	(-0.01)
b31	-0.308
	(-0.48)
b32	0.0892
	(1.09)
b33	-0.0033
	(-0.71)
b34	0.00003
	(0.55)
C11	-0.0021
	(-1.26)
C12	-0.0311*
	(-1.89)
C13	0.0334*
	(1.69)
C14	-0.011
	(-0.46)
C15	0.0018
	(0.08)

C21	0.0029
	(1.02)
C22	-0.100***
	(-2.86)
C23	0.128***
	(2.96)
C24	0.0949*
	(1.82)
C25	-0.0330
	(-0.62)
C31	0.00669
	(0.72)
C32	0.234**
	(2.39)
C33	-0.277***
	(-2.58)
C34	-0.00146
	(-0.01)
C35	-0.0727
	(-0.61)
D11	
D11	0.000201
	(1.00)
D12	-0.00165
	(-0.78)
D13	0.00142
	(0.51)
D14	0.00265

	(0.72)
D15	-0.00199
	(-0.51)
D21	-0.000396
	(-0.82)
D22	0.00506
	(0.55)
D23	-0.0205**
	(-2.28)
D24	-0.0167*
	(-1.76)
D25	0.0171
	(1.53)
D31	-0.00116
	(-0.96)
D32	-0.0128
	(-0.73)
D33	0.0275
	(1.42)
D34	0.0151
	(0.72)
D35	-0.00545
	(-0.26)
A11_0	
A11_0	0.0786***
	(2.93)
A11_1	0.000335
	(1.54)

A11_2	0.00611*
	(1.84)
A11_3	-0.00804***
	(-2.62)
A11_4	-0.00121
	(-0.45)
A11_5	0.00360
	(0.98)
A12_0	-0.0732***
	(-4.72)
A12_1	-0.000135
	(-1.03)
A12_2	0.00915***
	(2.79)
A12_3	-0.00328
	(-1.16)
A12_4	-0.00323
	(-1.50)
A12_5	-0.00480
	(-1.30)
A13_0	0.156**
	(2.14)
A13_1	-0.000278
	(-0.43)
A13_2	-0.0246***
	(-2.78)
A13_3	0.0216***
	(2.83)

A13_4	-0.00603
	(-0.88)
A13_5	0.00884
	(0.95)
A22_0	0.0700**
	(2.12)
A22_1	0.00000428
	(0.01)
A22_2	0.0160
	(1.07)
A22_3	0.00177
	(0.18)
A22_4	-0.00133
	(-0.29)
A22_5	-0.0162
	(-1.34)
A23_0	0.241***
	(3.67)
A23_1	0.000559
	(0.75)
A23_2	-0.0403*
	(-1.77)
A23_3	0.0144
	(0.79)
A23_4	-0.00548
	(-0.62)
A23_5	0.0363*
	(1.83)

A33_0	-1.371***
	(-6.27)
A33_1	0.00132
	(0.38)
A33_2	0.0485
	(1.40)
A33_3	-0.0611
	(-1.38)
A33_4	0.105***
	(5.21)
A33_5	-0.0791**
	(-2.08)
B11	
B11	-0.00173
	(-0.52)
B12	0.0132***
	(5.93)
B13	-0.0356***
	(-4.28)
B22	0.00969**
	(2.32)
B23	-0.0707***
	(-8.59)
B33	0.271***
	(20.34)
N	903

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

IGC

theigc.org