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An Empirical Study of Electricity Theft from Electricity Distribution Companies in Pakistan

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Electricity theft is a common problem in many countries and energy worth billions of dollars is stolen annually from electricity grids. The problem has socioeconomic, political, environmental and technical roots, but the solution is generally sought solely through technical measures. This paper empirically investigates the effects of various factors including electricity price, per capita income, probability of detection, fines collected from offenders, weighted temperature index and load shedding, that may explain the theft. The study employed annual panel data obtained from nine electricity distribution companies in Pakistan for the period 1988–2010. The study estimates the Fixed Effects models through the least squares dummy variable (LSDV) technique and Generalised Method of Moments (GMM). Our results indicate that per capita income has significant negative and electricity price a positive effect on electricity theft with sufficiently high coefficient values. The probability of detection variable appears with a positive sign in both estimations indicating a poor deterrence. The results of LSDV show a positive impact of fine on conviction on electricity theft. But in GMM estimation, this variable appears with a right sign. The results from both models are robust in the case of load shedding and temperature variables. The findings show that economic variables are most significant in explaining electricity theft. The findings may also be applicable in other developing countries where hefty amounts of revenues are lost due to electricity theft.

Keywords: Electricity Theft, Fixed Effects Model, Pakistan

1. INTRODUCTION

Electricity theft is common in many countries and a considerable amount is stolen every year from electricity grids. It deteriorates the financial condition of the utilities, curtails new investments for capacity development of electricity industry that eventually leads to electricity shortage [Jamil (2013)]. If the electric utilities concerned are public monopolies, they may seek public investment and resort to government subsidies for their financial survival and for continued supply of electricity maintaining the status quo. Financial condition of few electricity distribution companies in Pakistan is extremely poor as the revenues from sale of electricity fall short of the supply cost [Kessides (2013)]. Huge distribution losses adversely affect the utilities' profitability and consequently the quality of service. These losses include technical and non-technical losses where non-technical losses mainly constitute electricity pilferage and theft. The

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financial loss due to electricity theft alone accounts for hundreds of millions of dollars annually [see, for example, Smith (2004); Lovei and McKechnie (2000)]. The overall mismanagement of power sector including the heavy losses and theft *inter alia* resulted in accumulated circular debt of over Rs 850 billion in 2012 [IPP (2009); FODP (2010); Planning Commission (2013)].

Pakistan is facing acute electricity shortage and the honest consumers have to pay heavily for quite irregular supplies. The electricity tariff rates for consumers are essentially set on the higher side due to widespread electricity theft. Therefore, it is pertinent to put efforts to rectify this menace for the electricity sector. Electricity theft has socioeconomic, political and technical basis, but the solution is generally sought solely through technical measures. In a recent study on electricity theft in agricultural sector in Rajasthan, Katiyar (2005) finds that electricity theft is not possible to be controlled in agriculture sector through a purely technical approach. The role of socioeconomic and institutional factors is typically under-rated in explaining and handling electricity theft issue. There are a few contemporary studies that discuss theft and corruption in electric utilities [for example, Clarke and Xu (2004); Smith (2004); Estache, *et al.* (2006); Bó and Rossi (2007); Gulati and Rao (2007); Nakano and Managi (2008) and Nagayama (2010)].

There is vast literature on economics of crimes and overall corruption, however, few studies examine corruption particularly in energy sector [for example, Clarke and Xu (2004); Bó and Rossi (2007)]. Using enterprise level data on bribes paid to electric utilities in 21 transition economies from Eastern Europe and Central Asia, Clarke and Xu (2004) explore how characteristics of utilities taking bribes and the firms paying bribes affect corruption in the sector. The study favours privatisation as bribe is found more prevalent in public owned utilities; bribe is positively related with capacity constraints and negatively related with level of competition. Bó and Rossi (2007) trace link between inefficiency and corruption by using a dataset comprising firm-level information on 80 electricity distribution firms in Latin America for the period 1994–2001. The study finds that corruption makes the firms inefficient, as such firms employ relatively more inputs to produce a given level of output.

Smith (2004) examines electricity theft determinants, its consequences, and suggests some remedial measures. The study shows that electricity theft is strongly related to governance indicators, and that higher levels of electricity theft persist in countries with less effective accountability, political instability, low government effectiveness and higher corruption. He suggests that electricity theft can be reduced primarily by applying a mix of technical solutions such as tamper-proof meters associated with managerial methods such as inspection and monitoring, and overall restructuring the electricity sectoral ownership and regulation. In another recent study, Nagayama (2010) identifies the effects of power-sector reforms on the sectoral performance indicators (for instance, installed capacity, transmission and distribution losses) and finds that reform variables such as the entry of Independent Power Producers (IPPs), unbundling of generation and transmission, establishment of regulatory agencies, and the introduction of a wholesale spot market lead to the increased generation capacity as well as reduced transmission and distribution loss in the respective regions. On the whole, literature focuses mainly on supply aspects of electricity theft and identified that poor governance, lack of competition and inefficiency are major causes of electricity theft.

This study is based on the argument that electricity theft is a multidimensional issue and ought to be investigated from a broader perspective. We examine the role of various factors that affect electricity theft by using panel data of electricity distribution companies in Pakistan for the period 1988–2010. Each of the distribution company serves its customers in a specific region of Pakistan. The data shows that there are startling differences of electricity pilferage rates in different companies/regions. We explore the determinants of electricity theft in order to explore answers to a number of questions such as the following.

- Is electricity theft affected by the economic activity?
- How responsive are the consumers to the electricity tariff that is, if tariff rate increases, the consumers reduce their electricity consumption or opt for electricity theft? Answer to this question may depend on price elasticity of electricity demand and consumers' expected risk of detection.[1]
- Are the offenders responsive to the probability of detection and magnitude of fines?
- Does the climate affect the electricity theft?
- Whether quality of electricity service affects the consumer behaviour regarding their theft decision?

Our empirical analysis comes up with answers to these questions. We employed Fixed Effects modelling. The Fixed Effects models are estimated using least square dummy variables (LSDV) and generalised method of moments (GMM) methods. Our results indicate that per capita income has significant negative and electricity price has positive effect on electricity theft or pilferage with high magnitudes of coefficients. Similarly, temperature variable has significant positive impact on electricity theft. However, the probability of detection and penalty for the offence i.e. fine variables do not perform consistently in all the models, partly due to poor monitoring and the law implementation and partly due to data quality. The fine on theft detection is found significant with negative sign.

The remainder of this paper is organised as follows. Section 2 briefly describes the electricity theft situation in Pakistan. Section 3 provides the conceptual framework and Section 4 presents the model and variables. The econometric methodology is given in Section 5. The results are discussed in Section 6, while Section 7 concludes the paper.

2. ELECTRICITY THEFT SITUATION IN PAKISTAN

The study investigates electricity theft and estimates the contributions of factors by using a dataset of electricity distribution companies operating in Pakistan. There are nine distribution companies operating in the country including, Islamabad Electricity Supply Company (IESCO), Lahore Electricity Supply Company (LESCO), Gujranwala Electric

[1]Electricity demand is price elastic in case of Pakistan [see, for instance, Jamil and Ahmad (2011)]. Electricity theft is a criminal offence subjecting a person to a prison sentence up to three years or fine up to Rs 5000 or both as per legal provisions of utilities in Pakistan. See, for example, *Electricity Rules 1937*. Usually detection bills may be charged due to the provisions of Section 26A, S-39, S-39-A, S-44, S-48 on detection of theft or illegal abstraction of electricity (*Electricity Act-1910*).

Power Company (GEPCO), Faisalabad Electricity Supply Company (FESCO), Multan Electric Power Company (MEPCO), Peshawar Electricity Supply Company (PESCO), Quetta Electricity Supply Company (QESCO), Hyderabad Electricity Supply Company (HESCO) and Karachi Electric Supply Company (KESC). These distribution companies are public monopolies with the exception of KESC, which has been privatised since 2005 and operates in metropolitan Karachi and has exclusive rights to supply power in its jurisdiction.

A region of operation for each distribution company is established by the government and these regions possess different social, political and economic characteristics. This is why the likelihood and extent of theft, its detection and conviction rate and modes of theft differ among the utilities. In spite of such diversity, moderate to high rate of theft and moderate to low detection rates prevail in most of the distribution companies. The intensity and incidence of electricity theft may differ in different parts of the country, whereas electricity theft is a common practice in most places. The average distribution losses in 2012-13 were found to be as low 9.5 percent in IESCO to be as high as 36 percent in PESCO. The transmission and distribution losses of KESC exceed 40 percent for some of the years [KESC (2006)]. On average, 20-25 percent of total electricity generated in Pakistan is marked as distribution losses. Power theft has been so serious issue in Pakistan that the government had to deploy army to recover electricity charges of distribution companies in 1999. Table 1 shows the disparity in electricity losses among all the distribution companies.

Table 2 gives a glimpse of the theft detection, penalty and recovery against the fines imposed. There are differences in electricity theft, conviction rates and law enforcement among the utilities and regions. The situation is worse in KESC, PESCO and HESCO with high losses, high detections and low recovery of fines imposed. The situation is better in utilities of central Punjab like IESCO, FESCO and GEPCO, where the losses fall in the range of 10-13 percent during the period analysed.

Table 1

Profile of the Utilities and Distribution Losses in Pakistan During 2010

Utility / Distribution Company	Number of Consumers (Million)	Units Supplied (GWh)	Units Billed (GWh)	Distribution Losses (Percent)	Billing Recovery (Percent)
LESCO	3.18	16,101	13,880	13.7	93
GEPCO	2.45	6,987	6,220	11.0	96
FESCO	2.88	9,329	8,317	10.9	97
IESCO	2.06	8,396	7,572	9.8	96
MEPCO	4.06	12,225	9,915	18.9	94
PESCO	2.94	12,638	8,258	37.0	79
HESCO	1.51	8,275	5,395	34.8	60
QESCO	0.49	5,167	4,099	20.7	76
KESC	2.05	13,362	9,905	34.9	100
Pakistan	**17.8**	**92,480**	**73,561**	**20.4**	**89**

Note: GWh=Giga watt hours equivalent to one million KiloWatt hours, Source: Electricity Marketing Data, 35th Ed.

Table 2

Theft Detection, Penalty and Enforcement in 2009 in Pakistan

Utility	Cases Detected	Amount of Fine (Rs. Mn)	Recovery (Rs. Mn)	Percentage Recovery
LESCO	35,132	320	91	28
GEPCO	34,751	121	94	74
FESCO	36,473	177	94	53
IESCO	10,700	81	18	22
MEPCO	68,603	315	91	29
PESCO	270,000	1,865	11	0.01
HESCO	376,000	1,505	343	23
QESCO	8,857	16	11	70
KESC	10,700	81	18	22

Source: Statistics Department, WAPDA House, WAPDA Lahore, and Commercial Wing, KESC.

* Detection Bills are charged on detection of electricity theft that presumably contain electricity charges plus fine or penalty.

3. CONCEPTUAL FRAMEWORK

The economics of electricity theft is essentially concerned with the cost and benefits of limiting the non-violent crime of electricity theft from the electricity distribution systems. The benefits of curtailing theft are in the form of increased revenues of utilities and consequently, improved electricity supply for the consumers. The potential costs include surveillance expenditures of utilities, rewards to monitors, and price incentives to consumers. Corruption and bribe are common in regions where electricity theft is widespread. The factors that entrench corruption and electricity theft are their beneficial features for consumers in terms of lowering electricity cost as well as private illegal incomes for corruptible employees of utilities. The ultimate victim is the utility/government and honest consumers at large.

Economic theory suggests that crime is committed only if the gain from offence exceeds the expected cost. The economic cost-benefit analysis of electricity theft aims to develop optimal public and private policies to combat this crime. From enforcement point of view, individuals can be deterred either by increasing the fine or by increasing the probability of detection. The increase in probability of detection and conviction is costly as it essentially requires the utilities to increase surveillance expenditure. Alternatively, utilities can increase the expected cost of electricity theft by increasing the fine for convicted [see, for instance, Becker (1968); Becker and Stigler (1974)]. The study proposes that the probability of detection and conviction may complement the amount of fine in deterring individuals from committing the crime. Theft comprises of the incidents where distribution companies fail to recover their receivables due to illegal abstraction of electricity by consumer, and improper recording and/or reporting by their employees. As a result, the actual receivables are not recovered. Electricity theft harms the financial condition of electric utilities and negatively affects future investments in power sector.

Electricity industry in most of developing countries is characterised by extensive public interventions sometimes to pursue their social, economic and political objectives.

The result is widespread corruption in the sector, inefficiencies at the generation and distribution levels and poor financial performance of utilities. Joseph (2010) argued that getting the electricity prices right may not suffice in reducing the financial instability of utilities, when the system is burdened with electricity theft and corruption. An equally pertinent issue in most developing countries is non-payment of due electricity charges by customers.

Electricity is generated at various power stations, which are generally located at distances from the load centres or end-users. It is then transported to end-users through wires and conductors. Electricity delivered by utility may differ from electricity billed due to technical and non-technical losses. When electricity passes through a wire, a fraction is lost due to the resistance of the conductor and stepping up and down of voltage and this is generally called technical loss. Non-technical losses mainly constitute electricity theft. Electricity theft can take place through a number of means and ways. Electric utilities charge electricity on the basis of meter readings at the consumers' interface. The distribution lines of the utilities lie open and hence the chances exist of consumers' illegally abstracting electric power through by-passing or even with tempering the meter.

In order to supply electricity to its consumers, utility delegates to employees various activities, such as repairing and maintenance, theft identification and electricity retailing. Corruption facilitates electricity theft wherein consumer and utility employee collude for personal gains ultimately causing a loss to the utility and public at large. The utility employees directly interact with the consumers and hence may help consumers in hiding the actual electricity consumption by receiving nominal bribes from them. Both the corrupt employees and consumers gain through this illicit relationship.

We are primarily concerned with the cost and benefits of limiting electricity pilferage among consumers. The benefits of curtailing theft are increased revenues of utilities and improved investment. The potential costs may be increased surveillance expenditures as well as rewards and price incentives. Smith (2004) emphasised the link between corruption and electricity theft and states that low transmission and distribution losses (around 6 percent) are most common in countries with low corruption perception like Belgium, Finland and Germany and while higher losses (around 30 percent) are most common in countries with high corruption perception like Albania, Bangladesh, Haiti, India and Pakistan. The study further identifies that electricity theft is highly correlated with all governance dimensions, such as civil rights, democratic institutions and accountability. The deterrent measures adopted for curbing the electricity theft are mainly technical such as introduction of advanced electricity meters. To deal with the multi-dimensional inter-linked aspects, this study is structured to specify a model of electricity theft by identifying explicitly the major economic and institutional policy variables to combat electricity theft in Pakistan.

4. MODEL AND VARIABLE CONSTRUCTION

This section highlights the factors that might affect electricity theft in Pakistan. We employ the most relevant variables as regressors comprising of utility-specific variables as well as country-specific variables taken as common for all utilities. The analysis is based on a dynamic panel model for electricity theft using panel data for nine electricity distribution companies in Pakistan. The general regression equation is as follows.

$$TH_{i,t}= f(PD_{i,t},FN_{i,t},TM_{i,t},P_t,PCY_t,SH_t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where $TH_{i,t}$ represents the electricity theft variable, $PD_{i,t}$ probability of theft detection, $FN_{i,t}$ the fine recovered from culprits and $TM_{i,t}$, the temperature index.[2] Electricity price P_t, load-shedding SH_t and per capita income PCY_t variables are common for all distribution companies. All the variables are transformed in their natural logarithmic form. The model specified in Equation (1) is estimated by Fixed Effects Model using least-square dummy variable (LSDV) and generalised method of moments (GMM) methods. Furthermore, the models are estimated using the variables at their levels as well as in their first differences where individual effects of utilities are removed. However, the results are more robust for the variables at their levels and for the instruments in their first differences hence the results are reported for models at their levels.

4.1. Utility Specific Characteristics

The electricity theft by a consumer essentially bears some risk of being detected and fined. The probability of detection or conviction is constructed by taking ratio of theft detection cases in each utility and total number of consumers in that utility. Theoretically, it is plausible to assume that annual cumulative number of detections indicate the higher probability of being detected ($PD_{i,t}$), thus raising the associated risk for electricity stealing. So electricity theft is expected to be negatively related with the probability of detection that leads to lowering of the electricity theft.

The proposition that crime rate responds to corresponding benefits and risk, usually is called deterrence hypothesis. The econometric analysis of criminal behaviour generally applies arrest rates and sanctions imposed as measures of deterrence. People generally respond to the deterring incentives and that higher fines increase deterrence for all groups of individuals [Bar-Ilan and Sacerdote (2004)]. With similar intuition, the number of cases convicted of electricity theft and penalty imposed in the form of detection bills are electricity theft deterrent. Hence, we considered the probability of detection as measured by the amount of fine recovered ($FN_{i,t}$).

Temperature index ($TM_{i,t}$) calculates the intensity of cold and hot weather in area of operation of autility. Per capita electricity consumption will rise during extreme temperatures and the relative benefit of electricity theft will become more likely to offset the cost in terms of risk of detection for a consumer. Thus the temperature index is assumed to be positively related with the electricity theft. There may be potential endogeneity between electricity theft ($TH_{i,t}$) and cases of theft detection ($PD_{i,t}$). The higher theft rate may indicate higher detection cases, implying that higher probability of detection may be induced by electricity theft. The result would be that the dependent variable will be correlated with error term in the Fixed Effects and Random Effects

[2]We tried a number of variables as regressors in the analysis that appear insignificant including; country level corruption perception index, Gini coefficient to incorporate income inequality, socioeconomic index, per capita electricity consumption in each utility, time series of energy intensity constructed by taking the ratio of energy consumption in British Thermal Unit (BTU) and real GDP.

models and the least square estimates would be biased. To handle this issue, Generalised Method of Moments (GMM) is also applied for model estimation.

4.2. Country Specific Characteristics

For some variables, we do not have the data for each utility or region, hence we use the common country level data for all distribution companies. Average electricity price is positively related with the electricity theft due to higher net payoff from electricity theft in case of higher prices. In the presence of low probability of detection, low fines and widespread corruption the consumers become risk neutral and theory suggests that theft will tend to increase with tariff rate if offenders are risk neutral. If the system is already exposed to high rate of electricity theft, an increase in tariff rates may affect electricity demand and revenue of utilities in two ways. The honest consumers may cut their consumption of electricity, while the proportional number of dishonest consumers may increase their consumption. The result may be higher electricity consumption, higher bribe earnings for corrupt employees, higher electricity theft and lower revenues for utilities. It is due to the expectation that if the tariff rate is high, it will induce temptation among the consumers to steal electricity as in this case expected gains would be higher.

The quality of electricity supply service proxied by amount of load-shedding (SH_t) is another interesting variable in our model. The electricity shortage extensively affects those utilities that have higher level of theft. On one hand, the higher rate of load-shedding may reduce total electricity consumption and thus lower the amount of electricity theft. On the other hand, it may damage the relationship between the consumers and utility and generate a disregard of peak load by consumes thus resulting in inefficient use of energy. Thus load-shedding may increase or decrease electricity theft depending on the time and duration of load shedding. The rise in per capita income (PCY_t) is expected to lower the electricity theft. In general, the higher income may lead the consumers to avoid risk. Thus the income is expected to be negatively related with electricity theft.

4.3. Data Description and Sources

The data used in this study consist of a balanced panel from 9 Pakistani distribution companies for the period 1988–2010. The data mainly obtained from various organisations and publications that mainly include, *Electricity Marketing Data* by NTDCL, Planning and Statistics Departments of WAPDA, Pakistan Meteorological Department, the Federal Bureau of Statistics and *Annual Report* of KESC. We employed a number of company specific variables as well as macroeconomic variables. Table 3 gives the description and sources of data. Electricity theft is our dependent variable proxied by the distribution losses of electricity distribution companies in Pakistan.[3] Electricity price is important in explaining electricity theft and we use average price per unit (kilowatt hour) obtained by dividing the total revenue from electricity sale in the country by the electricity supplied.

[3]The distribution losses include mainly electricity theft and a small fraction of technical losses [Alam, *et al.* (2004)].

Table 3

Variables and Data Sources

Variable	Symbol	Variable Definition	Source
Per Capita Income	PCY_t	Real GDP per capita (Country level data)	Federal Bureau of Statistics, Islamabad, Pakistan
Electricity Price	P_t	Average electricity price (Country level data)	Planning Department, WAPDA, Lahore
Electricity Theft	TH_t	Distribution losses of electricity in percent	Electricity Marketing Data, NTDCL, Lahore
Probability of Detection	PD_t	Number of detection bills divided by total number of consumers	Statistics Department, WAPDA, Lahore
Fine per Incidence	FN_t	Amount of fines recovered divided by number of detection bills (Rs. Mn)	Statistics Department, WAPDA, Lahore
Load-shedding	SH_t	Percent capacity shortfall of real time electricity demand (country level data)	Electricity Marketing Data, NTDCL
Temperature	TM_t	Population weighted temperature index of the utilities' regions	Pakistan Meteorological Department, Islamabad

Currently, National Electric Power Regulatory Authority (NEPRA) announced a uniform electricity tariff rate in Pakistan and the data for average sale price at company level is not available, hence we use electricity price for KESC while all other distribution companies share the same electricity price.[4] The temperature variable is constructed by taking sum of degrees above 24 and below 12 from average monthly temperature at each weather station as follows. The heating degrees (HD) that require heating the space and water are calculated as follows:

$$HD=\Sigma_{j=}1.\ H(12-T_{j,avg}) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

where H is a dummy variable equal to 1 if average monthly temperature at a weather station is below 12°C, and zero otherwise. The average monthly temperature in the jth month is represented by $T_{j,avg}$. Similarly, the cooling degrees (CD) that require cooling the space and water are calculated as follows:

$$CD = \Sigma_{j=1}.\ H(T_{j,avg}- 24) \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

where C is a dummy variable equal to 1, if average monthly temperature is above 24°C. The temperature variable (TM_t), defined as a sum of degrees showing extreme temperatures in a year, is obtained by adding the two measures in Equations (2) and (3):

$$TM_t = HD + CD \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (4)$$

[4]Average price of electricity may actually vary in different companies due to varying composition of consumer categories and cross subsidisation across sectors.

The temperature variable is obtained by adding monthly discrepancies in degrees from lower and upper benchmarks at a weather station. The variable to capture the probability of detection is constructed by taking the annual number of thefts detections divided by total consumers for each distribution company.

5. ECONOMETRIC METHODOLOGY

We estimate the fixed effect model by relaxing the restriction on intercept and let the intercept to vary for each utility, still assuming that the slope coefficients are constant across the utilities. This is done in Fixed Effects model due to the fact that the intercept is time invariant although it varies across utilities. To estimate the Fixed Effects model, we apply least squares with dummy variables (LSDV) approach by including the cross-sectional dummies of utilities. The model can be written as follows.

$$TH_{i,t} = \beta_{0,i} + \beta_1 lnPD_{i,t} + \beta_2 lnFN_{i,t} + \beta_3 lnTM_{i,t} + \beta_4 lnP_t + \beta_5 lnPCY_t + \beta_6 lnSH_t + \beta_7 TH_{i,t-1} + \varepsilon_{i,t} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The subscript i denotes the ith utility ($i = 1, \ldots, N$) and the subscript t denotes the jth year ($t = 1, \ldots, T$). The subscript i on the intercept suggests that the intercepts may take different values across utilities.

The study also estimate the Fixed effects model through the system GMM to account for the endogeneity of the lagged dependent variable in the presence of possible autocorrelation in the random error. The GMM technique requires the specification of a set of moment conditions that the model should satisfy. It provides robust estimates in that it does not require information of the exact distribution of errors. For the GMM estimators to be identified there must be at least as many instrumental variables (including an intercept) as there are parameters to be estimated. GMM estimation accounts for unobserved utility specific effects, allows for the inclusion of lagged dependent variables as regressors and controls for endogeneity of all the explanatory variables by selecting parameter estimates such that the sample correlations between the instruments and the random errors of the model are close to zero. Least square estimator can also be viewed as a special case of GMM estimator, based upon the conditions that each of the right-hand variables is uncorrelated with the random errors of the equation.

The lagged variable on the right hand-side of the equation makes the model dynamic and changes the interpretation of the equation considerably. Without lagged variable, the independent variables produce observed outcome that is, $TH_{i,t}$ representing the full set of information. The lagged variable brings in the equation the entire history of the right hand-side variables such that any measured influence would be conditional on this history. The general approach to estimate such models relies on instrumental variables on GMM estimator [Arellano and Bond (1991); Arellano and Bover (1995)]. This is why, we also used GMM method that handles the potential endogeneity.

The LSDV estimation approach for the Fixed Effects Model is costly in terms of degree of freedom loss. Judson and Owen (1999) provide a guide to choosing appropriate techniques for panels of various dimensions and find that the LSDV estimator only performs well when the time dimension of the panel is large and propose that GMM is the best choice overall.

6. RESULTS AND DISCUSSION

This section presents the empirical findings based on the analytical framework developed in Section 3 by providing a menu of models, techniques and regressors. The Hausman test for the fixed and random effects regressions suggests that Fixed Effects Model is more appropriate in this case since the joint fixed effect is significant at 5 percent. The test statistic is 2.15 with probability 0.035. Hence, the Fixed Effects Model would be preferred choice on the basis of the test. Moreover, the results are more robust when models are estimated using variables at their levels. In order to take the specific nature of nine companies into account, we employed the Fixed Effects Model estimated through least square dummy variable (LSDV) regression model and GMM. In this study, the Fixed Effects Model is interpreted to mean that the impact of explanatory variables of the Equation (5) on electricity theft greatly depends on the utility specific characteristics. The results are presented at Table 4.

The intercept values of the nine utilities are different with highest in KESC. PESCO stands second followed by QESCO. These differences are due to the differentials in utility governance and prevalence of underground economy therein. The Fixed Effects model estimated with GMM uses the following set of variables as instruments.

List of Instruments:

d(TH_t(-1))	First difference of electricity theft, dependent variable.
d(PD_t(-1))	First difference of the number of recorded cases of electricity theft.
d(FN_t(-1))	First difference of the amount of recovery of fine recovered on theft.
d(P_t(-1))	First difference of the electricity price variable.
d(TM_t(-1))	First difference of the temperature index.
d(SH_t(-1))	First difference of load-shedding variable.
d(PCC_t(-1))	First difference of per capita electricity consumption.
d(CPI_t(-1))	First difference of Pakistani score of corruption perception index taken from Transparency International.
d(EI_t(-1))	First difference of energy intensity by taking ratio of energy consumption to real GDP.
d($GINI_t$(-1))	First difference of Gini coefficient, indicating income inequality.
d(PCY_t(-1))	First difference of real per capita income.

The results show that model performs well econometrically and the overall quality of results is satisfactory. The R-square and adjusted R-square are high enough, indicating strong explanatory power of the estimated equations. Most of the Durbin-Watson statistics fall in the non-rejection range indicating absence of considerable autocorrelation. The significance of *t*-statistics associated with most of the parameter estimates further indicates good performance of the estimated models. The performance of explanatory variables in the model estimated by LSDV and GMM is discussed in detail below.

The probability of detection variable has poor performance, as signs of its coefficients are against the theory. The result indicates that the performance of punishment for conviction or fine remains mixed in the models. The relatively weak performance of these variables despite their theoretical relevance to electricity theft

Table 4

Parameter Estimates of Electricity Theft Models

Variable	FE Model LSDV	FE Model GMM
Constant	0.196[c]	0.603[c]
	(1.89)	(1.72)
PD_t	0.010[a]	0.013
	(5.11)	(1.01)
FNt	0.003[b]	–0.004
	(2.09)	(–0.19)
Pt	0.079[a]	0.114[b]
	(3.56)	(2.37)
TMt	0.037[b]	0.072[a]
	(2.86)	(4.57)
PCYt	–0.081[a]	–0.154[b]
	(–3.41)	(–3.02)
SHt	0.008[a]	0.007[b]
	(4.01)	(2.87)
TH(-1)	0.010[a]	0.009[a]
	(31.83)	(7.69)
Fixed Effects		
GEPCO	0.016[a]	0.037[a]
	(3.49)	(5.01)
HESCO	0.023[a]	0.009
	(3.58)	(0.17)
IESCO	0.019[a]	0.048[a]
	(4.03)	(3.49)
KESC	0.069[a]	0.071[c]
	(5.76)	(1.66)
LESCO	0.008[c]	0.015
	(1.84)	(0.52)
MEPCO	0.007	–0.016[b]
	(0.72)	(–2.76)
PESCO	0.043[a]	0.052[b]
	(4.61)	(2.34)
QESCO	0.026[b]	0.049[b]
	(2.48)	(2.65)
R-Square	0.94	0.91
Adj. R-Square	0.92	0.90
DW Statistics	1.79	1.71
J-Stat	–	4.82
F-Stat*	10.12	7.89
(Probability)	(0.000)	(0.000)

Notes: FE stands for Fixed Effects model.

The figures in ( ) represent t-Statistics and superscript a, b and c denotes the level of significance at 1 percent, 5 percent and 10 percent respectively.

* Wald test of Normalised Restriction (=0), the significance of dummy variables.

may be due to ineffective surveillance and presence of widespread corruption. The effect of an increase in electricity price on electricity theft is positive as expected because rising electricity price increases the benefit from stealing electricity for the given levels of risk of being fined. The price variable is found to be significant with highly significant estimated regression coefficient value in all the models, signifying the role of electricity tariff rate in explaining electricity theft in our models. The effect of increase in per capita income on electricity theft is negative, complying with the assertion that the individuals become more risk averse as income rises for the same amount of pecuniary benefit. The per capita income variable significantly affects the electricity theft with highly significant estimated coefficient in all the models.

Our findings are consistent with Bò and Rossi (2007). Thus, firms in those countries would appear to be less efficient, because part of the energy they effectively distribute gets stolen, rather than sold. It again indicates the importance of economic variables such as, income and price and both the variables can be appropriately used for a better management of the sector in the country. It also shows that in an electricity supply system burdened with huge losses, an increase in electricity tariff rate may not increase the revenues of utility as it may lead to an increased level of electricity theft.

The effect of temperature on energy consumption is well established and a number of studies have shown that energy consumption is elastic to extreme temperatures. Table 4 shows that temperature appears significant with sufficiently high positive coefficient in all the estimated models. Another variable considered in the models is load-shedding, which has taken quite low and positive though highly significant coefficient value in both the estimations suggesting that the deteriorating quality of service adds to electricity theft.

7. CONCLUSION

Electricity theft is common crime in many countries and electric utilities worldwide have to forego huge amounts of revenues every year due to theft of electricity. It causes huge financial losses to utilities and hurts future investment for capacity additions. Electricity distribution companies and governments resort to technical and legal measures to combat this non-violent offense. As a result, formal laws and technical measures are generally introduced. Rather than concentrating only on the technical measures and law enforcement, this study intends to indicate the economic, social and meteorological factors affecting electricity theft in the context of a developing country where electricity theft situation is a serious phenomenon.

This paper has empirically investigated the effects of various factors in explaining electricity theft from electricity distribution systems using the panel data from nine electricity distribution companies of Pakistan for the period 1988–2010. The study estimates the Fixed Effects models using the OLS and GMM techniques. The empirical evidence from the estimated econometric models is by-and-large consistent with the conceptual framework, although the impact of the number of conviction cases is unclear because it either appears with wrong sign or is statistically insignificant.

The results indicate that the economic factors such as per capita income of the consumers and consumer price of electricity are key determinants of electricity theft as suggested by all the models. The electricity theft is negatively related with per capita income, implying that an increase in income level lowers the electricity theft with sufficiently higher coefficient value. The opposite is true for electricity price, which positively affects the electricity theft. It also emphasises the importance of minimising electricity theft since in the presence of widespread theft, the income and price elasticity estimates for electricity demand cannot be used as policy tools for achieving electricity conservation and efficiency goals. The effect of temperature on electricity theft is positive, which seems reasonable as the extreme temperatures lead to higher electricity consumption that may consequently induce electricity theft.

The results show that the tariff policy and the overall electricity demand in the country are important policy variables and the regulatory body needs to keep these factors in mind in decision-making regarding the overall electricity supply and tariff rate. The results from this study suggest that electricity price may not be used as an effective energy conservation tool in the presence of widespread electricity theft. Moreover, in such cases, excessive demand and power shortfalls cannot be reduced. The electricity price in Pakistan is already too high in relation to the quality of service and in real terms. For example, hours of work to buy 100 units of electricity in Pakistan would be more than 10 times the hours required to buy the same amount in a country like the USA. So, hard-core pricing mechanism cannot be applied to many such countries and the shortfall has to be met in long run through better planning and management. The equitable electricity prices can be achieved by minimising the cost of generation. Reduced load-shedding signify better quality of service that gives a positive gesture to the consumers, which may in turn oblige them to pay for the service. This suggests that the issues in supply and demand for electricity are inter-twined. The findings of the empirical study may be applicable in most of developing countries where hefty amounts of revenues are lost due to electricity theft every year.

The study suggests that the issues in supply and demand of electricity are inter-twined. The supply issues can be handled by keeping the consumer price of electricity right. On one hand, it is inevitable that utility revenues cover the generation and supply costs for proper functioning of utilities and sustainable electricity industry. Increasing electricity prices is a difficult decision for a political government and the government provides subsidy to electricity in the short term in view of rising costs of generation. The least cost optimisation for future electricity generation plans is very important to avoid price hikes since electricity availability is useless if it is not affordable. It will induce electricity theft as per analysis.

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