UNIVERSITY of RWANDA

College of Business and Economics

"ASSESSMENT OF FACTORS DRIVING ELECTRICITY THEFT IN RWANDA FROM 2002 UP TO 2019. A TREND IN CONSUMER BEHAVIOUR".

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Masters' of Science in Regulatory Economics and Competition Policy

by

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Under the supervision of

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June, 2021.

DECLARATION

I, the undersigned Innocent MUSAFIRI, a student at the University of Rwanda in Masters' of Science in Regulatory Economics and Competition Policy declare that the work presented in this thesis entitled **"Assessment of Factors driving electricity theft in Rwanda from 2002 up to 2019. A trend in consumer behaviour"** is mine and has never been presented or submitted in any University or other higher learning institutions for the same purpose.

Names: Mr Innocent MUSAFIRI

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Signature:……………………….

Date:…………………………….

APPROVAL SHEET

This thesis entitled "***Assessment of factors driving electricity theft in Rwanda from 2002 up to 2019. A trend in consumer behaviour"*** written and submitted by Innocent MUSAFIRI in partial fulfilment of the requirements for the degree of **Masters' of Science in Regulatory Economics and Competition Policy,** is hereby approved

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Supervisor

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Date

The thesis is accepted in partial fulfilment of the requirements for the Degree of Masters' of Science in Regulatory Economics and Competition Policy.

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Member of the Jury Member of the Jury

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Date Date

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Coordinator of Post Graduate Studies

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Date

DEDICATION

To my parents,

To my brothers and sisters, is dedicated this thesis.

CERTIFICATION

This is to certify that this research was conducted and completed at the University of Rwanda, the data used are secondary data retrieved from different sources as stipulated in the research content.

This is the work of Mr Innocent MUSAFIRI, a student of the University of Rwanda in Masters of Science in Regulatory Economics and Competition Policy, conducted under my guidance.

Supervisor: **Mr Etienne NDEMEZO, PhD**

Date: ……………………………………..

Signature:…………………………………

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To all of you, I say **"Thank you"** and may God bless you abundantly.

LIST OF ACCRONYMS

ARIMA: Autoregressive Integrated Moving Average

EUCL: Energy Utility Corporation Ltd

IPPs: Independent Power Producers

IEA: International Energy Agency

LCPDP: Least Cost Power Development Plan

OLS: Ordinary Least Square

REG: Rwanda Energy Group

SAIFI: System Average Interruption Frequency Index

SAIDI: System Average Interruption Duration Index

ABSTRACT

This study investigates the socioeconomic factors and governance indicators driving electricity theft in Rwanda, through empirical analysis. We used secondary quarterly data from 2002Q1 up 2019Q4, retrieved from different sources of data. The Ordinary Least Squares (OLS) method have been used to analyse the influence of socioeconomic factors and governance indicators have on the electricity theft and an Autoregressive Moving Average (ARIMA) model have been used to forecast the electricity theft, to reflect the trend in consumer behaviour, as long as electricity theft is concerned. Our study found that, among the socioeconomic variables, the unemployment and electricity access was found to be significant. On the other hand, among the governance indicators, the control of corruption and the rule of law was found to be significant as well. The study suggest that the unemployment positively influence the theft decisions of customers. On the other side, the control of corruption was found to be contributing to the reduction of electricity theft.

The forecast for 10 years to come, using ARIMA model, shows that the electricity theft will keep increasing, unless measures are taken to tackle these acts. The intense and surprise inspections would contribute to the reduction of electricity theft. In addition, the increase in electricity access should go hand in hand with educating customers on risks associated with tempering with power infrastructure as well as investment in new technologies to fast track the electricity theft practices. Limited data and collinearity issue have been our limitations in our study and proposal for further studies have been highlighted.

Key words: Electricity theft, Unemployment, Electricity Access, Control of Corruption, Rule of Law, ARIMA model.

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CHAPTER ONE: GENERAL INTRODUCTION

I.1. INTRODUCTION

The electricity supply we use to have at the proximity of our premises for lighting and powering on our electrical and electronic devices, usually reach us after taking very long distances, after passing across different components of the power system. This is due to the fact that the generating power stations are located far away from the load centres. Along the way, there are electricity losses occurred due to resistance in electric conductors, transformers losses and other losses in the components of the power system. These are called technical losses.

In addition to these losses, there are non-technical losses or commercial losses. These are usually results from the customers and utility staff behaviours as well as the utility recovery efficiency. They result from unbilled meters, unpaid bills, bribing the meter readers and electricity theft. The later contribute much in overall commercial losses and is one of the factors driving the revenue losses of the utility, and hampers the development of electricity sector in general[1].

This affect new investment, reduce the ability of the electricity sector to pay the maintenance of existing infrastructures and such losses are eventually charged to honest paying customers, through tariff setting as a loss reduction component. Electricity theft not only results in unbearable economic losses to the power suppliers but also endangers the safety of electricity users, the electrical systems and even the public at large.

The Government of Rwanda is committed to reach a universal electricity access by 2024[2]. This would be curtailed by pilferage of electricity, as hefty amount is lost and hence hindering new investment in generation. The cases of electricity theft have been growing during the last decades, which pushed the government of Rwanda to consider electricity theft as crime as stipulated in the law N°52/2018 of 13/08/2018 modifying the Law N°21/2011 of 23/06/2011 governing electricity in Rwanda as modified to date.

Furthermore, electricity theft is being done through several means including but not limited to tempering with meters, bypassing the meters, taping power lines or into neighbouring premises as well as illegal lines. These acts can cause injury and/or death.

[1] Quantification of Commercial Losses in Rwanda using Data Analytics
[2] Energy Sector Strategic Plan 2018/2019-2023/2024

In this regard, the National Utility has embarked on series of campaigns to fight and discourage fraudulent connections to preclude or reduce the cases of electricity theft. Following different inspections to customer's premises, different customers were caught red-handed including but not limited to households, small businesses, hotels, milling industries, bars/restaurants and industries. There has been a number of filed cases to competent court, and fines have been strictly applied to guilty customers. However, on the other hand, some of the customers have been denying the fact that they steal electricity, and this led the electricity utility to losses[3]

The research covers five chapters, containing the general introduction, the literature review, the chapter on the research methodology, the findings and interpretations, and finally, the conclusions and suggestions from the research is made to highlight key points to be considered on the side of electricity policy formulation.

I.2. PROBLEM STATEMENT

The issue of electricity theft in Rwanda have been leading to losses on both the side of electricity service providers as well as affecting the businesses, on the side of customers. As per the press release done by the Rwanda Energy Group (REG), the commercial loss incurred due to electricity theft is estimated to **6.5%**[4] of the total electrical energy generated in the country and out of which a big share emanates from the electricity theft. The amount of electricity stolen is evaluated to Rwandan francs **1,9 billion** per year**.** This affects new investment of the Utility, the ability of the electricity sector to pay for the maintenance and upgrade of existing electricity infrastructures, affect the tariff, as the cost for the loss reduction will increase and affects the universal access targeted by 2024.

The research aims to assess socioeconomic and governance factors driving electricity theft, which lead to such losses and hence, hinder the efficiency of the national electricity provider. In long run, it aims to develop a model that will facilitate the policy makers in setting more appropriate policies in minimizing the electricity theft in Rwanda, by relatively improving the Utility's efficiency.

I.3. RESEARCH OBJECTIVES

The objectives are classified as general and specific parts. The general objective will cover the broad idea of the influence the explanatory variables have on the explained variable whereas,

[3] https://www.reg.rw/fileadmin/user_upload/Press_release_power_theft_24_Jan_2019.pdf

[4] https://www.reg.rw/fileadmin/user_upload/Press_release_power_theft_24_Jan_2019.pdf

the specific objective covers the particularity of each or parts of explanatory variables have on the explained variable. It will also highlight the policy measures that will help in improvement of the explained variable.

I.3.1. General Objective

The main objective of this study is to investigate the factors influencing electricity theft in Rwanda.

I.3.2. Specific Objectives

i) To analyse the contribution of socio-economic variables on electricity theft

ii) To analyse the contribution of governance indicators on electricity theft.

I.3.3. Research Questions

The profound exploration of the possible determinants of electricity theft will be done based on the following questions:

i) Is there a mutual relationship between socioeconomic variables and electricity theft?

ii) Is there a mutual relationship between governance indicators and electricity theft?

I.3.4. Hypothesis Formulation

Based on the above research questions and objectives, the following hypothesis have been formulated and tested:

H0: There is no significant relationship between socioeconomic variables, including governance indicators, and electricity theft.

H1: There is significant relationship between socioeconomic variables, including governance indicators, and electricity theft.

I.3.5. Significance of the Study

Generally, the power system has losses, classified as technical and non-technical losses, which cannot be avoided, but can be minimised. In developed countries, these losses are ranging between **4%** to **8%**, as they have efficient power systems[5]. Currently, the total losses of the Rwanda National Grid is **19.1%**[6]. This combines the technical and non-technical losses.

[5] Transmission and Distribution Losses

[6] RURA Annual Report, 2019-2020

Electricity theft is counted as non-technical losses, and it is the most contributing component among others.

Electricity theft has socioeconomic, political and technical basis but the solution is generally being solely solved through technical measures[7]. The study will make an empirical analysis to provide a valuable information for policy makers and will be focusing on socio-economic and governance causes leading to the electricity theft in Rwanda.

I.3.6. Scope and Organisation of the Study

The study is related to investigation of the relationship between socio-economic variables and electricity theft. The income per capita, the electricity access, the electricity price, the electricity per capita consumption, the unemployment rate, the tertiary education are socio-economic parameters that are expected to influence the electricity theft.

In addition, the government variables have influence on the electricity theft. They include, but not limited to the control of corruption, the rule of law, the regulatory quality, the government effectiveness, the political stability and non-violence. The total population have been considered as the total customers requesting for connection. Generally, the study is organised in the following chapters:

Chapter one introduces the theoretical relationship between the socioeconomic activities and electricity theft. It also gives highlights on electricity theft status in Rwanda.

It is composed of the problem statement, research objectives, hypothesis formulation, significance of the study as well as the scope of the study.

Chapter two covers the literature review of relevant theories and studies from different sources that touched on electricity theft and related topics. It also covers the electricity sector profile and the possible catalyst of electricity theft.

Chapter three covers the research methodology, which consist of data collection techniques, model and variables construction, variables explanations as well correlation between variables.

Chapter four is about findings and interpretations of the results in a proper and meaningful ways.**Chapter five** summarises the findings, provide conclusions and suggestions to the policy makers as well as for further investigations on the research topic.

[7] Jamil & Ahmed.; “An Empirical Study of Electricity Theft from Electricity Distribution Companies in Pakistan”.

CHAPTER TWO: LITERATURE REVIEW

A preliminary literature review shows that studies related to electricity supply are plenty, but few of them highlighted the issue of electricity theft in electricity supply industry. For those tackling the issue of electricity theft, Jamil and Ahmed [2] made an empirical study on electricity theft from electricity distribution companies in Pakistan. They argued that the electricity theft is a multidimensional issue and ought to be investigated from a broader perspective. They examined the role of various factors affecting electricity theft in various distribution companies in Pakistan for the period 1988-2010 and find that the probability of detection does not perform consistently in combating electricity theft. Golden and Min [3] analysed the theft and losses of electricity in an Indian State, whereby they found that electricity theft is substantially greater when the elections of State Assembly is held as compared to other years. In his internship report, Sylvestre [4] made a quantification of commercial losses in Rwanda, using Data Analytics and found that the method fails to localise the theft suspect or any other commercial losses due to lack of real time data. This is a drawback to know the exact number of theft cases around the country and apply related fines.

The electricity law, as modified to date, provide for fines, especially in the Art. 5, 11 and 12 whereby the electricity theft is subjected to imprisonment not less than six (6) months but not exceeding one (1) year and define specific amount as fines ranging from one (1) million to five (5) millions Rwandan francs as fines.

Other literature was based on electricity consumption. For example, Chain [5] highlighted the factors affecting electricity consumption in residential customers, but did not tackle the issue of theft in that customer category. The study find that the air conditioners consume a large portion of electricity in Taiwan, followed by refrigerators and rice cookers. Ibraheim [6] investigated the causal relationship between electricity consumption at a macro level and sectoral levels in three economic sectors, namely the agricultural sector, industrial and services sector in Egypt during the period 1971-2013. Zhongdong et al. [7] highlighted the relationship between the effects of electricity production on industrial development and sustainable economic growth.

Economic of crime have known plenty of literature as well as the corruption. In their article entitled “the economics of crime”, Eide, Rubin & Shepherd [8] stated that Bentham (1789, 1843, p. 399) wrote that “. . . the profit of the crime is the force which urges man to delinquency: the pain of the punishment is the force employed to restrain him from it. If the first of these forces be the greater, the crime will be committed; if is the second, the crime will not be committed."

In the same article, the authors stated that as the total outcome of a criminal act is uncertain, Becker employs the usual assumption that people act as if they were maximizing expected utility, and that utility is a positive function of income. The individual's expected utility $E[U]$ from committing an offense is expressed as:

$$E[U] = PU(Y - f) + (1 - P)\,U(Y),$$

where $U(\cdot)$ is the individual's von Neumann–Morgenstern utility function, P is the subjective probability of being caught and convicted, Y is the monetary plus psychic income (i.e. the monetary equivalent) from an offense, and f is the monetary equivalent of the punishment.

Most of these literatures did not talk about the theft, which is evolving nowadays and contribute much in hindering the development of electricity sector in Rwanda. This, as stated before, contributed losses of around 2Bn Frw to the Utility per year.

CHAPTER THREE: RESEARCH METHODOLOGY

III.1. RESEARCH DESIGN

The research considered the socioeconomic perspective, including the governance indicators, and the direct use perspective. The socioeconomic perspective covers variables such as the per capita income, the electricity access, the electricity per capita consumption, the tertiary education level, the control of corruption, the rule of law, the regulatory quality, the government effectiveness, the political stability and non-violence, the unemployment, the total population, etc.[8]

The direct use perspective is considered as the factors affecting one's decisions with regards to electricity consumption[9]. The variables falling in direct use perspective are expected to be including, the electricity price, the magnitude of fines, the probability of detection, etc. They are expected to be part of factors contributing to the electricity consumption behaviour in Rwanda, and hence are basis for theft factors determination.

III.2. MODEL AND VARIABLES CONSTRUCTION

This section highlights the factors that might affect electricity theft in Rwanda. We employed the most relevant explanatory variables consisting of socio-economic and governance indicators variables[10]. The analysis is based on linear regression of the form Ordinary Least Squares (OLS) for Electricity Theft, as a dependent variable, using quarterly time series data from the year 2002 up to the year 2019.

The general regression equation is estimated as

$$ETH_t = \beta_0 + \beta_1 EPt + \beta_2 PCY + \beta_3 EA + \beta_4 CC + \beta_5 RL + \beta_6 RQ + \beta_7 GE + \beta_8 PSNV + \beta_9 UE + \beta_{10} TP + \beta_{11} TRE + \beta_{12} PCC + \beta_{13} TR + \beta_{14} TE + E_t$$

Where: E_t is the common error term. The values β_0 and β_i are respectively the slope and intercept of the model. β_i the i^{th} intercept, meaning the impact of the i^{th} explanatory variables on the explained variable. The names of the variables are detailed as follow:

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[8] The factors affecting electricity consumption and the consumption characteristics in the residential sector-A case example of Taiwan

[9] Idem

[10] The determinants of Electricity theft: An empirical analysis of Indian states

ETH_t: Electricity theft

EP_t: Electricity Price

PCY: Per Capita Income

EA: Electricity Access

CC: Control of Corruption

RL: Rule of Law

RQ: Regulatory Quality

GE: Government Effectiveness

PSNV: Political Stability and Non-Violence

UE: Unemployment

TP: Total Population

TRE: Time required to get connected

PCC: Per Capita Consumption of Electricity

TR: Tax Revenues

TE: Tertiary Education

However, the variables may be subjected to past values, that is why we opted to adopt a model to take into consideration the past values. We will be using autoregressive integrated moving average (ARIMA) model to forecast the trend in electricity theft in Rwanda.

The model is specified as $ETH_t = \beta_0+\beta_1 ETH_{t-1}+\mu_t$ where ETH_{t-1} implies the lags of the series variable to be forecasted. The above specification implies that the electricity theft in time t is explained by its immediate past value in time $t-1$ and an error term u_{t-1}. In the same way, the future value of electricity theft, that is ETH_{t+1} will depend on the present value of electricity theft ETH_t as well as its present error term μ_t. The value of β_1 should, in absolute value, be less than one ($|\beta_1|<1$)

For an ARIMA model to be accurate, it must fulfil the following criteria:

- Has high number of significant coefficients
- Highest Adjusted R^2

- Lowest Akaike’s Information Criterion
- Lowest Schwartz Criterion
- Lowest Hannan-Quinn Criterion

III.3. DATA SOURCE AND REQUIREMENTS

Data on the mentioned perspective have been collected from different sources of data. The table below indicate the meaning and source of data to be used in our research.

Table 1: VARIABLES AND DATA SOURCES

Variable	**Symbol**	**Variable definition**	**Source**
Electricity theft	*ETH*	6.5% of the transmission and distribution (T&D) losses.	Rwanda Energy Group and International Energy Agency (IEA)
Electricity Price	*EP*	The average electricity price	Reports from the Rwanda Utilities Regulatory Authority.
Per capita income	*PCY*	GDP per capita for Rwanda	The World Bank
Electricity access	*EA*	The access rate to electricity (Country level)	The World Bank
The control of corruption	*CC*	The scores of a country in combatting the corruption.	The World Bank
The rule of law	*RL*	The level at which the laws are respected by citizens	The World Bank
The regulatory quality	*RQ*	The quality of the regulator decisions on the Utility.	The World Bank
Government Effectiveness	*GE*	The effectiveness and efficiency of the government.	The World Bank
Political Stability and Non violence	*PSNV*	The fact that there is stability in a given country and that there is no violence	The World Bank
Unemployment	*UE*	The rate of unemployment (% of total labour force)	The World Bank

Total Population	*TP*	The total population treated as the number of customers in need of electricity	The World Bank
Time required to get electricity	*TRE*	Time required to be connected to electricity, with regard to make easy doing business	The World Bank
Per capita consumption of electricity	*PCC*	The electricity consumption per person	The World Bank
Tax Revenues	*TR*	The tax revenues (% GDP) considered as declared based on input production.	The world Bank
Quality of electricity infrastructure	*Quality of Infrastructure*	The quality of electricity infrastructure as ranked by the World Bank	The World Bank
Tertiary Education	*Tertiary Education*	School enrollment, tertiary (% gross)	The World Bank

III.3.1. Electricity theft

The electricity theft data has been calculated as a 6.5% of distribution losses[11]. The total generation have been calculated by addition the total generation on grid with the total import, minus the total export from the International Energy Agency. The distribution losses have been calculated by making the difference between the total generation and the net consumption. It can also be retrieved from the Rwanda Data Portal and applying the 6.5% of theft, both methods yield the same results.

Several kinds of electricity theft are prevalent in all power systems. The extent of electricity theft depends upon the variety of factors, from the cultural to the power utility management strategies.

III.3.2. Electricity Price

The electricity price have been collected from the Rwanda Utilities Regulatory Authority's reports. The Rwanda Utilities Regulatory Authority have the mandate to regulate electricity

[11] https://www.reg.rw/fileadmin/user_upload/Press_release_power_theft_24_Jan_2019.pdf

sector from the year 2001. Since then, the Regulatory Authority is setting the electricity end-user tariffs as provided for by the Electricity Law, enacted in 2001. Additionally, the Regulatory Authority have the mandate to license, establish different regulatory tools governing activities in the electricity sector, advise the government on the energy sector related policies, disputes and complaints handling as well as monitoring licensee's performance to ensure the compliance on the terms and conditions of their licenses[12].

By setting the electricity end-user tariffs, the Regulatory Authority ensures that the Electricity Utility covers the cost of service. This means that there is no profit margin allowed to the Electricity Utility.

The main advantage of a uniform price or tariff arrangement is that of equity. It allows all users to access electricity at the same cost, preventing those in remote areas, low demand areas, from being penalised by having to pay more for electricity and so enabling them to use it to improve their livelihoods and compete on a more level playing field. We used the average prior subsidy tariff in our model.

III.3.3. Per capita income

The per capita income for any nation is calculated by dividing the country's national income by its population. The increase in per capita income, indicates the economic growth of the country.

Fantom & Serajuddin (2016) argue that per capita income reflects both the average economic wellbeing of a population and its capacity to engage in international financial transactions-a measure of its creditworthiness. The per capita income data was retrieved from the World Bank.

III.3.4. Electricity Access

The electricity access data have been retrieved from the World Bank and this covers the grid access percentage as the area of study concern the grid customers. In its second Rwanda Energy Sector Development Policy Financing, the World Bank (2018) argue that achieving universal access to electricity is at the heart of Rwanda's National Strategy for Transformation, which aims to lay the foundations for achieving upper-middle income country status by 2035 and high

[12] RURA website: www.rura.rw

income status by 2050. The National Strategy for Transformation identifies the importance of universal electricity access for achieving the envisioned social transformation and aims to expand electricity access to 100 percent households by 2024. The strategy envisages expansion of electricity sector based on least-cost principles and competitive procurement to provide quality, reliable, and affordable electricity to consumers and aims at prioritizing energy-intensive industries and productive uses of electricity as measures to reduce the cost of doing business in Rwanda[13].

III.3.5. Unemployment rate

The unemployment rate data have been collected from the World Bank. This have been taken into consideration as we judge that being unemployed lead to reduced income and hence can influence ones decision with regards to electricity theft.

III.3.6. Total population

The population represent the demand and electricity generation has to keep up with the demand resulting from economic development, population increase, urbanisation and the electricity dependency of modern technology. As the population increase, there is an increase in electricity consumption and hence increased revenues to the Utility. An increase in population with low electricity consumption patterns are related to poorer strata of the population. The data related to total population has been retrieved from the World Bank and this has been considered to represent the total eligible customers of the Electricity Utility.

Blimpo and Cosgrove-Davies (2019) argue that the rate of access to electricity in Sub-Saharan Africa is substantially lower than what it could be, considering levels of income and the electric grid footprint. The lack of access to electricity imposes significant constraints on modern economic activities, provision of public services, and quality of life, as well as on adoption of new technologies in various sectors such as education, agriculture, and finance. Not only much lower access rate than that in other global regions, but also the total number of people without electricity has increased in recent decades as population growth has outpaced growth in electrification.

[13] The World Bank: "Second Rwanda Energy Sector Development Policy Financing"

III.3.7. Time required to get connected

The data related to the time required to get electricity have been retrieved from the World Bank and this have been considered with intention to assess the time taken in connecting new customers as we consider that the delay may affect one's decision with regard to the electricity theft. This is considered as of high importance, considering the geospatial set up of our country, which is of thousand hills. The limited assets of the Utility can also pose barriers in reducing the time required to be connected to electricity, which can influence the theft decisions of the customers.

III.3.8. Electricity per capita consumption

The electricity per capita consumption data was retrieved from the World Bank and this represents the total consumption leveraged to individual. We judge that increase in electricity per capita consumption implies increase in revenues to the Electricity Utility but also can be an indication of increase in electricity theft.

III.3.9. Tax revenues

The tax revenues is judged as the clearance declaration with the Tax Authority. This have been considered to cater for inputs as they govern the output, and hence the declaration with the Tax Authority. The inputs include the consumed electricity, and as there is increase in taxes, it implies increase in electricity consumption and probable increase in electricity theft.

III.3.10. Literacy rate

The literacy rate also has been taken into account to cater for the fact that once the people are literate, their way of looking at things change. Being literate is an added advantage to know laws and regulations related to a given sector.

III.3.11. Percentage of recovery

The percentage of recovery is the rate or effectiveness of the electric utility in recovery. This would affect the electricity theft decision of the customers, depending on whether this parameter is low or high. Once the percentage of recovery is low, it is likely that the unpaid bills will increase and will decrease on the opposite side.

III.3.12. Quality of infrastructure

The quality of infrastructure is an indicator of how good or bad is the infrastructure of countries. The better the infrastructure, the lesser will be the losses of power during the transmission and distribution while the reverse will lead to more losses of power. This parameter is also used to determine the willingness to pay for bills as it affect the quality of service. Unfortunately, complete data of this indicator was not available at the time of research.

III.3.13. Tertiary education

The tertiary education have been considered to count for the education level of the managers and hence affect their decisions in opting for electricity pilferage. The highly educated people would indicate reduced theft decisions.

In addition to the abovementioned variables, include the magnitudes of fines and the probability of detection. These two variables are also considered to have potential influence on theft decisions. Unfortunately, to get the probability of detection would require having the total number of Utility's customers and the total registered theft cases. These data was not provided at the time of the research.

After considering all information related to the explained and explanatory variables, we need to declare our data as time series, to tell the system that we are using the time series data. This have the purpose of being able to use the time commands.

However, note that for the case of time series data, making regression without lags fails to account for the relationship over time and may lead to overestimates of the relationship between the independent and dependents variables. To count for lags, implies that we are taking into consideration the effect of the previous value on the current one. To take into consideration this fact, the usage of an Autoregressive Moving Average (ARIMA) model have been adopted.

The ARIMA model, also known as the Box-Jenkins methodology, is used to forecast the trend of variables using their own information. It helps policy makers, government regulators, investors to take informed decisions. To apply the ARIMA model, the underlying assumptions must be stationarity and invertibility. This have undergone nine (9) steps for identification of the best model, which must have high number of significant coefficient, highest adjusted R^2, lowest Akaike's Information Criterion, lowest Schwartz criterion and lowest Hannan-Quinn criterion. The results, as shown in the findings, show that the ARIMA (1, 1, 2) is the best model to be used to forecast the trend in electricity theft, as it fulfils the mentioned conditions of the best model. The results was find to be surprising.

CHAP FOUR: FINDINGS AND INTERPRETATIONS

In this study, we assessed the factors contributing to the electricity theft in Rwanda. Those factors might be socioeconomic factors such as per capita income, electricity per capita consumption, unemployment, total population and tertiary education. Other factors are related with the direct use, such as the electricity price and electricity access, as well as governance indicators such as the control of corruption, the rule of law, the regulatory quality, the political stability and nonviolence.

IV. 1. DESCRIPTIVE STATISTICS

Before engaging any regression analysis, it is better to know what the data convey or what the data is leading to. The descriptive analysis will help us to know whether the sample is normally distributed and will easily indicate if there are outliers in the data. It also provides the measures of tendency that is the mean, median and mode, as well as the measures of dispersion that is the range, variance and standard deviation. In the same way, it measures the normality, that is the kurtosis as a measure of degree of sharpness and skewness as a measure of asymmetry. The standard deviation shows how far are the observations from the sample average.

Table 2: Descriptive statistics of the socioeconomic variables

Variable	Electricity Theft	Electricity Price	Per Capita Income	Electricity Access	Unemployment	Total Population	Electricity per Capita Consumption	Tertiary Education
Observation	*72*	*72*	*72*	*72*	*72*	*72*	*72*	*72*
Mean	*.0016*	*122.11*	*5.1*	*16.12*	*1.01*	*10.09*	*.0306*	*5.34*
Std. Dev.	*.00125*	*51.1*	*1.88*	*9.75*	*0.11*	*1.25*	*.0055*	*1.99*
Min	*.00041*	*42*	*0.645*	*4.8*	*0.831*	*8.1*	*.02165*	*1.77*
Max	*.00391*	*208*	*10.56*	*35.87*	*1.178*	*12.376*	*.0384*	*7.667*
Variance	*$1.57e^{-06}$*	*2617.1*	*3.57*	*95.13*	*.0012*	*1.56*	*$3.04e^{-04}$*	*3.98*
Skewness	*0.705*	*-0.090*	*0.28*	*0.89*	*-.014*	*.193*	*-0.198*	*-0.69*
Kurtosis	*1.880*	*2.03*	*3.05*	*2.40*	*1.501*	*1.77*	*1.42*	*1.63*

Table 3: Descriptive statistics of the Governance Indicators

Variable	Control of Corruption	Rule of Law	Regulatory Quality	Government Effectiveness	Political Stability & Non Violence
Observations	*72*	*72*	*72*	*72*	*72*
Mean	*0.188*	*-0.362*	*-0.278*	*-0.2008*	*-0.4730*
Std. Dev.	*0.454*	*0.369*	*0.381*	*0.365*	*0.543*
Min	*-0.617*	*-0.916*	*-0.975*	*-1.070*	*-2.058*
Max	*0.76248*	*0.1286*	*0.24649*	*0.246*	*0.11859*
Variance	*0.2066*	*0.136*	*0.145*	*0.1335*	*0.2954*
Skewness	*-0.404*	*-0.0307*	*-0.140*	*-0.8831*	*-1.135*
Kurtosis	*1.597*	*1.543*	*1.492*	*2.569*	*3.462*

(Source: **STATA Software results)**

The **observation** indicate the number of fact or figure collected in a given variable. The minimum allowable observation for a research is **30**. We can easily find that we have **72** observations for the socioeconomic and governance indicators variables.

The **mean** indicates the average value of all the observations of a given series. It used to measure the central tendency of series. We distinguish arithmetic mean and geometric mean.

The **standard deviation** is an indication of how far observations are as compared to the sample average.

The **minimum** indicates the lowest value, while the **maximum** indicates the highest value of all the observations.

The **variance** is a measure of dispersion. It tells us how widely distributed our observations are from one another.

The **kurtosis** measures the peakness or the flatness of the distribution of the series. We conclude a normal distribution when we have a kurtosis equalled to 3. Above this number, we have a positive kurtosis, which is peaked curve, implying higher values. On the other hand, when the kurtosis is less than 3, we have a flattened curve, which implies lower values. In short, the kurtosis determines the heaviness of the distribution tails.

From the above descriptive statistics, we can observe that the electricity theft, the electricity access, the unemployment, the government effectiveness and the political stability and non-violence have an excess kurtosis of around zero. This means that they follow the normal distribution. The per capita income has an excessive positive kurtosis, which indicate heavy tails on either side, or many occurrences far from the head, indicating large outliers. On the other hand, the remaining variables such as the electricity price, the total population, the electricity per capita consumption, the tertiary education, the control of corruption, the rule of law and the regulatory quality have excess negative kurtosis, implying flattened curve and lower values. This indicate the small outliers in the series.

The **skewness** measures the degree of asymmetry of the series. When the skewness is equalled to zero, then the distribution is symmetric around its mean. That it follows a normal distribution. When the skewness is positive, then we have the long right or positive tail, that is higher values. On the other hand, we will have long left or negative tail. That is lower values.

From our descriptive statistics, we observe that the electricity theft, the electricity price, the electricity access, the total population, the per capita consumption of electricity and the tertiary education have a positive skewness. That imply that they have long right or positive tail. On the other hand, we can observe that the per capita income, the unemployment, the control of corruption, the rule of law, the regulatory quality, the government effectiveness and the political stability and non-violence have a negative skewness, that is they have a long left or negative tail.

IV. 2. CORRELATION TEST

In order to know the strength of the relationship between the variables, the test for correlation among variables have been done. The correlation matrix has been produced in order to denote association between two distinct variables. The association is assumed to be linear, that is the increase or decrease in one variable of fixed amount of one unit, increase or decrease in the other. The degree of association is estimated by the correlation coefficient, where a complete correlation is expressed by **±1.** Once one variable increases as the other increase as well, we will experience a positive coefficient and in the case one variable increase as the other decreases, we will experience a negative coefficient. Broadly, the results show that the rule of law is highly correlated with the control of corruption where the correlation coefficient between the two variables is 0.96. This means that the rule of law improves in the same direction as the control of corruption. In the same way, the regulatory quality is highly correlated with the rule of law where the correlation coefficient between the two variables is 0.97, implying the improvement in the same direction for both variables. This reflect that the regulatory quality should be correlated with the control of corruption, which exactly make a correlation coefficient equivalent to 0.97, and this imply improvement of both variables in the same direction. Remark that the per capita income has relatively low or negative correlation coefficients with other variables. This implies that the increase or decrease in per capita income goes in opposite direction as compared to other variables, except the total population and the tertiary education. This implies that as the population increase with increase in education, the income increase, as there are enough and skilled labour.

Table 4: Correlation Matrix of variables (N=12)

Variables	**Electricity Price (EP)**	**Per Capita Income (PCY)**	**Electricity Access (EA)**	**Control of Corruption (CC)**	**Rule of Law (RL)**	**Regulatory Quality (RQ)**	**Government Effectiveness (GE)**	**Political Stability & Non Violence (PSNV)**	**Un-employment (UE)**	**Total Population (TP)**	**Electricity Per Capita Consumption (PCC)**	**Tertiary Education (TE)**
EP	1											
PCY	-0.33	1										
EA	0.89	-0.38	1									
CC	0.88	-0.44	0.75	1								
RL	0.94	-0.45	0.88	0.96	1							
RQ	0.87	-0.47	0.80	0.97	0.97	1						
GE	0.89	-0.43	0.74	0.91	0.90	0.85	1					
PSNV	0.90	-0.39	0.72	0.87	0.88	0.81	0.97	1				
UE	0.64	-0.51	0.53	0.85	0.78	0.87	0.67	0.67	1			
TP	0.96	0.40	0.93	0.91	0.97	0.93	0.88	0.87	0.73	1		
PCC	0.83	-0.45	0.82	0.93	0.94	0.96	0.82	0.78	0.84	0.93	1	
TE	0.88	0.47	0.72	0.97	0.94	0.95	0.91	0.90	0.89	0.90	0.90	1

(Source: **STATA Software results)**

Before transforming our data into quarterly form, we used to face the collinearity issue, when the socioeconomic and governance indicators were included in the same regression. The collinearity issue has an implication in econometric analysis, such as the potentiality in affecting the regression coefficients; it affects the regression beta weights, the standards errors and the corresponding statistical significance levels.

Their identification is that the R-squared will be high; beta coefficients will not be statistically significant and contrary to that expected a priori, large standards errors and small t-statistics.

They are corrected by, if possible, collecting more data, change the scope of analysis, do not include collinear variables in the same regression or drop the highly collinear variables (Gujarati, 2004).

After transforming our annual data into quarterly data, in order to increase the number of observations, we opted to not include collinear variables in the same regression and drop collinear variables. The dropped collinear variables are the per capita income under socioeconomic variables and the government effectiveness and the political stability and non-violence under the governance indicators variables.

IV. 3. REGRESSION OUTCOME

From the below regression outcome, the number of observation indicate the sample size. The study suggests **72** observations, while the literature suggest a minimum of **30** observations. The F-value indicate how jointly significant the independent variables are in predicting the dependent variable. The higher the F-statistics, the better the model. The probability value is **0.0000** and it indicates the significance of F-value and if the probability value is less than 5%, the better the model. The R-squared indicate the total variation in dependent variables that are explained by the independent variables. The higher the R-squared, the better the model. In our regression, we found that the R-squared is equal to **99%.**

The adjusted R-squared is an indication of whether an independent variable improves or not, the model. It increases to a given value, whenever the added independent variable improves the model and will decrease, otherwise.

The root MSE indicate the standard error of the entire regression. The sum of squares has two part. The sum of squares for models, which is obtained within the model and for residuals, which is due to randomness. The degree of freedom model is computed as *k-1*, where k is the number of restrictions we have in the model. It is made of intercept and the number of independent variables available in the model.

The standard error shows the deviation of the coefficient. It tells how much deviation occurs from predicting the slope or the coefficient. We can observe a very minimum deviation of the slope or coefficient in our model. The t-value measures the number of standard errors that the coefficient is from zero and it can be found by dividing the coefficient by the standard error. The p-value of the t-statistics is the smallest evidence available or required to reject the null hypothesis. In other words, it tells us how significance the coefficient is. The 95% confidence interval contains the coefficient if it is significant, or else otherwise. We observe that all the coefficients are included in the confidence intervals except the variables whose coefficients are not significant.

The coefficient implies the estimate of the independent variables and the constant. The sign of the coefficient indicates the direction of the relationship between the dependent and independent variable. The following table is an overall output of the socioeconomic and governance indicators' variables regression over the electricity theft.

Table 5: Regression outcome

Variable Name	**Coefficient value**	**t-statistics**	**p-values**	**Significance (p-value <5%)**
Electricity Access	$3e^{-4}$	3.47	0.001	Significant
Total Population	$-4.72e^{-5}$	-0.37	0.709	Non-Significant
Unemployment	$1.85e^{-3}$	2.51	0.015	Significant
Electricity per Capita Consumption	$5.06e^{-3}$	0.33	0.739	Non-Significant
Tertiary Education	$-1.87e^{-4}$	-2.81	0.007	Significant
Control of Corruption	$-2.27e^{-3}$	-7.34	0.000	Significant
Rule of Law	$6.35e^{-3}$	8.99	0.000	Significant
Regulatory Quality	$-5.92e^{-4}$	-1.18	0.242	Non-Significant
Constant	$3.21e^{-3}$	3.06	0.003	Significant

(Source: **STATA Software results)**

The significance of a dependent variable is explained by the p-value, which should be less than **5%.** Otherwise, the significance can be explained by chance alone.

From this result, the electricity access positively affects the electricity theft, looking at the positive sign of the coefficient. The study suggests that one-unit increase in electricity access, will increase the electricity theft by $\mathbf{3e^{-4}}$ unit. This means that as the electricity access increases, that is more people are being connected, there will be an increase in electricity theft as many people will have access to electricity. The rate of electricity theft will be increasing as the access rate increases.

The unemployment rate positively affects the electricity theft, in a sense that one unit of increase in unemployment, will increase the electricity theft by $\mathbf{1.85e^{-3}}$ unit. This reflects one of our suggested source of electricity theft activities, in the literature review, being carried out by those individuals dropped by the utility during restructuring of the Electricity Utility around the years 2015. Unemployed, thus, non-wealthier citizen is likely to be tempted to commit crimes, including to be easily influenced in taking electricity theft decisions.

The tertiary education has a negative impact on the electricity theft. The increase in one unit of tertiary education, will reduce the electricity theft by $\mathbf{1.87e^{-4}}$**.** This is interpreted by the fact that as there is increase in education level and increase in numbers of educated citizen, there are improvement in risk measurement and hence reduce the electricity theft decisions by customers.

The control of corruption negatively affects the electricity theft. The study suggests that the increase in one unit of the control of corruption index will reduce the electricity theft by $\mathbf{2.27e^{-3}}$**.** This reflect that as the corruption is reduced, that is increase of the country in index rating of the control of corruption, the theft of electricity will be reduced as well.

The rule of law has been found to positively affect the electricity theft. The study suggests that the increase in one unit of the rule of law will likely increase the electricity theft by $\mathbf{6.35e^{-3}}$. This should not be the case, because as the rule of law reigns, the crimes should reduce, and thus reduction in electricity theft. This variable might be influenced by uncontrolled factors, falling in the error term.

The regulatory quality has been found to be negatively affecting the electricity theft. The increase in one unit of the regulatory quality will reduce $\mathbf{5.92e^{-4}}$ unit of the electricity theft. This reflect the fact that as the sector regulator is efficient, the theft in electricity will reduce as well. Considering the significant variables from the main results of the regression, the model is suggested as follow:

$$ETH_t = 3.21e^{-3} + 3e^{-4}EA + 1.85e^{-3}UE - 1.87e^{-4}TE - 2.27e^{-3}CC + 6.35e^{-3}RL + 1.56e^{-06}$$

From this analysis, we found that the electricity theft is influenced by the analysed socioeconomic and governance indicators variables. The socioeconomic variables found to be associated with the electricity theft are the electricity access, where we found that as the access rate increases, the electricity theft would increase as well, as many people will be connected. However, the electricity access should go hand in hand with technologies that can mitigate the theft of electricity.

The unemployment has been found to be also influencing the electricity theft as being unemployed lead to poverty, thus non-wealthier citizen will be easily trapped in theft activities.

The rule of law is found to be not promising as it positively affects the electricity theft. The law must reign and be enforced. A policy formulation should emphasize on the above stated variables, which have been found to be positively contributing to the increase in electricity theft. Briefly, rethink about the electricity access, unemployment as well as the rule of law.

IV. 4. AN ARIMA MODEL

In order to make analysis of the trend in consumer behaviour, the forecast of electricity theft have been taken into consideration where we used the autoregressive integrated moving average model, known as ARIMA model.

The ARIMA model is a statistical analysis that uses a time series data to predict the future trends. In order for it to be accurate, it has to fulfil the following assumptions:

- Has high number of significant coefficients
- Has highest adjusted R^2
- Lowest AIC (Akaike’s Information Criterion)
- Lowest Schwartz criterion
- Lowest Hannan-Quinn criterion

The ARIMA model is a combination of key aspects of the model itself. This include:

- Autoregressive which uses the independent relationship between an observation and some number of lagged observations,
- Integrated which is the use of differencing of preliminary observations in order to transform our time series into stationarity.
- Moving average which cater for the dependency between an observation and a residual error.

The above-mentioned components have been expressed as parameters in our model, with a standard notation being ARIMA (p, d, q) which automatically reflect the order of the model being used (Gujarati, 2004). In order to know the values for the p, d and q, that is the order of the model, the autocorrelation and partial autocorrelation test have been done. The following tables indicate the test results:

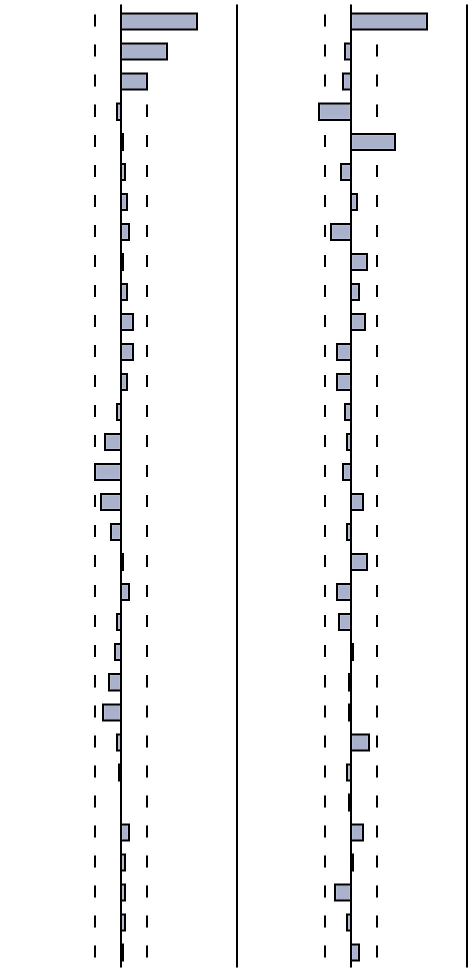
Date: 07/07/21 Time: 23:37
Sample: 2002Q1 2019Q4
Included observations: 72

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.968	0.968	70.302	0.000
		2	0.931	-0.093	136.27	0.000
		3	0.893	-0.036	197.80	0.000
		4	0.853	-0.036	254.83	0.000
		5	0.811	-0.068	307.08	0.000
		6	0.767	-0.026	354.62	0.000
		7	0.725	-0.016	397.65	0.000
		8	0.681	-0.040	436.23	0.000
		9	0.637	-0.028	470.50	0.000
		10	0.590	-0.071	500.38	0.000
		11	0.540	-0.074	525.81	0.000
		12	0.486	-0.078	546.80	0.000
		13	0.430	-0.074	563.51	0.000
		14	0.377	0.012	576.54	0.000
		15	0.326	0.013	586.49	0.000
		16	0.280	0.021	593.93	0.000
		17	0.238	0.034	599.41	0.000
		18	0.197	-0.027	603.24	0.000
		19	0.157	-0.025	605.73	0.000
		20	0.118	-0.029	607.16	0.000
		21	0.079	-0.044	607.80	0.000
		22	0.041	0.004	607.98	0.000
		23	0.006	-0.001	607.99	0.000
		24	-0.027	-0.002	608.07	0.000
		25	-0.056	0.003	608.42	0.000
		26	-0.081	0.012	609.18	0.000
		27	-0.101	0.016	610.40	0.000
		28	-0.117	0.025	612.06	0.000
		29	-0.128	0.037	614.11	0.000
		30	-0.141	-0.057	616.64	0.000
		31	-0.156	-0.051	619.79	0.000
		32	-0.172	-0.057	623.73	0.000

Figure 1: Autocorrelation and partial autocorrelation test results, at level.

The gradual decay or decline of the autocorrelation part shows us that our variable is not stationary at level. That is why we have to run the similar test, that is the autocorrelation and partial autocorrelation test, at first difference. The following is the results of the test:

Date: 07/07/21 Time: 23:38
Sample: 2002Q1 2019Q4
Included observations: 71



	AC	PAC	Q-Stat	Prob
1	0.673	0.673	33.496	0.000
2	0.422	-0.055	46.897	0.000
3	0.223	-0.072	50.702	0.000
4	-0.049	-0.289	50.889	0.000
5	0.020	0.387	50.919	0.000
6	0.036	-0.092	51.021	0.000
7	0.053	0.058	51.247	0.000
8	0.078	-0.185	51.742	0.000
9	0.020	0.153	51.774	0.000
10	0.063	0.070	52.117	0.000
11	0.105	0.117	53.066	0.000
12	0.109	-0.135	54.112	0.000
13	0.062	-0.123	54.452	0.000
14	-0.048	-0.062	54.664	0.000
15	-0.155	-0.026	56.882	0.000
16	-0.236	-0.079	62.140	0.000
17	-0.175	0.111	65.064	0.000
18	-0.092	-0.044	65.898	0.000
19	0.009	0.134	65.905	0.000
20	0.073	-0.126	66.449	0.000
21	-0.025	-0.101	66.516	0.000
22	-0.051	0.014	66.791	0.000
23	-0.113	-0.021	68.179	0.000
24	-0.159	-0.018	70.961	0.000
25	-0.025	0.157	71.031	0.000
26	-0.009	-0.040	71.041	0.000
27	-0.004	-0.023	71.043	0.000
28	0.068	0.110	71.603	0.000
29	0.037	0.020	71.771	0.000
30	0.035	-0.143	71.922	0.000
31	0.040	-0.042	72.133	0.000
32	0.020	0.073	72.184	0.000

Figure 2: The autocorrelation and partial autocorrelation test results at first difference

Here we consider the autocorrelation and partial autocorrelation to identify the possible models to be used. Recall that the model is of the format ARIMA (p, d, q) where the value for ***p*** is retrieved from the partial autocorrelation and ***q*** is derived from the autocorrelation analysis. This means that with the autocorrelation, we are going to determine the moving average (MA) components and with the partial autocorrelation, we are going to determine the autoregressive (AR) components.

We have to consider the lags that cross the threshold or goes beyond the line of the confidence bounds, in order to know the order of the model. Looking at the results, we found that lag 1, 2 and lag 3 on the autocorrelation part go beyond the threshold line of the confidence bound or confidence interval. This imply that we have **first, second** and **third** order moving average(MA) process and lags 1, 4 and lag 5 of the partial autocorrelation part goes beyond the threshold line of the confidence bounds, which implies that we have **first**, **fourth** and **fifth** order autoregressive(AR) process (Gujarati, 2004). This means that, the possible ARIMA models are ARIMA(1,1,1) ARIMA(1,1,2) ARIMA(1,1,3), ARIMA(4,1,1) ARIMA(4,1,2), ARIMA(4,1,3), ARIMA(5,1,1), ARIMA(5,1,2), ARIMA(5,1,3).

The next stage is to estimate our models to find the one that is accurate, as compared to others, and hence is qualified to be used for forecasting our series. The estimation results are highlighted in the below table:

Table 6: ARIMA model assumption values

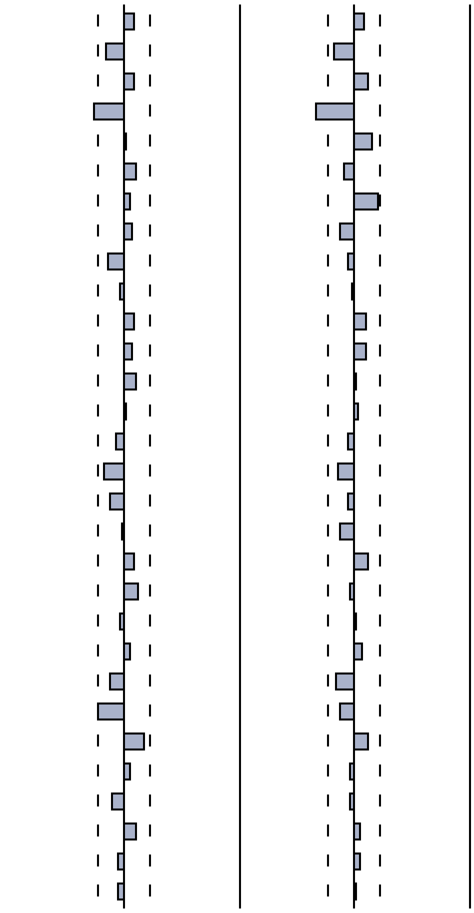
Parameter	**ARIMA (1,1,1)**	**ARIMA (1,1,2)**	**ARIMA (1,1,3)**	**ARIMA (4,1,1)**	**ARIMA (4,1,2)**	**ARIMA (4,1,3)**	**ARIMA (5,1,1)**	**ARIMA (5,1,2)**	**ARIMA (5,1,3)**
# of sign. Coeff.	**2**	**3**	**1**	**2**	**2**	**3**	**3**	**2**	**1**
Adjusted R^2	**0.460**	**0.451**	**0.465**	**0.471**	**0.361**	**0.088**	**0.463**	**0.357**	**0.02**
AIC	**-16.442**	**-16.457**	**-16.453**	**-16.455**	**-16.266**	**-15.910**	**-16.425**	**-16.245**	**-15.824**
Schwartz	**-16.346**	**-16.360**	**-16.356**	**-16.356**	**-16.168**	**-15.811**	**-16.326**	**-16.146**	**-15.724**
Hannan-Quinn	**-16.404**	**-16.418**	**-16.414**	**-16.416**	**-16.227**	**-15.871**	**-16.386**	**-16.206**	**-15.785**

(Source***:* EViews Software results**)

Remark that the ARIMA (1, 1, 2) meet the assumptions of being accurate. It has the highest number of significant coefficient, lowest Akaike's information criterion, lowest Schwartz criterion and lowest Hannan-Quinn criterion, by considering the implication of the negative sign, even though it has low adjusted R^2. Therefore, the ***ARIMA (1, 1, 2)*** model is chosen to make our forecast for the electricity theft. To confirm our identified model, we have to estimate it, and see if there are no other possible models we might have omitted. This is done through residual diagnostics. The results are as follow:

Date: 07/07/21 Time: 23:32
Sample: 2002Q3 2019Q4
Included observations: 70
Q-statistic probabilities adjusted for 2 ARMA term(s)

Autocorrelation | Partial Correlation



	AC	PAC	Q-Stat	Prob
1	0.087	0.087	0.5494	
2	-0.172	-0.180	2.7299	
3	0.092	0.131	3.3685	0.066
4	-0.268	-0.344	8.8620	0.012
5	0.009	0.167	8.8687	0.031
6	0.108	-0.086	9.7926	0.044
7	0.051	0.208	10.001	0.075
8	0.070	-0.119	10.402	0.109
9	-0.155	-0.057	12.394	0.088
10	-0.036	-0.013	12.502	0.130
11	0.091	0.105	13.209	0.153
12	0.073	0.101	13.668	0.189
13	0.108	0.019	14.706	0.196
14	0.018	0.027	14.736	0.256
15	-0.078	-0.055	15.300	0.289
16	-0.188	-0.142	18.593	0.181
17	-0.116	-0.063	19.873	0.177
18	-0.018	-0.119	19.907	0.224
19	0.083	0.117	20.593	0.245
20	0.118	-0.025	21.987	0.233
21	-0.029	0.023	22.071	0.281
22	0.050	0.072	22.331	0.323
23	-0.127	-0.172	24.056	0.290
24	-0.239	-0.130	30.317	0.111
25	0.185	0.117	34.152	0.063
26	0.047	-0.037	34.410	0.078
27	-0.114	-0.049	35.938	0.073
28	0.110	0.064	37.378	0.069
29	-0.053	0.060	37.718	0.082
30	-0.055	0.016	38.101	0.096

Figure 3: Residuals diagnostics test results

We observe that the forth lag cuts off the confidence interval for both the autocorrelation and the partial autocorrelation parts. The latter have the same scenario on lag number five and lag number seven. This lead us to make test of other possible models, considering the components we identified for both the autoregressive and moving average components(i.e ARIMA(4,1,4), ARIMA(5,1,4) and ARIMA(7,1,4). The table below indicate the results of the test.

Table 7: Assumptions values for the residual test models

Parameter	ARIMA(4,1,4)	ARIMA(5,1,4)	ARIMA(7,1,4)
# of sign. coeff.	**3**	**1**	**1**
Adjusted R^2	**0.172**	**-0.014**	**-0.017**
AIC	**-16.007**	**-15.789**	**-15.757**
Schwartz criterion	**-15.908**	**-15.689**	**-15.655**
Hannan-Quinn criterion	**-15.968**	**-15.749**	**-15.717**

(Source**: EViews Software results)**

We remark that the above estimated models does not meet the requirements of being accurate, as compared to the ARIMA (1, 1, 2) model chosen early. Therefore, we can confirm and adopt it for forecasting our series.

We opted to make a forecast for ten years to come, that is from ***2019Q4*** to ***2024Q4***, and this imply the change in range of our series, in order to include the values to be forecasted, which reflect an additional ***20 observations.*** The figure below indicate the graph for the forecasted values for **5 years.** By making the forecast, we found that the forecasted electricity theft data lies between the plus or minus two standards errors, which imply that it fits the 95% confidence interval, which indicate that the model fit is appropriate, as it can be viewed on the following plot.

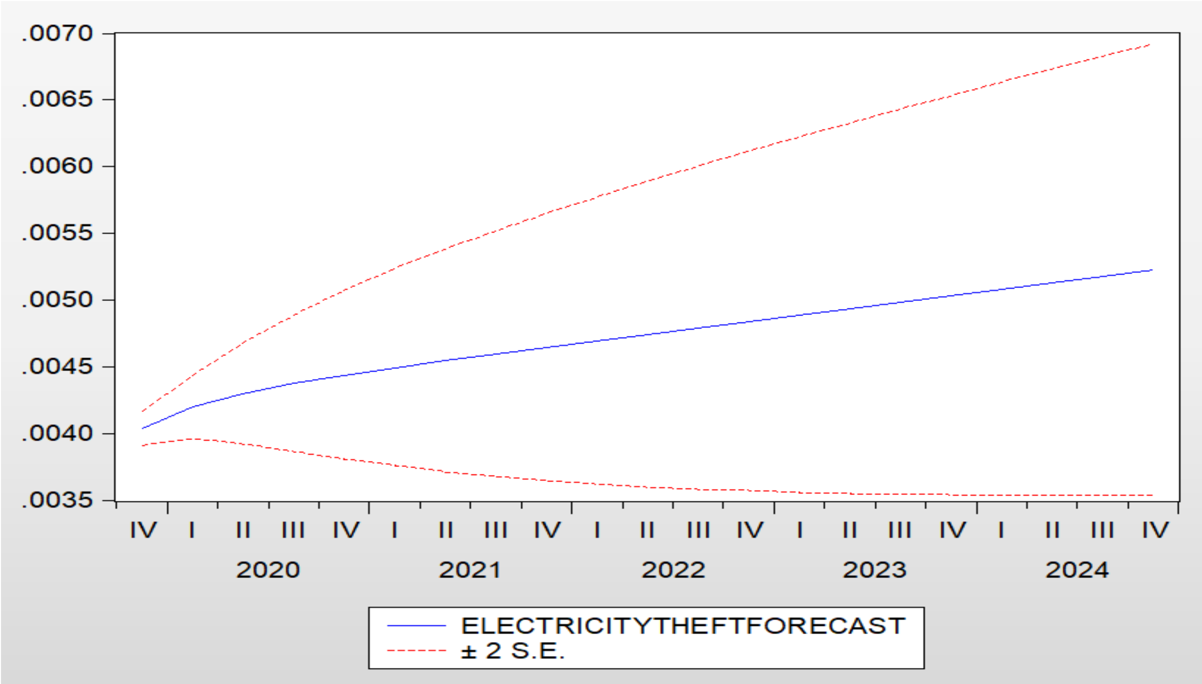


Figure 4: Graph for the 10 years forecasted values for the electricity theft

Following is a graph indicating both the actual values and forecasted values, on the same plot, for us to know how close is our forecasted values to our actual values.

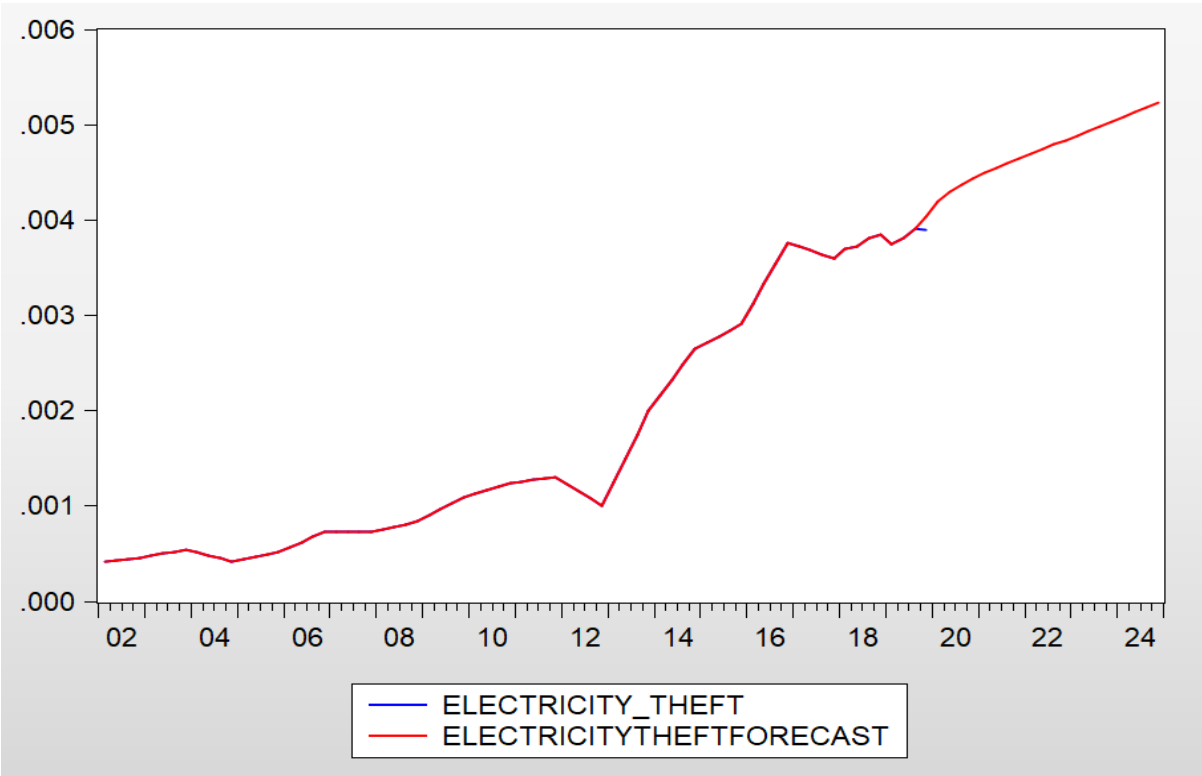


Figure 5: Trend in electricity theft

We observe no deviation on the forecast graph of the forecasted values as compared to the actual values and the prediction is almost the same, except for the period beyond our actual series limit, where we observe a constant increase of the future values of electricity theft. Overall, we conclude that the forecast is good.

From the below graph, we observe that most of the electricity theft data fall within the 95% confidence interval, which implies that the model fit is appropriate. This implies that the relationship of the electricity theft and that of the forecasted values, ***2019Q4-2024Q4,*** is linear.

It reflects that the variances of the error term are equal and the outliers are not so many as there are no significant number of residual values falling out of the 95% confidence interval, as it can be seen on the below plot.

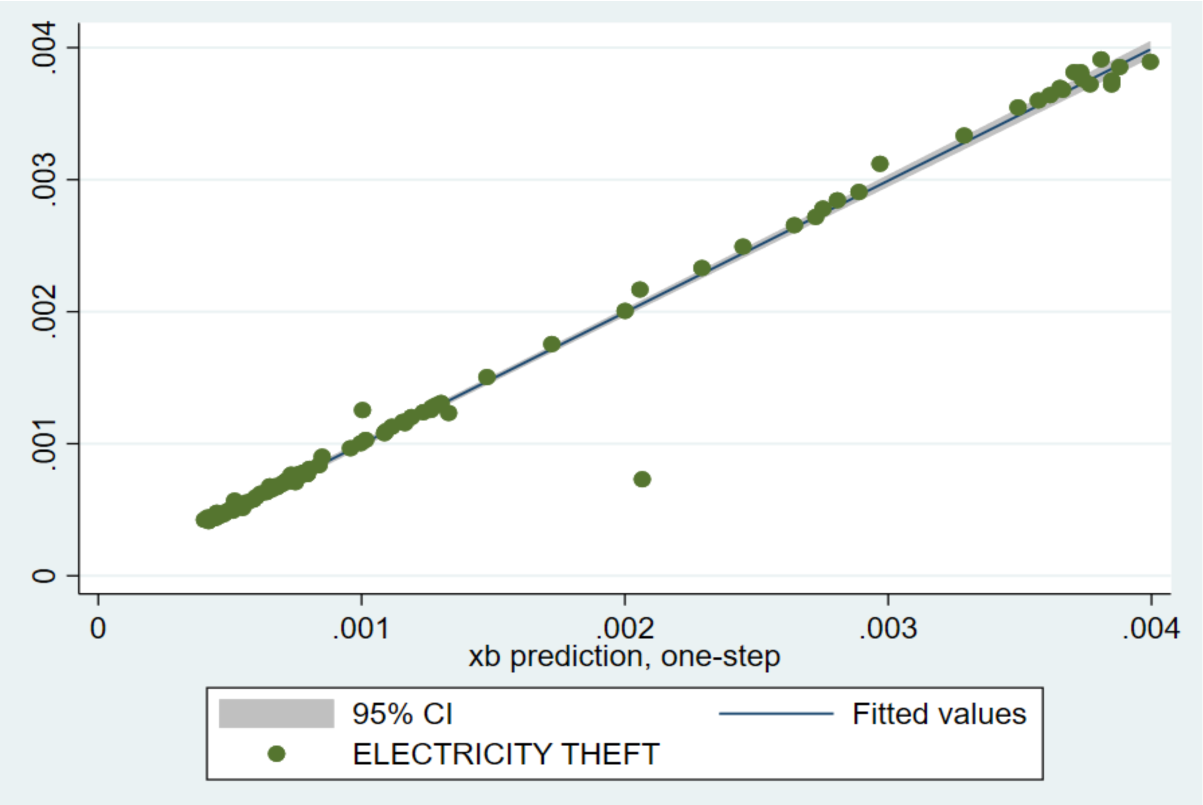


Figure 6: Plot of the forecasted vs actual values with the confidence interval

CHAPTER FIVE: CONCLUSION AND SUGGESTIONS

V.1. CONCLUSIONS

The study have an objective of assessing the factors, be it socioeconomic or governance factors, driving electricity theft in Rwanda, with specific objective of analysing the contribution of socioeconomic and governance indicators variables on electricity theft in Rwanda, to analyse the trend of electricity theft, and hence suggest the policy implications to reduce the electricity pilferage acts in the country. It has been achieved through an econometric study which shows that electricity access and unemployment variables are contributing on electricity theft. The control of corruption is playing its role on the fight against the electricity theft but the rule of law is not playing the expected role in combating the electricity theft. The study revealed that being educated is not enough to combat electricity theft. It should be accompanied by sensitization on the drawbacks of electricity theft. We used time series quarterly data of the dependent variable, which is electricity theft, and that of its explanatory variables, from the first quarter of the year 2002 to the fourth quarter of the year 2019. The Ordinary Least Square (OLS) method have been used to analyse the effects of socioeconomic and governance indicators variables on electricity theft via STATA software and, to analyse the trend in electricity theft, the forecast of the dependent variable have been done using autoregressive moving average (ARIMA) model, via EViews software.

V.2. SUGGESTIONS

We found strong positive contribution of unemployment on electricity theft where we found that an increase in one unit of the unemployment rate would increase the electricity theft by $\mathbf{1.85e^{-3}}$ unit. Considering the significance level of the unemployment, less than 5%, we rejected the null hypothesis, which stated that there is no significant relationship between the socioeconomic variables and electricity theft and concluded that, the unemployment, as part of the socioeconomic variables, have an influence on the electricity theft. It is suggested that the Utility gather the dropped technicians during restructuring in 2015, and make them their informers as long as the electricity theft is concerned. This can be done by developing a scheme of award and incentives to those informers, based on the numbers and magnitudes of revealed acts of thefts.

The study also found that the increase in electricity access rate, that is more people get connected, would increase the electricity theft as well. The study suggested that an increase in one unit of electricity access would increase the electricity theft by $\mathbf{3e^{-4}}$ unit. The significance level of the electricity access is found to be less than 5%, which led to the rejection of the null hypothesis and concluded that the electricity access have an influence on the electricity theft. This is obvious, considering that, as more and more persons get connected to the electricity supply, the probability in electricity theft will increase, considering the economic of crime theory, seen in the literature review. To tackle this, the Utility should invest in smart meters that report the real time consumption as well as any attempt of tempering with it for any purpose including the electricity theft. This might affect the electricity price, but as it is administrated, no relative impact will be noticed, and if any, it would be compensated by the reduced investment in new electricity generations projects, that would cover the overall losses. The intense and surprise inspections by the Utility would go long way in combating the electricity theft. We suggest that this should go hand in hand, for the long run, with the privatization process to improve the management efficiency, especially the distribution section of the power system (Onat, 2018).

The rule of law was found not to be promising, as it positively affects the electricity theft. We suggest the intense participation of crimes investigators and prosecutors to tackle the persistent acts of stealing electricity. Awareness and sensitization of these sectors would much more engage them to treat these acts as economic crimes and destructive to the public fortune. The electricity law should be revisited, especially the magnitude of fines, again considering the economic of crimes theory, seen in the literature review. This should consider separating the fines related to the electricity theft and that related to other theft of power infrastructure, as the magnitudes of their effect is very different, with regard to the economic of crime as well.

Being educated was found to be contributing to the reduction of electricity theft, considering the sign of the coefficient. The study suggested that the increase in one unit of tertiary education would reduce the electricity theft by $\mathbf{1.87e^{-4}}$ unit. The significance level of the tertiary education lead us to the rejection of the null hypothesis, and concluded that the tertiary education have a negative influence on the electricity theft, that is will lead to its reduction. However, being literate is not enough. The citizen should be educated on the disadvantages of thieving electricity and its associated risks on health and economy. This can be done in different units of the society, like in churches, schools, public and commercials institutions to attract attention of the public opinion on the negation situations caused by illegal electricity usage in terms of social responsibility and ethical values. In addition to this, it is especially necessary to increase the support of the local government and private sector in fighting against the electricity theft. This can be done by alerting districts mayors, sector executive secretary and private sector in general about the losses being incurred by the Utility via electricity theft, and hence set up a combined effort to reduce them.

Measures to combat the corruption should be emphasised to keep fighting the electricity theft, as the study revealed that the control of corruption contributed to the reduction of electricity theft. The study suggested that an increase in one index of the control of corruption would reduce the electricity theft by **$2.27e^{-3}$** Unit**.** The significance level of the control of corruption, less than 5% lead to the rejection of the null hypothesis, stating that there is no relationship between the governance indicators, including the control of corruption, and the electricity theft, and concluded that there is a strong relationship between the governance indicators and electricity theft. The existing measures to combat the corruption, especially in electricity sector, can be supported by investments in infrastructure aiming at subjects like billing of consumption by remotely reading the meters and determination of unpaid bills.

LIMITATIONS AND SUGGESTIONS FOR FURTHER STUDIES

During this study, I have not been provided with the data related to all the variables we were in need, such as the magnitudes of fines, the probability of detection, the rate of recovery of the utility. In addition to this, they were not enough data related to the quality of infrastructure, the time required to get connected to electricity and the tax revenues. Further study should emphasise and consider them for more investigation on how to tackle the electricity theft in Rwanda.

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ANNEXURE I. BACKGROUND

I. STRUCTURE OF A POWER SYSTEM

The Power System is an interconnection of different components with the purpose of generating, transmitting, distributing and sale of electricity. The latter is generated at various power stations, which are generally located far away from load centres or end-users. The figure below illustrate the structure of a power system:

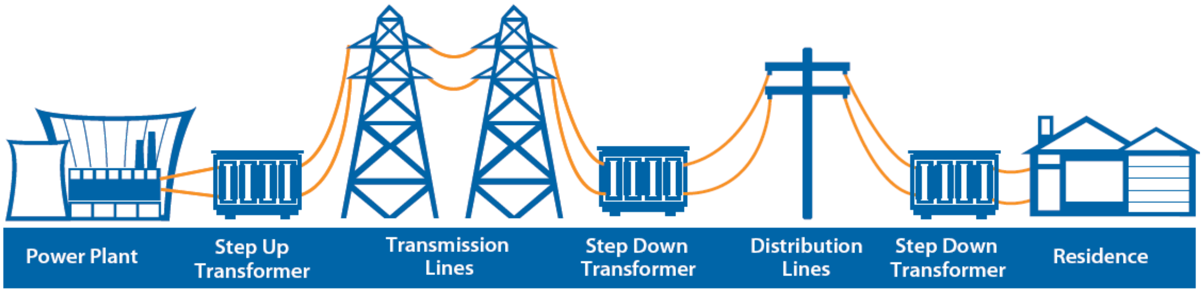

Figure 7: Power system structure

The power plant, also referred as generating stations, is a component of the power system destined to generating electricity. The generation of electricity can be done using different resources, including but not limited to water, sun, wind, fossil fuels, nuclear, etc. The generated electricity is feed in the grid, after being transformed in facilitation of the transformers.

A transformer is a component of a power system whose role is to step up the voltage level, for the purpose of transmitting to long distances or step down the voltage levels, for a purpose of distribution and/or utilisation.

A transmission line is a mechanical structure with tapped conductors, which is used to transmit electrical power over long distances. The said transmission is done on high voltage[14].

Distribution line can also be of mechanical, concrete or of poles structure with tapped conductors, to distribute electrical energy to end-users, represented by residence in our scheme.

The commercial losses are being incurred at distribution part of the power system, where the consumers are connected, including the electricity theft, which represent a big percentage of commercial losses.

[14] Principles of power systems

II. RWANDA'S ELECTRICITY SECTOR PROFILE

The electricity sector in Rwanda is a fast growing one whose first generating station was commissioned in 1959. It is a state owned utility, which is unbundled on the generation side. Currently, the total installed capacity is estimated to be around **228.102MW[15],** which include the shares of Independent Power Producers **(IPPs)** and regional shared generation.

In addition, the country can also import and export electricity from and to neighbouring countries. The transmission and distribution is owned by a state utility, which perform the transmission, distribution and trade of generated electricity.

On the other hand, the generated electricity from the privately owned generating stations is supplied to the grid based on Power Purchase Agreements (PPAs) between the Electricity Utility Corporation Limited (EUCL) and IPPs and then distributed to different customers. The Power Purchase Agreements can be either a **take and pay** or a **take or pay** contracts. The trade of electricity is done domestically and internationally with bordering countries.

The transmission and distribution is done on different values of voltage level, from 230/400V, 15kV, 30kV, 110kV and 220kV. Most of the customers are connected on low voltage (230/400V) and few of them are on medium voltage (30kV and 15kV), especially large customers[16].

As stated before, the Government of Rwanda have a target to achieve a universal electricity access by 2024. In order to achieve this target, in a timely and efficient manner, the Government of Rwanda has, via the Rwanda Energy Group, put in place the Least Cost Power Development Plan (LCPDP), with the purpose to highlighting the low cost generation plan[17]. These investments are expected to be done by the Government or by the IPPs. Note that the generation investment done by the government is not recovered in the tariff. Only the operations and maintenance are taken into consideration, and hence recovered via the tariff. As compared to other countries in the region, Rwanda is among the countries with higher tariff of electricity. The following table indicate the electricity price comparison.

[15] RURA Annual Report, 2019-2020
[16] Transmission and Distribution Reticulation Standards, July 2018 and March 2020.
[17] Least Cost Power Development Plan, 2019-2020

Table 8: Electricity prices in East African countries

Regional Countries	***Electricity Prices (in Frw/KWh)***	
	For households	For businesses
Rwanda	256.550	95.580
Uganda	192.674	162.804
Tanzania	99.530	102.469
Burundi	-	-
Kenya	209.782	168.683
DRC	61.504	98.248

(Source: www.globalpetrolprices.com)

The high electricity tariff in Rwanda is mainly due to factors, including but not limited to:

- The terms and conditions of contract negotiated in previous years, when we had scarce electricity. This means that they were not enough supply to meet the demand in place.
- Fluctuations in exchange rate, i.e the local currency losing its value as compared to the US dollar.
- Fluctuations in fuel price, this imply the increase in operations and maintenance cost.
- Minimum economies of scale, as most of the power plants we have are very small.

These factors contribute on increase of electricity tariff and this is expected to keep increasing as time goes on.

III. CATALYSTS OF ELECTRICITY THEFT

III.1. Technicians dropped by the Utility

In 2015, the restructuring took place in Electricity Utility, which left several individuals unemployed. Among them, include technicians who are still being seen as the Utility's staff by the electricity customers. They still have equipment they were using to perform their job (overall, badges, cards, etc.) and nowadays, they are telling customers that they may arrange them to have less amount on the bill. They are commonly known as **"Abahigi"**

III.2. Faulty meters

Currently, the meters are getting faulty easily. This is being due to the type of meters which are being used for the new connections. These meters are very sensitive to the power quality and in case of faulty, be it natural hazards or operations requirements, they are being damaged.

The replacement of the meter took same few days, as the report have to be done in order to submit the meter to the laboratory for meter testing. The laboratory also took additional time to make test and revert. In between, the customer is left without power. From here, the customer is tempted to contact technicians for arrangement to get the power.

III.3. Quality of Service

The quality of service is a broad topic and can be affected by all aspect of operations of the Utility. From the number of personnel to the types and number of assets, the Utility is facing a challenge on a daily basis to provide assistance to the customers. In addition to this, aging infrastructure contribute to the poor quality of service. Aging infrastructure pose a network challenge, including but not limited to voltage drop, increase in reactive power, frequent load shedding, etc. The delay in customer support when there is a breakdown can influence the willingness of the customers to pay for the service[18].

The main quality of service indicators is the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). As per the Energy Sector Strategic Plan, projected to the financial year 2023/2024, SAIDI is expected to be reduced to **14.1 hours** of interruptions per year from **36 hours** of interruptions per year as basis from the year 2017/2018. On the other hand, SAIFI is expected to be reduced to **91.7 times** of interruptions per year in the financial year 2023/2024 from **229 times** as a basis for the financial year 2017/2018. This will be reached through initiatives of network upgrade to be undertaken by the National Electricity Utility[19].

III.4. Point of connection configuration

Considering the setup of the supply or the point of connection configuration, it is easier to temper with meter and/or bypass it because it is easily accessible. In order to minimise the theft cases, the Electric Utility is adopting the method of having the meters installed on poles and the customer will have access on the keypad for the sole purpose of token inputs.

IV. Modes of electricity theft

IV.1. Fraud

Fraud is when the consumer deliberately tries to deceive the utility. A common practice is to temper with the meter so that a lower reading of power use is shown than in the normal reading

[18] An Empirical study of Electricity theft from electricity distribution companies in Pakistan
[19] Energy Sector Strategic Plan 2018/19-2023/2024

case. This can be a risky procedure for an amateur and many cases for electrocution have been reported[20].

IV.2. Stealing electricity

Electricity theft can be arranged by rigging a line from the power source to where it is needed by bypassing a meter. Smith [8] stated that the illegal lines are easy to detect, as they are often above ground and highly visible. However, corrupt staff from the electricity organization may take bribes to allow such practices to continue. On a larger scale, businesses may bribe power organization staff to rig direct lines to their buildings or offices and the power does not go through a meter. The bribes can be much less than the cost of the electricity consumed. Money also can be given to inspectors to keep them from finding and/or reporting the theft cases.

IV.3. Billing irregularities

Billing irregularities can occur from several sources. Some electric utilities may not be very effective in measuring the amount of electricity used and unintentionally can give a higher or lower figure than the accurate one. The unintentional irregularities may even out over time. However, it is also very easy in some systems to arrange for much lower bills to be given than for the electricity actually consumed. Employees may be bribed to record the meter at a lower number than is shown.

The consumer pays the lower bill and the meter-reader earns unofficial salary. In another type of billing irregularity, office staff can move the decimal point to the left on the bill so that a person or company pays 20,300.59 Frw instead of 203,005.9 Frw

Smith [8] kept on stating that consumers may know that some electric utility staff are ‘‘on the take’’ for providing these services. Employees may keep payments. The staff can easily earn from this type of corruption, as it is not easy to detect. Corrupt practices may become institutionalized to the extent that employees regard the illicit payments as part of the job.

IV.4. Unpaid bills

Some persons and organizations do not pay what they owe for electricity. Residential or business consumers may have left the city or an enterprise has gone bankrupt. Some systems have chronic non-payers, the very rich and politically powerful who know that their electricity

[20] https://www.reg.rw/media-center/details/news/press-release-31-october-2017/

will not be cut regardless of whether they pay or not. Some analysts may not regard non-payment by very rich and politically powerful individuals as ‘‘theft.’’ However, when it becomes institutionalized, people and organizations expect that they can get away with it, unpaid bills should fall into the ‘‘theft’’ category.

ANNEXURE II. Quarterly Data

Period	ETH	EA	EP	PCY	TP	UE	PCC	TE	CC	GE	PSNV	RL	RQ
2002Q1	0.000424	5.924994	42	6.063114	8.1	0.8315	0.025193	1.77531	-0.38267	-1.07009	-2.05892	-0.89451	-0.71512
2002Q2	0.000435	6.205741	42	7.562317	8.187	0.851	0.025489	1.84583	-0.39463	-1.01643	-1.9237	-0.88152	-0.71464
2002Q3	0.000445	6.486488	42	9.061521	8.274	0.8705	0.025784	1.91635	-0.40659	-0.96278	-1.78848	-0.86853	-0.71416
2002Q4	0.000455	6.767235	42	10.56073	8.361	0.89	0.02608	1.98687	-0.418551	-0.90913	-1.65326	-0.855539	-0.713675
2003Q1	0.000478	7.043294	42	8.082672	8.41525	0.89725	0.026241	2.092118	-0.43051	-0.855477	-1.518036	-0.842547	-0.713194
2003Q2	0.000501	7.319352	42	5.604618	8.4695	0.9045	0.026401	2.197365	-0.442468	-0.801823	-1.382811	-0.829555	-0.712713
2003Q3	0.000523	7.595411	42	3.126564	8.52375	0.91175	0.026562	2.302613	-0.454426	-0.74817	-1.247587	-0.816562	-0.712232
2003Q4	0.000546	7.871469	42	0.64851	8.578	0.919	0.026723	2.40786	-0.466384	-0.694517	-1.112363	-0.80357	-0.711751
2004Q1	0.000514	8.141721	42	1.966557	8.61125	0.92025	0.025763	2.518673	-0.459945	-0.660118	-1.131045	-0.807486	-0.699948
2004Q2	0.000482	8.411974	42	3.284604	8.6445	0.9215	0.024802	2.629485	-0.453507	-0.625719	-1.149727	-0.811401	-0.688146
2004Q3	0.00045	8.682226	42	4.602651	8.67775	0.92275	0.023842	2.740297	-0.447068	-0.59132	-1.168409	-0.815316	-0.676343
2004Q4	0.000419	8.952478	42	5.920698	8.711	0.924	0.022882	2.85111	-0.440629	-0.556921	-1.187092	-0.819231	-0.66454
2005Q1	0.000442	7.914359	51.815	6.291044	8.7415	0.923	0.022596	2.894273	-0.48496	-0.644419	-1.140882	-0.843575	-0.742207
2005Q2	0.000466	6.876239	61.63	6.66139	8.772	0.922	0.02231	2.937435	-0.529292	-0.731916	-1.094672	-0.867919	-0.819873
2005Q3	0.00049	5.83812	71.445	7.031737	8.8025	0.921	0.022023	2.980598	-0.573624	-0.819414	-1.048462	-0.892263	-0.897539
2005Q4	0.000514	4.8	81.26	7.402083	8.833	0.92	0.021737	3.02376	-0.617956	-0.906912	-1.002252	-0.916607	-0.975205
2006Q1	0.000569	6.362089	88.945	7.24499	8.87475	0.911	0.02213	3.242918	-0.515487	-0.74371	-0.922218	-0.85631	-0.895589
2006Q2	0.000623	7.924177	96.63	7.087896	8.9165	0.902	0.022524	3.462075	-0.413019	-0.580507	-0.842183	-0.796013	-0.815972
2006Q3	0.000678	9.486266	104.315	6.930802	8.95825	0.893	0.022917	3.681232	-0.31055	-0.417304	-0.762149	-0.735717	-0.736356
2006Q4	0.000733	11.04835	112	6.773709	9	0.884	0.02331	3.90039	-0.208082	-0.254101	-0.682115	-0.67542	-0.65674
2007Q1	0.000731	11.30719	112	6.320032	9.05	0.877	0.023659	3.941365	-0.15638	-0.23934	-0.601163	-0.650846	-0.651855
2007Q2	0.000728	11.56603	112	5.866355	9.1	0.87	0.024009	3.98234	-0.104678	-0.224579	-0.520211	-0.626273	-0.64697
2007Q3	0.000726	11.82487	112	5.412678	9.15	0.863	0.024358	4.023315	-0.052976	-0.209817	-0.43926	-0.601699	-0.642086
2007Q4	0.000724	12.08371	112	4.959001	9.2	0.856	0.024707	4.06429	-0.001274	-0.195056	-0.358308	-0.577125	-0.637201
2008Q1	0.000753	10.56278	112	5.777858	9.275	0.85725	0.025155	4.142073	0.023112	-0.179054	-0.349714	-0.552165	-0.604553

2008Q2	0.000781	9.041856	112	6.596714	9.35	0.8585	0.025603	4.219855	0.047498	-0.163051	-0.341121	-0.527206	-0.571906
2008Q3	0.00081	7.520928	112	7.415571	9.425	0.85975	0.02605	4.297638	0.071883	-0.147049	-0.332527	-0.502246	-0.539259
2008Q4	0.000838	6	112	8.234428	9.5	0.861	0.026498	4.37542	0.096269	-0.131047	-0.323934	-0.477287	-0.506611
2009Q1	0.000902	8.046798	112	7.036722	9.55	0.89825	0.027042	4.599065	0.094684	-0.135864	-0.369501	-0.483192	-0.459915
2009Q2	0.000966	10.0936	112	5.839016	9.6	0.9355	0.027587	4.82271	0.093098	-0.140682	-0.415068	-0.489098	-0.413218
2009Q3	0.001029	12.14039	112	4.641311	9.65	0.97275	0.028131	5.046355	0.091513	-0.1455	-0.460634	-0.495003	-0.366521
2009Q4	0.001093	14.18719	112	3.443605	9.7	1.01	0.028676	5.27	0.089928	-0.150317	-0.506201	-0.500909	-0.319824
2010Q1	0.001129	13.06539	112	3.7306	9.775	1.0255	0.029682	5.434975	0.155856	-0.126311	-0.447674	-0.45837	-0.289164
2010Q2	0.001166	11.9436	112	4.017595	9.85	1.041	0.030688	5.59995	0.221785	-0.102305	-0.389148	-0.415832	-0.258505
2010Q3	0.001202	10.8218	112	4.304591	9.925	1.0565	0.031694	5.764925	0.287714	-0.078299	-0.330621	-0.373294	-0.227845
2010Q4	0.001239	9.7	112	4.591586	10	1.072	0.0327	5.9299	0.353643	-0.054293	-0.272094	-0.330756	-0.197185
2011Q1	0.001256	9.975	112	4.767298	10.05	1.0795	0.033128	6.192128	0.354632	-0.023118	-0.24835	-0.326561	-0.183871
2011Q2	0.001274	10.25	112	4.943011	10.1	1.087	0.033555	6.454355	0.35562	0.008056	-0.224606	-0.322365	-0.170556
2011Q3	0.001291	10.525	112	5.118723	10.15	1.0945	0.033982	6.716582	0.356609	0.039231	-0.200862	-0.318169	-0.157241
2011Q4	0.001309	10.8	112	5.294435	10.2	1.102	0.03441	6.97881	0.357597	0.070406	-0.177118	-0.313974	-0.143927
2012Q1	0.001233	12.475	115.5	5.47124	10.275	1.111	0.034468	6.930595	0.407686	0.040741	-0.190492	-0.303395	-0.132899
2012Q2	0.001156	14.15	119	5.648045	10.35	1.12	0.034527	6.88238	0.457775	0.011076	-0.203866	-0.292817	-0.121872
2012Q3	0.00108	15.825	122.5	5.82485	10.425	1.129	0.034586	6.834165	0.507864	-0.018589	-0.217241	-0.282238	-0.110844
2012Q4	0.001004	17.5	126	6.001654	10.5	1.138	0.034645	6.78595	0.557952	-0.048254	-0.230615	-0.271659	-0.099817
2013Q1	0.001255	16.925	131.75	5.047103	10.55975	1.148	0.034704	6.926645	0.575456	-0.03126	-0.200699	-0.242426	-0.073195
2013Q2	0.001505	16.35	137.5	4.092552	10.6195	1.158	0.034763	7.06734	0.592959	-0.014265	-0.170783	-0.213192	-0.046573
2013Q3	0.001755	15.775	143.25	3.138001	10.67925	1.168	0.034822	7.208035	0.610462	0.002729	-0.140868	-0.183958	-0.019951
2013Q4	0.002006	15.2	149	2.183449	10.739	1.178	0.034881	7.34873	0.627965	0.019724	-0.110952	-0.154724	0.00667
2014Q1	0.002168	16.35	149	2.5271	10.805	1.17575	0.03494	7.358068	0.661594	0.00846	-0.161581	-0.101825	0.066626
2014Q2	0.002331	17.5	149	2.870751	10.871	1.1735	0.034999	7.367405	0.695224	-0.002804	-0.212211	-0.048927	0.126581
2014Q3	0.002493	18.65	149	3.214401	10.937	1.17125	0.035058	7.376742	0.728854	-0.014068	-0.26284	0.003972	0.186537
2014Q4	0.002655	19.8	149	3.558052	11.003	1.169	0.035117	7.38608	0.762483	-0.025332	-0.31347	0.056871	0.246492
2015Q1	0.002718	20.55	157.25	4.202295	11.068	1.1625	0.035176	7.442397	0.730791	-0.03046	-0.231792	0.055257	0.245615

2015Q2	0.002781	21.3	165.5	4.846537	11.133	1.156	0.035235	7.498715	0.699098	-0.035588	-0.150114	0.053643	0.244738
2015Q3	0.002844	22.05	173.75	5.49078	11.198	1.1495	0.035294	7.555032	0.667405	-0.040716	-0.068437	0.052029	0.243861
2015Q4	0.002907	22.8	182	6.135022	11.263	1.143	0.035353	7.61135	0.635712	-0.045843	0.013241	0.050415	0.242984
2016Q1	0.00312	24.4425	182	5.416097	11.3305	1.1355	0.035412	7.625342	0.637815	-0.009855	-0.003794	0.063274	0.209017
2016Q2	0.003334	26.085	182	4.697171	11.398	1.128	0.035471	7.639335	0.639917	0.026133	-0.020829	0.076132	0.175051
2016Q3	0.003547	27.7275	182	3.978246	11.4655	1.1205	0.035919	7.653327	0.642019	0.062122	-0.037864	0.088991	0.141085
2016Q4	0.003761	29.37	182	3.25932	11.533	1.113	0.036367	7.66732	0.644122	0.09811	-0.054899	0.101849	0.107119
2017Q1	0.003721	30.5525	184.5	2.763939	11.6025	1.1005	0.036425	7.593972	0.64135	0.140296	-0.019164	0.108543	0.116909
2017Q2	0.003681	31.735	187	2.268558	11.672	1.088	0.036483	7.520625	0.638579	0.182481	0.016572	0.115236	0.126698
2017Q3	0.00364	32.9175	189.5	1.773177	11.7415	1.0755	0.036931	7.447277	0.635808	0.224667	0.052307	0.121929	0.136488
2017Q4	0.0036	34.1	192	1.277796	11.811	1.063	0.036991	7.37393	0.633036	0.266852	0.088043	0.128622	0.146278
2018Q1	0.003695	34.25414	196	2.392516	11.881	1.0515	0.0370259	7.211877	0.619365	0.251841	0.09568	0.125917	0.131321
2018Q2	0.003722	34.40829	200	3.507236	11.951	1.04	0.037159	7.049825	0.605694	0.236831	0.103317	0.123212	0.116363
2018Q3	0.003814	34.56243	204	4.621957	12.021	1.0285	0.037385	6.887772	0.592022	0.22182	0.110954	0.120507	0.101406
2018Q4	0.003853	34.71657	208	5.736677	12.091	1.017	0.037659	6.72572	0.578351	0.206809	0.118591	0.117802	0.086449
2019Q1	0.003752	34.87071	182	5.950222	12.162	1.02025	0.037821	6.603137	0.57485	0.201362	0.117861	0.107398	0.084183
2019Q2	0.003814	35.02485	186	6.163768	12.234	1.0235	0.037922	6.480555	0.571349	0.195916	0.117132	0.096995	0.081917
2019Q3	0.003911	35.71899	200	6.377313	12.305	1.02675	0.038155	6.357973	0.567847	0.190469	0.116402	0.086592	0.079651
2019Q4	0.003893	35.87313	204	6.590858	12.376	1.03	0.038421	6.23539	0.564346	0.185023	0.115672	0.076188	0.077384

Period	ETH	EA	EP	PCY	TP	UE	PCC	TE	CC	GE	PSNV
2002Q1	0.000424	5.924994	42	6.063114	8.1	0.8315	0.025193	1.77531	-0.38267	-1.07009	-2.05892
2002Q2	0.000435	6.205741	42	7.562317	8.187	0.851	0.025489	1.84583	-0.39463	-1.01643	-1.9237
2002Q3	0.000445	6.486488	42	9.061521	8.274	0.8705	0.025784	1.91635	-0.40659	-0.96278	-1.78848
2002Q4	0.000455	6.767235	42	10.56073	8.361	0.89	0.02608	1.98687	-0.418551	-0.90913	-1.65326
2003Q1	0.000478	7.043294	42	8.082672	8.41525	0.89725	0.026241	2.092118	-0.43051	-0.855477	-1.518036
2003Q2	0.000501	7.319352	42	5.604618	8.4695	0.9045	0.026401	2.197365	-0.442468	-0.801823	-1.382811

2003Q3	0.000523	7.595411	42	3.126564	8.52375	0.91175	0.026562	2.302613	-0.454426	-0.74817	-1.247587
2003Q4	0.000546	7.871469	42	0.64851	8.578	0.919	0.026723	2.40786	-0.466384	-0.694517	-1.112363
2004Q1	0.000514	8.141721	42	1.966557	8.61125	0.92025	0.025763	2.518673	-0.459945	-0.660118	-1.131045
2004Q2	0.000482	8.411974	42	3.284604	8.6445	0.9215	0.024802	2.629485	-0.453507	-0.625719	-1.149727
2004Q3	0.00045	8.682226	42	4.602651	8.67775	0.92275	0.023842	2.740297	-0.447068	-0.59132	-1.168409
2004Q4	0.000419	8.952478	42	5.920698	8.711	0.924	0.022882	2.85111	-0.440629	-0.556921	-1.187092
2005Q1	0.000442	7.914359	51.815	6.291044	8.7415	0.923	0.022596	2.894273	-0.48496	-0.644419	-1.140882
2005Q2	0.000466	6.876239	61.63	6.66139	8.772	0.922	0.02231	2.937435	-0.529292	-0.731916	-1.094672
2005Q3	0.00049	5.83812	71.445	7.031737	8.8025	0.921	0.022023	2.980598	-0.573624	-0.819414	-1.048462
2005Q4	0.000514	4.8	81.26	7.402083	8.833	0.92	0.021737	3.02376	-0.617956	-0.906912	-1.002252
2006Q1	0.000569	6.362089	88.945	7.24499	8.87475	0.911	0.02213	3.242918	-0.515487	-0.74371	-0.922218
2006Q2	0.000623	7.924177	96.63	7.087896	8.9165	0.902	0.022524	3.462075	-0.413019	-0.580507	-0.842183
2006Q3	0.000678	9.486266	104.315	6.930802	8.95825	0.893	0.022917	3.681232	-0.31055	-0.417304	-0.762149
2006Q4	0.000733	11.04835	112	6.773709	9	0.884	0.02331	3.90039	-0.208082	-0.254101	-0.682115
2007Q1	0.000731	11.30719	112	6.320032	9.05	0.877	0.023659	3.941365	-0.15638	-0.23934	-0.601163
2007Q2	0.000728	11.56603	112	5.866355	9.1	0.87	0.024009	3.98234	-0.104678	-0.224579	-0.520211
2007Q3	0.000726	11.82487	112	5.412678	9.15	0.863	0.024358	4.023315	-0.052976	-0.209817	-0.43926
2007Q4	0.000724	12.08371	112	4.959001	9.2	0.856	0.024707	4.06429	-0.001274	-0.195056	-0.358308
2008Q1	0.000753	10.56278	112	5.777858	9.275	0.85725	0.025155	4.142073	0.023112	-0.179054	-0.349714
2008Q2	0.000781	9.041856	112	6.596714	9.35	0.8585	0.025603	4.219855	0.047498	-0.163051	-0.341121
2008Q3	0.00081	7.520928	112	7.415571	9.425	0.85975	0.02605	4.297638	0.071883	-0.147049	-0.332527
2008Q4	0.000838	6	112	8.234428	9.5	0.861	0.026498	4.37542	0.096269	-0.131047	-0.323934
2009Q1	0.000902	8.046798	112	7.036722	9.55	0.89825	0.027042	4.599065	0.094684	-0.135864	-0.369501
2009Q2	0.000966	10.0936	112	5.839016	9.6	0.9355	0.027587	4.82271	0.093098	-0.140682	-0.415068
2009Q3	0.001029	12.14039	112	4.641311	9.65	0.97275	0.028131	5.046355	0.091513	-0.1455	-0.460634
2009Q4	0.001093	14.18719	112	3.443605	9.7	1.01	0.028676	5.27	0.089928	-0.150317	-0.506201
2010Q1	0.001129	13.06539	112	3.7306	9.775	1.0255	0.029682	5.434975	0.155856	-0.126311	-0.447674
2010Q2	0.001166	11.9436	112	4.017595	9.85	1.041	0.030688	5.59995	0.221785	-0.102305	-0.389148
2010Q3	0.001202	10.8218	112	4.304591	9.925	1.0565	0.031694	5.764925	0.287714	-0.078299	-0.330621
2010Q4	0.001239	9.7	112	4.591586	10	1.072	0.0327	5.9299	0.353643	-0.054293	-0.272094

2011Q1	0.001256	9.975	112	4.767298	10.05	1.0795	0.033128	6.192128	0.354632	-0.023118	-0.24835
2011Q2	0.001274	10.25	112	4.943011	10.1	1.087	0.033555	6.454355	0.35562	0.008056	-0.224606
2011Q3	0.001291	10.525	112	5.118723	10.15	1.0945	0.033982	6.716582	0.356609	0.039231	-0.200862
2011Q4	0.001309	10.8	112	5.294435	10.2	1.102	0.03441	6.97881	0.357597	0.070406	-0.177118
2012Q1	0.001233	12.475	115.5	5.47124	10.275	1.111	0.034468	6.930595	0.407686	0.040741	-0.190492
2012Q2	0.001156	14.15	119	5.648045	10.35	1.12	0.034527	6.88238	0.457775	0.011076	-0.203866
2012Q3	0.00108	15.825	122.5	5.82485	10.425	1.129	0.034586	6.834165	0.507864	-0.018589	-0.217241
2012Q4	0.001004	17.5	126	6.001654	10.5	1.138	0.034645	6.78595	0.557952	-0.048254	-0.230615
2013Q1	0.001255	16.925	131.75	5.047103	10.55975	1.148	0.034704	6.926645	0.575456	-0.03126	-0.200699
2013Q2	0.001505	16.35	137.5	4.092552	10.6195	1.158	0.034763	7.06734	0.592959	-0.014265	-0.170783
2013Q3	0.001755	15.775	143.25	3.138001	10.67925	1.168	0.034822	7.208035	0.610462	0.002729	-0.140868
2013Q4	0.002006	15.2	149	2.183449	10.739	1.178	0.034881	7.34873	0.627965	0.019724	-0.110952
2014Q1	0.002168	16.35	149	2.5271	10.805	1.17575	0.03494	7.358068	0.661594	0.00846	-0.161581
2014Q2	0.002331	17.5	149	2.870751	10.871	1.1735	0.034999	7.367405	0.695224	-0.002804	-0.212211
2014Q3	0.002493	18.65	149	3.214401	10.937	1.17125	0.035058	7.376742	0.728854	-0.014068	-0.26284
2014Q4	0.002655	19.8	149	3.558052	11.003	1.169	0.035117	7.38608	0.762483	-0.025332	-0.31347
2015Q1	0.002718	20.55	157.25	4.202295	11.068	1.1625	0.035176	7.442397	0.730791	-0.03046	-0.231792
2015Q2	0.002781	21.3	165.5	4.846537	11.133	1.156	0.035235	7.498715	0.699098	-0.035588	-0.150114
2015Q3	0.002844	22.05	173.75	5.49078	11.198	1.1495	0.035294	7.555032	0.667405	-0.040716	-0.068437
2015Q4	0.002907	22.8	182	6.135022	11.263	1.143	0.035353	7.61135	0.635712	-0.045843	0.013241
2016Q1	0.00312	24.4425	182	5.416097	11.3305	1.1355	0.035412	7.625342	0.637815	-0.009855	-0.003794
2016Q2	0.003334	26.085	182	4.697171	11.398	1.128	0.035471	7.639335	0.639917	0.026133	-0.020829
2016Q3	0.003547	27.7275	182	3.978246	11.4655	1.1205	0.035919	7.653327	0.642019	0.062122	-0.037864
2016Q4	0.003761	29.37	182	3.25932	11.533	1.113	0.036367	7.66732	0.644122	0.09811	-0.054899
2017Q1	0.003721	30.5525	184.5	2.763939	11.6025	1.1005	0.036425	7.593972	0.64135	0.140296	-0.019164
2017Q2	0.003681	31.735	187	2.268558	11.672	1.088	0.036483	7.520625	0.638579	0.182481	0.016572
2017Q3	0.00364	32.9175	189.5	1.773177	11.7415	1.0755	0.036931	7.447277	0.635808	0.224667	0.052307
2017Q4	0.0036	34.1	192	1.277796	11.811	1.063	0.036991	7.37393	0.633036	0.266852	0.088043
2018Q1	0.003695	34.25414	196	2.392516	11.881	1.0515	0.0370259	7.211877	0.619365	0.251841	0.09568
2018Q2	0.003722	34.40829	200	3.507236	11.951	1.04	0.037159	7.049825	0.605694	0.236831	0.103317

2018Q3	0.003814	34.56243	204	4.621957	12.021	1.0285	0.037385	6.887772	0.592022	0.22182	0.110954
2018Q4	0.003853	34.71657	208	5.736677	12.091	1.017	0.037659	6.72572	0.578351	0.206809	0.118591
2019Q1	0.003752	34.87071	182	5.950222	12.162	1.02025	0.037821	6.603137	0.57485	0.201362	0.117861
2019Q2	0.003814	35.02485	186	6.163768	12.234	1.0235	0.037922	6.480555	0.571349	0.195916	0.117132
2019Q3	0.003911	35.71899	200	6.377313	12.305	1.02675	0.038155	6.357973	0.567847	0.190469	0.116402
2019Q4	0.003893	35.87313	204	6.590858	12.376	1.03	0.038421	6.23539	0.564346	0.185023	0.115672

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