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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:

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

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:

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

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):

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

[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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Macro-economic Policies and Energy Security—Implications for a Chronic Energy Deficit Country

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The paper assesses the energy sector's foreign exchange requirements for meeting energy consumption and for capital expenditures, and identifies its implications for the country's macroeconomic policy and management. We develop a conceptual model for projecting the energy sector's long-term requirements for foreign exchange. The model indicates that the country's chronic dependence on oil imports is likely to expose the economy to high and volatile oil prices. A fundamental issue for Pakistan is how the energy projects requiring large inflows of foreign capital and technology will be financed. The main implication of our analysis is that there will be continuing pressure on the country's foreign exchange resources. The demand for foreign exchange by the year 2024-25 is projected to be US$ 20-21 billion without the FDI in new power generation. However, when we include the requirements of foreign exchange for capital expenditure, the total FX requirements are in the range of US$ 23-24 billion. An implication of the country's chronic energy deficiency is that the macroeconomic policies, particularly the foreign exchange rate policy, need to be redefined to reflect the projected demands on hard currencies and their expected scarcity value. It is likely that Pakistan will remain dependent on foreign imports to meet its energy requirements for a long time and will need to generate commensurate foreign exchange resources to ensure long-term energy security.

JEL classification: E66, F37, Q43
Keywords: Macroeconomic Policy, Exchange Rate Policy, Energy Security

1. INTRODUCTION

Pakistan's energy crisis, despite being a focus of political, technical and economic analyses and discussions, seems to be continuing unabated. Not with standing the fact that there have been numerous studies that have identified critical issues and the available options in the energy sector, the energy deficit seems to be ever-increasing. An issue that has been overlooked in this debate relates to how the energy sector's foreign exchange requirements for meeting current consumption and for capital expenditures for creating domestic capacity would be financed. This paper seeks to address this question, and follows up with identifying its implications for the country's macroeconomic policy and management.

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In order to address the energy crisis, the government is planning and implementing various structural measures, such as increasing share of renewable energy production, diversification and rebalancing of the energy production mix, reducing oil intensity, and exploring fossil fuels [Pakistan (2013); NEPRA (2013)]. However, the energy infrastructure and production projects are heavily capital and technology intensive. They necessitate foreign investment with concomitant foreign exchange liabilities for repatriation of returns and the principle. Moreover, the gestation periods for such measures to make a substantial impact is generally quite long. In addition to the increasing energy demand in the country, volatile oil prices pose another challenge that call for physical and financial strategies for hedging price risk. Such strategies, however, also require substantial foreign exchange resources [Bacon and Kojima (2008); Daniel (2001)].

It is likely that Pakistan will remain dependent on foreign imports to meet its energy requirements for a long time [Ahmed (2007)], and will need to generate commensurate foreign exchange resources to ensure long-term energy security. The paper addresses the implications for macro-economic policies given the country's chronic dependence on imported energy and continuing pressure on its foreign exchange resources. More specifically, the study first rigorously establishes the above *chronic energy deficit* hypothesis. Second, it elaborates the logical consequences of this condition for the demand for foreign exchange. Third, the paper discusses implications for macro-economic strategies, in particular, with respect to the foreign exchange regime and related interest rates, foreign trade, and domestic and foreign direct investment policies. We make international comparisons of macro-economic policies adopted by countries which face secular energy deficits comparable to Pakistan. After discussing various policy alternatives, the paper concludes with some recommendations.

With regards to the continuing energy crisis in Pakistan, there have been a number of academic studies and policy papers on the subject [e.g., Alahdad (2012); Ghayur (2007); Malik (2008, 2010); Siddiqui (2004); Kugelman (2013)]. The major focus of these studies has, however, been on basic long-term structural measures designed to reduce oil consumption over the long run, achieve energy portfolio diversification away from oil-fired power generation, improve energy efficiency, and demand management. These strategies provide the potential to reduce exposure to high and volatile oil prices, but do not address the long-term fundamental problem of *energy poverty*. In general, there is a dearth of studies on the implications of energy deficit for macro-economic policies for the energy-importing developing countries. Other studies deal with the impact of energy shortages on the macro-economies, energy production strategies, and demand management. For example, see Finleya (2012), Bielecki (2002), Pandey (2006), Labandeira and Manzano (2012) and Munasinghe (1984). On the contrary there have been a number of studies with respect to oil exporting and developed countries [IMF (2003); IMF (2012); Sturm, *et al.* (2009)] that examine the macro-economic policy options for oil surplus countries. Moreover, the policy options and alternative strategies have to be country specific and must take into account the country's economic and industry structures. Therefore, this paper is likely to contribute significantly to the development of a long-term economic strategy to enhance energy security for Pakistan.

2. BACKGROUND ON THE OIL SECTOR

Pakistan is an oil producer, but the domestic production of crude oil meets only 16-20 percent of the total consumption. Importing crude oil, high-speed diesel, fuel oil and other petroleum products fills the remaining 80-84 percent of demand. The oil prices in the international markets steadily increased since 2001; over 2001-2013 the crude prices increased five times. Though the consumption of petroleum products only increased marginally, the rise in the petroleum prices brought the country's current account under strain. The share of import bill for petroleum products in current account balance increased from 23 percent to 35 percent in last twenty years. The increase in the world oil prices, particularly in 2004-2008, led the government to roll back its deregulation policy and exert a greater control on the sector, with a view to protecting the consumer from the brunt of full pass-through of the international prices. The government uses direct and indirect price controls (moral suasion) to keep oil products and LPG prices low for the benefit of the consumers. It results in domestic prices being below the prevailing international prices.[1] This implicit price ceiling reduces the quantity of LPG imports; consequently a shortage results, and a "black market" emerges with end-users paying higher prices. The Oil and Gas Regulatory Authority (OGRA) sets the price ceilings through official notification. The price is based on the Arab Gulf fuel ex-refinery/import-parity price, and other charges include customs and excise duty, sales tax, other levies and a distribution margin.

Following the sharp rise in the world oil prices during the 2004-2008 period, the government took several steps to protect consumers by imposing a cap on the domestic sale prices [MPNR (2005)]. The policy of providing relief to the consumers was also implemented by reducing the petroleum development levy (PDL) which overtime was reduced to zero. In 2004, the government also started to pay a 'price differential claim' (PDC) to compensate the oil companies for the lower price charged to the consumers, particularly for kerosene and diesel oil. The oil policy therefore not only led to the government subsidising oil consumption, but also resulted in reducing the tax revenues accruing to the government. Over time, the policy has had a substantial negative impact on the fiscal position of the government. Despite the government's efforts to provide subsidies to cushion the increases in international oil prices, the increase in the end-user domestic prices has led to fierce protests. There have been numerous strikes and price increases at the pump have been challenged in the courts. On the other hand, the energy policy quite predictably has resulted in continuing energy shortages manifested as blackouts of unprecedented duration and frequency. It is said that one of the major causes of the ruling PPP government's defeat at the polling booth in May 2013 has been its failure to satisfactorily address the energy crisis. Besides the government, the oil companies have also been blamed for exploiting the situation and profiteering at the expense of the public.

Another factor exacerbating the energy crisis has been the rising demand for energy fuelled by robust economic growth over 2002-2007; the average real rate of

[1]For example, the ceiling was about US$300 per ton, against international LPG prices exceeding US$500 per tonne at times. In April 2006, wellhead LPG prices were increased from Rs 17,000 (US$283) per tonne to Rs 20,200 (US$337).

growth was 6.22 percent over this period. Besides the energy sector the transport sector is another main user of the petroleum products. The demand for petroleum products from this sector was attenuated somewhat by a large scale substitution of gasoline and heavy fuel oil with natural gas. The conversions were the result of government's pricing structure, which created financial incentives in its favour. A record number of gasoline powered vehicles were switched to CNG to the point that Pakistan had the third largest number of CNG vehicles in the world, with 63.3 percent of the vehicles running on CNG.[2]

Pakistan has been so far self-sufficient in natural gas, but the gas reserves are depleting at a fast rate and gas shortages have started to appear. Pakistan's reserves-to-production (R/P) ratio stood at slightly less than 35 years in 2004. At the end of 2012 it is estimated to be only 15.5 years.[3] As such, the country's import of natural gas (LPG) will become substantial in the near future. This will be true particularly as the Iran-Pakistan gas pipeline becomes operational, though it stands a very small chance because of the non-availability of finance as per the recent announcement of the Iranian government. The price gap between the government's implicit ceiling on LPG prices and corresponding import-parity prices has contributed to supply shortages. Although in the recent years the government has raised the price of gasoline in order to partially offset the lower prices of kerosene and diesel, the net subsidy has been large and has contributed to fiscal deficits.

Management of the demand side has also been lacking. The policies to discourage use of large automobiles, air-conditioners and other power-guzzling appliances have been either absent or non-effective. Nominal energy conservation campaigns have mostly relied on public exhortations without much effect on consumer behaviour. Steps to combat energy pilferage and payment delinquencies have also not yielded the desired results, partly because of the ability of the opposition groups and vested interests to block such moves by the government.

The impact of energy crisis on the macro-economy is also well documented in the academic literature, financial press and government policy documents. The Planning Commission estimates that as a result of losses from power and gas shortages, the average GDP growth rate of Pakistan's economy has decreased by 3-4 percent since 2010 onward [NEPRA (2012)]. Technical experts on the energy industry, like Zahid Hussain (ex-CEO of OGDC), Shahid Sattar of Planning Commission and others, are on record drawing a grave outlook for the energy sector. At a seminar held at PIDE in May 2013, Sattar said that the Planning Commission estimates show that the power sector deficit will balloon to Rs 742 billion ($7.4 billion) in the current financial year. The circular debt has touched around the Rs 600 billion-mark, while the overall losses may touch Rs 2,000 billion up to June 30, 2013. Pakistan is currently spending two percent of GDP on the power sector, which needs to be jacked up to 4-4.5 percent on an immediate basis to cater to the demand. In order to end the power crisis, Pakistan will have to focus on nuclear civil energy and the production of electricity through coal. A visiting senior fellow at PIDE, Alahdad, attributed the prevailing condition to lost opportunities,

[2] IANGV (International Association for Natural Gas Vehicles). Current Natural Gas Vehicle Statistics.
[3] BP Statistical Review of World Energy 2013.

prohibitive delays, implementation performance and reform reversals. "The story of Pakistan's energy sector is symptomatic of virtually all sectors of the economy. At the micro level, the decision-making in the sector remains inherently flawed, and policy initiatives are reduced to shooting in the dark." The overwhelming evidence from energy analysts points to the absence of coordinated policy formulation as a fundamental issue. Alahdad identified coordinated policy formulation as a fundamental issue and advocated adopting the concept of Integrated Energy Planning and Policy Formulation (IEP) and the institutional structure, which supports it [also see a recent monograph, Alahdad (2012)]. Rashid Amjad pointed out that the integration of energy plans with economic objective remains weak. Stagnation in exports is well documented in recent years, e.g., see Haque (2011).

According to *the Economist* (2013), "Not charging consumers for electricity has created a big problem for Pakistan. At the end of 2012 the country's stock of energy-industry debt was $9.1 billion—about 4 percent of GDP—according to a report funded by the United States Agency for International Development (USAID) and carried out by the national Planning Commission. The same USAID–backed report claims power shortages retard economic growth by at least 2 percent a year. The situation is deteriorating as the debt mountain grows. Riots break out each summer in protest." The basic fact remains that the integration of energy policy plans with macro-economic objectives has remained weak since late 1970s and early 1980s. Pakistan export sector growth has not managed to offset the rising oil import bill, resulting in high levels of energy subsidies to the magnitude of Rs 1,400 billion with little progress to show.

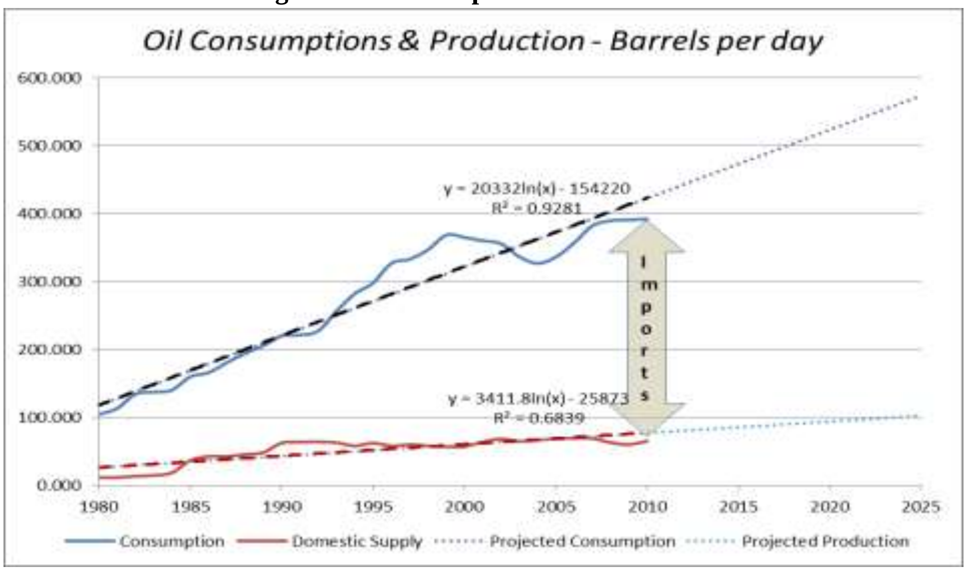
To add to the energy woes, unfortunately, the deteriorated security situation in Pakistan has led to a significant decline in foreign investment in the energy sector as well as in the overall economy. It is appalling to note that in a globally integrated economy and a global liquidity environment in recent years, net foreign direct investment in Pakistan for 2008-13 are USD 5.4, 3.7, 2.2, 1.6, 0.8 and 1.8 billion for each year. The net foreign inflows in oil and gas development and exploration declined by 11 percent to $560 million in 2013, as compared to $629 million in the previous fiscal year. The oil and gas sector contributed 39 percent to the FDI during FY13 as compared to 77 percent in 2012, mainly due to the worsening law and order situation in Balochistan and Khyber Pakhtunkhwa (KPK), where exploration activities witnessed contraction. However, it is encouraging to see a fresh inflow of FDI in the energy sector in 2014 of $1.2 billion (*Business Recorder* February 2, 2014).

Meekal (2012) has summed up this current situation as "a never-ending energy crisis that has crippled growth and employment prospects, especially in the SME sector which is the main-stay of the economy in terms of value-addition, employment, living standards and exports." Realistically speaking, any decent/worthy economist of our generation would be hard pressed to declare the Pakistan's macroeconomic situation in general and energy policy in particular as "satisfactory and sustainable." Borrowing a famous political phrase from President Clinton campaign in 1992, "it is the economy, stupid," we argue in this paper that Pakistan's macroeconomic policies are inherently inconsistent, *ad hoc* and have significantly contributed to the current crisis in energy, and other sectors of the economy.

3. PAKISTAN'S CHRONIC ENERGY DEFICIENCY

Figure 1 below conveys our *chronic energy deficit* hypothesis by making a comparison of the country's long-term domestic production and consumption and presents a picture of long-term import dependency. The figure also shows fitted trend lines for the two series using logarithm functions; estimated equations for time (t) are also reported. Detailed statistics on the domestic consumption and production are provided in Table A-I in the Appendix.

Fig. 1. Oil Consumption and Production



As the figure indicates, the consumption-production gap has grown from 83,000 to 327,000 barrels of crude oil per day from 1980 to 2010. The historic average compound annual growth rate (CAGR) of consumption has been 3.51 percent p.a., compared to 1.75 percent p.a. for the domestic production. As a matter of fact, the domestic production has been at a virtual standstill level since the early 1990s.

As a result of the persistent consumption-production gap, the country has become chronically dependent on oil imports, rendering the economy as greatly exposed to high and volatile oil prices. Yépez-García and Dana (2012) lay down the key indicators of a country's vulnerability to higher and volatile oil prices. These include a greater share of oil imports in percent of gross domestic product (GDP), a high proportion of oil usage in the primary energy supply, and a rise in oil imports and expenditures over time. When we examine such indicators in relation to Pakistan, as is shown in Table 1, they indicate a high degree of the country's vulnerability.

As the Table shows, over the last ten years, the oil imports have increased from 2.7 percent of the GDP to over 6 percent in current USD terms, while these have increased from 2.4 percent of the country's GDP (in constant USD) to about 10 percent in recent years. As a percentage of total imports, the oil imports have doubled to about 35 percent over the ten year period. More importantly, oil import expenditure, as a percentage of exports, has increased from 18 percent to 57 percent. An important factor has been that the country's exports, which are the main component of the country's capacity to pay for imports, have not kept pace with the oil import requirements. The last column in the Table points out to the other aspect of the country's vulnerability, i.e., increasing reliance on the imported oil sources for power generation, the percent of total electricity production from furnace oil increasing from about 16 percent in year 2003-04 to over 35 percent for year 2011-12, and is expected to be higher for the year 2012-13.

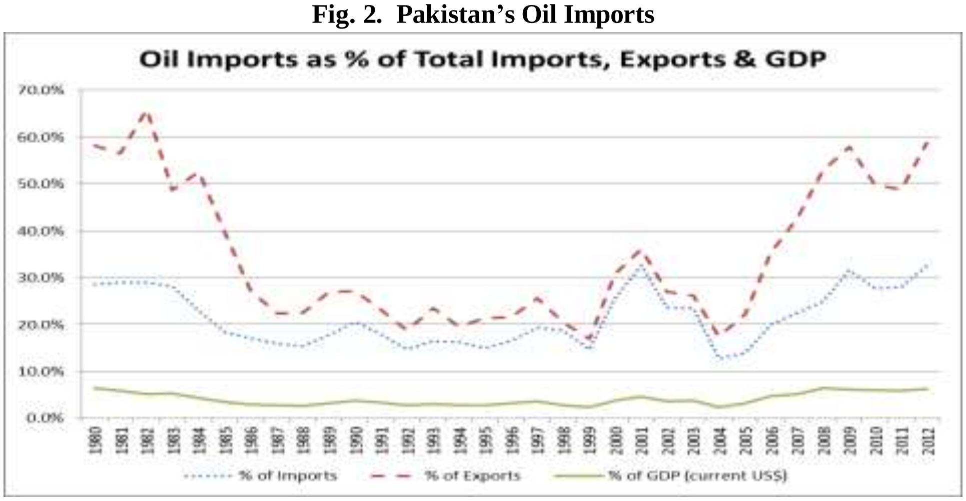
Table 1

Petroleum and Products Imports as Percentage of Key Indicators

Year	% of Exports	% of Imports	% of GDP (Constant 2005 US$)	% of GDP (Current US$)	Electricity Production from Oil Sources
2003-04	18.3%	16.6%	2.4%	2.7%	15.7%
2004-05	24.5%	18.7%	3.5%	3.6%	15.9%
2005-06	36.0%	23.8%	5.4%	5.4%	20.3%
2006-07	42.5%	27.2%	6.3%	5.8%	28.6%
2007-08	51.4%	29.7%	8.5%	7.3%	32.2%
2008-09	52.5%	31.6%	8.0%	6.1%	35.4%
2009-10	53.2%	33.5%	8.1%	6.5%	38.0%
2010-11	48.6%	34.3%	9.2%	7.0%	35.2%
2011-12	58.2%	35.5%	10.4%	6.8%	35.4%
2012-13	56.8%	35.3%	9.8%	6.1%	n.a.

A longer-term picture of the Pakistan's oil imports in relation to imports, exports and the GDP is depicted in Figure 2. As the figure shows, the oil imports have assumed an increasing role in the economy. More pertinently, as a growing percentage of exports, the oil imports have come to claim a large share of the export earnings, which have been on the rise since 2004 in particular. However, the figure also shows that in the 1980s the country experienced a similar rise in the oil imports relative to exports. It seems that the reliance on oil imports is a more fundamental and long-term problem.

Fig. 2. Pakistan's Oil Imports



4. ENERGY PROJECTS AND THE CAPITAL EXPENDITURE REQUIREMENTS

A fundamental reason for Pakistan' chronic deficiency in the energy sector is the fact that the country is lacking resources. There are no major oil deposits, and unexploited hydro-electric sites are limited and small. Due to political choices regarding the nuclear weaponry and technology in the past, driven by security concerns, the options of building new nuclear plants for civilian use also seem to be limited in view of the associated international concerns. The recent China-Pakistan Nuclear Reactor deal (WSJ, Oct. 16, 2013) involves Pakistan acquiring two large nuclear power reactors (1000 MW each) from China and will cost $9.1 billion. Notwithstanding the opposing international stance, the capital investment will need to be serviced, which will require additional foreign exchange earnings. There are prospects for coal based energy plants, mainly based on Thar Coal Field, but these are still shrouded in technological and financial uncertainties. However, besides the constraint of natural resources, another constraint involves financing energy projects that require large inflows of foreign capital and technology, even if there is a miraculous expansion in the country's resource endowment. This financial constraint has not been addressed adequately in previous studies on Pakistan.

There are various projects and structural measures in the planning and implementing stages relating to an increasing share of renewal energy production, diversification and rebalancing of the energy production mix. This will reduce oil intensity and exploration for fossil fuels [see for example, Pakistan (2013); NEPRA (2013)]. However, the energy infrastructure and production projects are heavily capital and technology-intensive that will necessitate large initial foreign investment as well as subsequent foreign exchange outflows on account of repatriation of returns and the principle. Moreover, the gestation periods for energy projects are generally quite long, which increases the final capital costs due to interest that would accrue during the period of construction.

The Capital expenditure (CAPEX) requirements for energy projects vary depending on the individual country, type and technology of plant. The US Energy Information Agency (EIA) provides estimates of the "overnight" capital required for various types of energy projects.[4] These costs, summarised below, indicate that a power project will call for a capital cost in the range of $2.1 to $8.3 billion in the USA. Capital costs for developing countries are much lower, but still substantial compared to their resources.

As a reference we can consider India's Ultra Mega Power Projects (UMPP). These are a series of ambitious power projects planned by the Government of India to provide "power for all" by the end of the Eleventh Five-Year Plan (2007–2012). The UMPPs would create additional capacity of at least 100,000 MW. The projects, with an average capacity of 4000 MW are estimated to cost approximately INR15,000 crores, roughly equivalent to USD 2.5 billion each.

[4]The term "overnight" refers to the cost of the project as if it would be constructed 'overnight' and no interest was incurred during its construction.

Table 2

Overnight Capital Cost ($/kW)

Type of Plant	Min	Max	Average
Coal	2,934	6,599	4,416
Natural Gas	676	7,108	2,132
Uranium	5,530	5,530	5,530
Biomass	4,114	8,180	6,147
Wind	2,213	6,230	4,222
Solar	3,873	5,067	4,374
Geothermal	4,362	6,243	5,303
Municipal Solid Waste	8,312	8,312	8,312
Hydroelectric	2,936	5,288	4,112

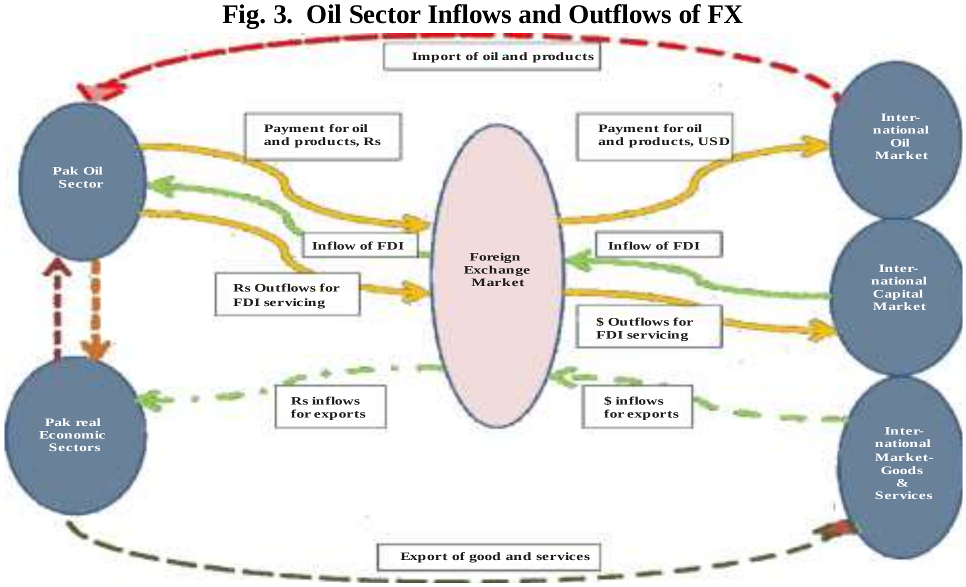
Source: US Energy Information Agency, http://www.eia.gov/forecasts/capitalcost/

As discussed in the previous section, it is likely that Pakistan will remain dependent on foreign imports to meet its energy requirements in the future and the country will need to generate adequate foreign exchange resources to secure its energy needs. We can then proceed to develop a simple model for estimating the country's foreign exchange requirements.

5. PROJECTION OF FOREIGN EXCHANGE REQUIREMENTS

The main implication of the country's chronic dependence on imported energy is a continuing pressure on its foreign exchange resources. In this section, we develop a conceptual model for projecting the demands on the foreign exchange resources given the energy sector's long-term reliance on imports and foreign direct investment in building new power capacity. The conceptual model is schematically presented in Figure 3.

Fig. 3. Oil Sector Inflows and Outflows of FX



Our model for projecting future FX requirements is a two-sector model: the energy sector and the rest of the economy. The energy sector imports oil and incurs payment obligations in foreign exchange. Besides oil and related imports, the energy sector also requires foreign exchange that can materialise as FDI for plant, equipment and technology. The inflow of FDI, however, creates obligations to service the capital investments; if these are debt inflows, it would involve interest and repayments of the principal. If these are equity investments, we will need to repatriate profits to the investors' commensurate with their expected risk adjusted returns as well as provide for possible liquidation. In addition, there would be obligations such as payments for royalties, management and licensing fees, etc. These three kinds of foreign exchange transactions are shown in Figure 3 as solid lines. As far as the non-energy sector is concerned, we, for this exercise, may assume that the import of goods and services are paid for by this sector's matching exports. Thus, any increase in the FX earnings from exports of goods and services, would be offset by additional imports of goods and services other than oil. These transactions are depicted in the figure as dotted lines. This simplification allows us to focus on the oil sector's FX requirements, which are relevant to the present analysis.

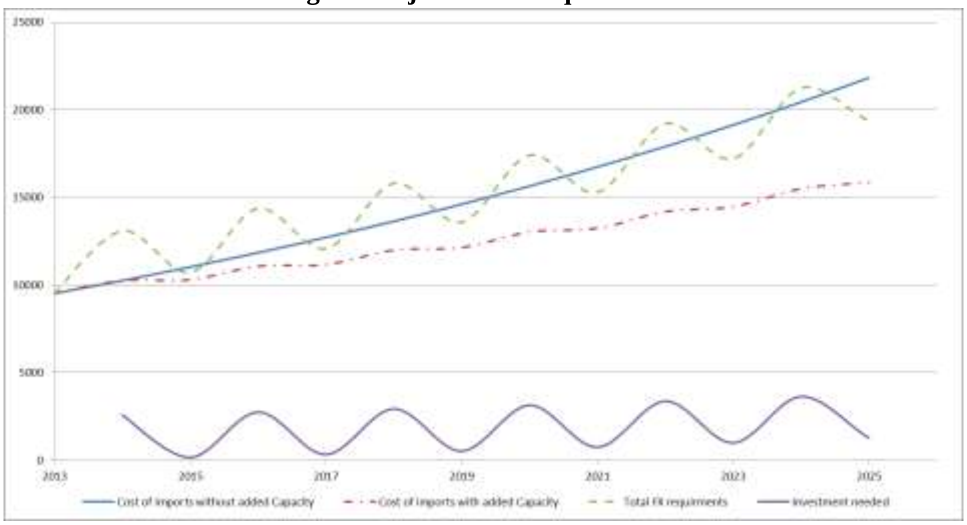
6. MODEL SIMULATION RESULTS AND PROJECTIONS

Given the simplified model for the oil sector's FX flows in Figure 3, we conduct a simulation exercise under certain simplifying assumptions and stylised facts as explained below.

Our starting points are the country's current GDP, its oil consumption, production and import levels. We assume as a base case that the country would target a 6 percent per annum real growth rate in its GDP, and that the oil consumption is a direct function of the GDP. This implies that the country's energy intensity is held constant, though it can be argued that it may increase or decrease as incomes rise. At the first pass, we hold the current domestic production of oil as constant, which allows us to determine the quantity and the value (assuming constant oil prices) of the oil imports. Next, the required quantity of oil imports (in M tons) is converted into TWh (tera watt hours) per year. We assume that the country would invest in the energy sector each year to create additional power capacity that would be adequate to meet the annual addition in import requirements. The additional capacity is created at an assumed overnight cost of $2,000 per KW (base case). We assume that the new power generating capacity comes on stream in the following year, which will help to attenuate the import bill in the following year. Thus, the foreign exchange required as FDI is projected. The final calculation involves determining the servicing obligations resulting from the FDI, which are assumed to be 10 percent of the projected cost per year, as a base case. Working with these assumptions, we project 13 years into the future up to year 2025. Our projections are, however, based on the assumed growth rates and are, therefore, subject to related limitations.

The results of the simulation are presented in Table A-II (in the Appendix) and are shown in Figure 4. The results show that, by increasing domestic production capacity, the oil sector is able to reduce its FX requirements, compared to when no new capacity is added. The demand for foreign exchange by the year 2025 is projected to be US$ 21.8 billion without FDI in new power generation; this demand with the FDI forthcoming will be curtailed to US$ 15.8 billion, a saving of about 27 percent. However, when we include the CAPEX foreign exchange requirements, the total FX requirements are in the range of US$19-21 billion, essentially eliminating these savings. The main conclusion that can be drawn from our simulation is that the oil sector is likely to remain a substantial net user of the foreign exchange resources. Table A-IV contains results from simulating foreign exchange requirements for the year 2025 under various assumptions regarding rate of growth, FDI servicing and the required CAPEX per KW capacity.

Fig. 4. Projected FX Requirements



7. IMPLICATIONS FOR MACRO-ECONOMIC STRATEGIES

The country's chronic energy deficiency has broad implications for macro-economic policies and management with respect to: the foreign exchange regime, interest rates, foreign trade, savings, and domestic and foreign direct investment policies. The energy deficiency, and its logical consequences for the demand for foreign exchange in particular, have implications for exchange rate policies; see e.g., Mangla (2011) and Ahmad (2009).

Pakistan has experienced a real growth rate of about 4.1 percent per annum over 1991-2010, which is not much higher than the *Hindu growth rate* of 3.5 percent.[5] As a comparison, the economy of India has been growing at a rate of around 6-8 percent since economic liberalisation began in the 1990s. The energy deficiency directly affects the economic growth rates and can be a binding constraint on the country's growth. In order to achieve a growth rate unconstrained by energy availability, the country must be able to import its energy requirements and/or expand its domestic energy production through capital investment. Either way, the country would require foreign exchange resources. As we have shown in the previous sections, the energy sector is likely to remain a net user of

[5]The 'Hindu rate of growth' is a derogatory term referring to the comparatively low annual growth rate of the socialist economy of India before 1991. At the same time, Pakistan grew by 5 percent, Indonesia by 6 percent, Thailand by 7 percent, Taiwan by 8 percent, and South Korea by 9 percent. The term was coined by Indian economist Raj Krishna and popularised by Robert McNamara.

foreign exchange funds. Thus, the logical way out is to expand the export capabilities and making export expansion central focus of the growth strategy.

In 2000, Pakistan officially moved away from the managed exchange rate to a floating exchange rate regime and can be categorised as managed floater per its official pronouncements.[6] IMF's *de facto* classification of exchange rate regimes, as of July 31, 2006, however, notes that, "the regime operating *de facto* in the country is different from its *de jure* regime," and categorises Pakistan as following "other conventional fixed peg arrangements". A study by Rajan (2011) examining the exchange rate regimes in Asian countries over 1999-2009 period finds that, "Pakistan seems to operate rather ad hoc adjustable pegs." However, it finds insufficient evidence for the existence of any systematic exchange rate fixity, but notes a high degree of influence of the US dollar and negligible influence of the other currencies for Pakistan, suggesting that the country manages its currency against the US dollar.

Considering that the energy sector is central to the economic growth and shall likely remain import dependent, the FX policy needs to be redefined to reflect the projected demands of hard currencies. The FX rate, which would reflect its expected scarcity value, will be helpful in expanding exports and curtailing domestic consumption of oil and related products. Contrary to the above logical implication, there is empirical evidence that the Pakistani rupee "suffers from chronic overvaluation," [Ahmad (2009)]. There is also empirical support for Pakistan's economy as a victim of the *Dutch Disease*, an affliction caused by unrequited transfers and foreign aid.[7] Under this condition, remittances cause an appreciation of the real exchange rate, and loss of competitiveness of Pakistan's exports sector and at the same time increase share of the non-tradable sector in the economy. Makhlouf and Mughal (2011), Javaid (2009) and Ahmed (2009) find empirical support for the Dutch Disease hypothesis for Pakistan.

The exchange rate has to be consistent with the reality of the country's chronic energy deficit. This implies that the exchange rate should not only reflect its fair value notwithstanding the Dutch Disease, but may also be tilted in favour of the export sector. The current managed-float seems to be focused on the overall balance of payment, aimed at keeping a stable level of foreign reserves. Yet, the country has experienced declining foreign exchange reserves over the recent years. In order to create a fair playing field for the export sector, the managed-float regime should instead be focused on the current account balance minus the transfer payments. Such a policy would imply a higher FX rate compared to the rate prevailing under the current policy; i.e., a depreciation of rupee compared to its current value. Periodic capital account shocks, e.g., in 2013, are evidence to the adjustment of the Pakistani rupee. There would be a concurrent and steady buildup of foreign exchange reserves that may prove beneficial in other ways. First, it would exert a beneficial impact on the exports and at the same time a stronger dollar will also discourage excessive import consumption and help with energy demand management. Second, a steady increase in the FX reserves would provide more confidence to the foreign investor, which may be critical to attracting the needed FDI to the country. Third,

[6]See Janjua (2007) for details on the history of exchange rate regimes in Pakistan.

[7]The term originally referred to natural resource discovery, but has been used with reference to "any development that results in a large inflow of foreign currency, including a sharp surge in natural resource prices, foreign assistance, and foreign direct investment."

increases in the FX reserves would help to sterilise foreign exchange inflows, curbing inflation in the country. Fourth, a steady increase in FX reserves commensurate with the growth in the country's exports and GDP is also required to support trade transactions.

Exchange rate policies followed by China and India, two oil importing countries, have led to a steady increase in their foreign exchange reserves, which are currently reported at $3,557 and $281 billion respectively (until recently Indian reserves exceeded $300 billion). There is a consensus that China manages its currency to be undervalued in pursuit of an export led growth strategy. The steady increase in the Indian FX reserves also points out to a slight undervaluation of the INR.

Another aspect of the exchange rate policy relates to its volatility. As Engel and Hakkio (1993) explain, the system of fixed but adjustable rates, as followed by Pakistan, introduces a new kind of volatility: volatility caused by the expectations of exchange rate realignments. By eliminating the market's uncertainty about the future exchange rate, a system of absolutely fixed exchange rates reduces *normal* volatility. However, when the rates are fixed but adjustable, the market knows that realignment may occur and the speculation around the magnitude and timing of the realignment will be reflected in exchange rate volatility. Therefore, between realignments, exchange rate volatility will tend to be within normal limits, but around the time of realignments it can be extreme. If the equilibrium rate continues to trend upward or downward, then the incidence of realignment increases, and with it the incidence of extreme volatility also rises.

From the point of view of the foreign investor, a volatile and steadily weakening currency is an anathema to FDI. With larger FX reserves the float managers are in a stronger position to dampen volatility, absorb short-term shocks, and thus reduce FX economic and transaction exposure for the foreign investor.

In addition to the exchange rate policy within the managed-float regime, there are implications for the monetary and fiscal policies. Inflation and interest rates differentials are main determinants of the FX rate, which are affected by monetary and fiscal policies. Fundamental macro-economic relationships link saving gaps, public deficits and current account deficits. It is quite basic that exchange rates would be strengthened by subduing inflation and curtailing fiscal deficits. However, from the perspective of meeting the energy sector's projected FX requirements, a prudent management of the monetary and fiscal policies assumes greater significance.

Monetary policy can also be helpful by maintaining higher real interest rates. Due to historical inflation rates well in excess of nominal interest rates, the real interest rates in Pakistan have tended to be negative. Partly because of this, in addition to the adverse security situation, Pakistan has not been the beneficiary of foreign capital flows to the same extent as other emerging countries. India, for example, has been able to capitalise on the global liquidity resulting from quantitative easing policies followed by major developed countries.

As a case in point, India's central bank recently raised policy interest rates for the fourth time in six months to fight high inflation, while pulling away from the emergency measures recently put in place to support the slumping rupee. In a related move, RBI started subsidising some of the cost of hedging against currency risk in foreign currency deposits and loans. The programme has raised $10 billion since then; the interest rate of about 4 percent on the NRI deposits has been so attractive that some international banks have even been offering loans to non-residents (WSJ, Oct 24, 2013). Thus, measures to reduce FX risk with guarantees for repatriation and against restriction/partial blocking of FX funds would be necessary for attracting foreign direct and portfolio investment.

In addition to the monetary and fiscal policy measures that are consistent with the long-term dependence on imported energy, institutional and governance measures will need to be addressed; these issues have been extensively discussed, e.g., see [Uppal (2011)]. Non-economic measures, such as ensuring political stability and security, in support of FDI and foreign portfolio investment have been thoroughly discussed in the literature and there is a body of good practices that are recommended for creating a suitable environment.

8. CAPITAL ACCOUNT AND MACROECONOMIC POLICY

Finally, a few observations on the capital account and the macroeconomic policy are warranted. Theoretically, the opening of the capital account should improve the country's access to private foreign capital, *ceteris paribus*, but because of domestic security and economic and political concerns, the inflow of private capital has significantly fallen over 2009-2013. Haque (2011) has demonstrated that although capital outflows were not a major cause of the decline in foreign exchange reserves during Pakistan's economic crisis of 2008, the open capital account and rupee convertibility have made the country more vulnerable to outside shocks. Haque further identifies three areas where policy-makers in Pakistan face serious challenges, i.e., (i) macroeconomic management, (ii) controlling tax evasion, which the Pakistani rupee's convertibility has made easier, and (iii) minimising the real cost of portfolio investment to the country.

The movement of capital and international trade are two indicators of global integration. The magnitudes of these two flows relative to Pakistan's GDP provide a good indication of its degree of global integration. Unfortunately, Pakistan's scores on both these accounts have continuously deteriorated. The ratio of foreign trade (i.e., exports plus imports) to GDP for Pakistan fluctuated between 40 and 45 percent during 2004-08, but fell sharply to less than 35 percent in 2009 and continues to fall in recent years. On the contrary, India's trade ratio gradually rose to about 50 percent of GDP, which was initially of the same order of magnitude as Pakistan's; India has become more globalised in its trade sector.

An open capital account also calls for a more vigilant macro-economic management because of a potential for economic disruption and increased vulnerability to external shocks. As Reinhart and Rogoff (2008) note: "Periods of high international capital mobility have repeatedly produced international banking crises, not as famously as they did in the 1990s, but historically," (p. 8). Similarly, Rodrik and Subramanian (2008) observe that "countries that grow more rapidly are those that rely less and not more on foreign finance; and in turn foreign capital tends to go to countries that experience not high, but low productivity growth." Haque notes, "The high dependency on foreign sources to finance domestic investment has made Pakistan's economic performance highly vulnerable to outside factors. There is little question that this dependency will have to be reduced and domestic savings rate drastically raised if economic growth in Pakistan is to reach levels comparable to the rapidly growing Asian economies."

In summary and in looking at the broader picture, it is the trade deficit, rather than the decline in capital flows, that is the basic cause for loss of foreign exchange reserves. Thus, energy deficit and concomitant foreign exchange liabilities will require a significant boosting of Pakistan's exports. In recent years the country has come to rely on foreign remittances to meet import requirements. These inflows are, however, a mixed bag as alluded before. In addition, recent global economic developments, such as tapering off the quantitative easing and recent volatility in emerging economies, FX volatility and capital account deficits and higher interest rates in the BRICs economies are not good omens for the Pakistan's economy and its trade sector.

9. SUMMARY AND CONCLUSIONS

Pakistan's economy is greatly exposed to high and volatile oil prices when compared to commonly used economic indicators of a country's vulnerability; these include a greater share of oil imports in a percent of gross domestic product (GDP), a high proportion of oil usage in the primary energy supply, and rising oil imports and expenditure over time. It is likely that Pakistan will remain dependent on foreign imports to meet its energy requirements for a long time to come and will need to generate commensurate foreign exchange resources to ensure long-term energy security. An issue which has been investigated in this analysis relates to how the energy sector's foreign exchange requirements for meeting current consumption and for capital expenditures for creating domestic capacity would be financed. This paper has tried to address this question and identify its implications for the country's macroeconomic policy and management.

The paper addresses the implications for macro-economic policies given the country's chronic dependence on imported energy and continuing pressure on its foreign exchange resources. The basic fact remains that the integration of energy policy plans with macro-economic objectives has remained weak. Pakistan's export sector growth has not managed to offset the rising oil import bill. To add to the energy woes, the deteriorated security situation in Pakistan has led to a significant decline in foreign investment.

We have proposed a *chronic energy deficit* hypothesis by developing a model for projecting the energy sector's long-term requirements for foreign exchange. An analysis of the country's long term import and capital inflow requirements presents a picture of long-term import dependency. As a result of the country's chronic dependence on oil imports, the economy will remain greatly exposed to high and volatile oil prices.

A fundamental issue for Pakistan is how the energy projects requiring large inflows of foreign capital and technology would be financed. The energy infrastructure and production projects are heavily capital and technology intensive, and will necessitate large initial foreign investment as well as subsequent foreign exchange outflows on account of repatriation of returns and the principle. It is this financial constraint, which has not been addressed adequately in previous studies. The main implication here is that there will be a continuing pressure on the county's foreign exchange resources. Any increase in the FX earnings from exports of goods and services in the normal course is likely to be offset by additional import of goods and services other than oil.

We conducted a simulation exercise, which shows that when we include the required FDI for the CAPEX, the oil sector requires additional net inflows of FX resources 6 percent to 18 percent above the base case. The demand for foreign exchange by the year 2024-25 is projected to be US$ 20-21 billion without the FDI in new power generation. However, when we include the CAPEX foreign exchange requirements, the total FX requirements are in the range of US$ 23-24 billion.

The country's chronic energy deficiency has broad implications for macro-economic policies and management with respect to the foreign exchange regime and foreign direct investment policies. Our analysis suggests that the FX policy needs to be redefined to reflect the projected demands on hard currencies. The FX rate, which would reflect its expected scarcity value will be helpful in expanding exports and curtailing domestic consumption of oil and related products. Moreover, Pakistan's economy is likely afflicted by the *Dutch Disease,* which is an affliction caused by unrequited transfers and foreign aid, and leads to appreciation of the real exchange rate and weakening of the competitiveness of Pakistan's exports sector. Therefore, our exchange rate policy has to be consistent with these realities.

APPENDIX

Table A-I

Pakistan's Oil Consumption (Thousand Barrels Per Day)

Year	Petroleum Consumption	Domestic Oil Supply	Consumption-Production Gap	Domestic Production %
1980	104.000	11.200	92.800	10.8%
1981	113.000	11.200	101.800	9.9%
1982	134.000	13.200	120.800	9.9%
1983	137.000	14.200	122.800	10.4%
1984	140.000	18.200	121.800	13.0%
1985	159.672	36.200	123.472	22.7%
1986	165.748	42.109	123.639	25.4%
1987	180.425	42.070	138.355	23.3%
1988	194.201	45.144	149.057	23.2%
1989	205.635	48.031	157.604	23.4%
1990	220.051	62.039	158.012	28.2%
1991	221.059	63.341	157.718	28.7%
1992	227.210	63.675	163.536	28.0%
1993	256.420	62.549	193.871	24.4%
1994	282.170	57.651	224.519	20.4%
1995	298.094	61.948	236.146	20.8%
1996	326.903	57.624	269.279	17.6%
1997	333.036	59.560	273.476	17.9%
1998	346.835	57.843	288.992	16.7%
1999	368.569	56.572	311.997	15.3%
2000	365.014	56.763	308.252	15.6%
2001	360.125	63.374	296.750	17.6%
2002	355.895	67.931	287.964	19.1%
2003	336.599	64.330	272.269	19.1%
2004	326.846	66.592	260.255	20.4%
2005	336.186	68.126	268.060	20.3%
2006	357.077	69.257	287.820	19.4%
2007	382.259	68.687	313.573	18.0%
2008	389.752	62.604	327.148	16.1%
2009	390.935	59.846	331.089	15.3%
2010	392.300	64.898	327.402	16.5%
CAGR	**3.51%**	**1.75%**		

Table A-II

Projected Foreign Exchange Requirements for the Oil Sector – USD Million

Year	Without New Capacity	Capital Cost	With Added Capacity	For FDI Servicing	Total (Incl. CAPEX)
2013	9,525	0	9,525	–	9,525
2014	10,254	2,581	10,254	258	13,093
2015	11,027	155	10,298	274	10,726
2016	11,846	2,745	11,073	548	14,366
2017	12,714	329	11,166	581	12,076
2018	13,634	2,929	11,993	874	15,797
2019	14,610	524	12,142	926	13,592
2020	15,644	3,137	13,028	1,240	17,404
2021	16,740	744	13,238	1,314	15,296
2022	17,902	3,370	14,189	1,651	19,210
2023	19,134	991	14,469	1,750	17,211
2024	20,439	3,631	15,495	2,114	21,240
2025	21,823	1,268	15,853	2,240	19,362
Average	15,481	1,867	12,767	1,148	15,781

Table A-III

Total FX Requirements for the Year 2025 (USD Million)
(Projections under Different Assumptions)

Annual Growth Rate		FDI Servicing Cost		CAPEX Cost (per KW)	
3%	$13,350	4%	$18,017	$ 1,250	$ 18,046
4%	15,073	6%	18,466	$ 1,500	18,485
5%	17,066	8%	18,914	$ 1,750	18,923
6%*	19,362	10%	19,362	$ 2,000	19,362
7%	21,995	12%	19,810	$ 2,250	19,800
8%	25,005	14%	20,258	$ 2,500	20,239
9%	28,435	16%	20,706	$ 2,750	20,677

* Base case.

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Burning of Crop Residue and its Potential for Electricity Generation

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This paper identified the factors influencing the rice crop residue burning decision of the farmers and the potential of the burnt residue to generate electricity. For this study, data were collected from 400 farmers in the rice-wheat cropping system. Effects of different variables on the burning decision of rice residue are investigated through logit model. A number of factors had significant effects on the burning decision of crop residue. These included farming experience of the farmer, Rajput caste, farm size, owner operated farm, owner-cum-tenants operated farm, silty loam soil type, livestock strength, total cost associated with the handling of residue and preparation of wheat field after rice, availability of farm machinery for incorporation, use of residue as feed for animals, use of residue as fuel, intention of the respondent to reduce turnaround time between harvesting of rice and sowing of wheat, convenience in use of farm machinery after burning of residue and the geographic location of farm. The overall quantity of rice straw burnt is estimated to be 1704.91 thousand tonnes in the rice-wheat cropping areas with a potential to generate electric power of 162.51 MW. This power generation from crop residues would be a source of income for the farmers along with generation of additional employment opportunities and economic activities on sustainable basis. In order to minimise the cost of haulage of rice straw, installation of decentralised power plants at village level would be a good option. Further, use of rice crop residue as an energy source can help in reducing foreign exchange requirements for import of furnace oil.

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1. INTRODUCTION

Most of the villages in Punjab have inadequate electricity supply. These villages have to face electricity shut downs because of severe electricity shortage in Pakistan. In Pakistan, household sector was the largest consumer of electricity with a share of 46.5 percent while major sources of electricity generation were fossil fuel (64.1 percent) and hydro (31.9 percent) during 2011-12 [Pakistan (2013)]. Due to political reasons, Government of Pakistan is not developing new hydro resources for electricity generation but generates electricity through burning of fossil fuel, which produces greenhouse gases. Moreover, high oil prices have adverse impacts on the economy of Pakistan. Thus, it is important to explore new means of electricity generation.

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Bioenergy accounts for about 10 percent of total energy consumption in the world and it is expected that this source will play greater role in near future [Jiang, *et al.* (2012)]. Research work indicates that open field burning of crop residue is a common practice in many countries [Gadde, *et al.* (2009)]. It has been estimated that annually on average 730 teragram (tg) of biomass are burnt in Asia and out of which 250 tg are from agricultural burning. Open burning of biomass is emitting 0.37 tg of SO_2, 2.8 tg of NOx, 1100 tg of CO_2, 67 tg of CO and 3.1 tg of methane. However, emissions of crop residues burning is contributing about 0.10 tg of SO_2, 0.96 tg of NOx, 379 tg of CO_2, 23 tg of CO and 0.68 tg of CH_4 [Streets, *et al.* (2003)]. A growing concern regarding residue burning emerges from its effects on air pollution and climate change. Incomplete combustion of biomass such as agricultural residues generates black carbon [Kante (2009); Bond, *et al.* (2013)] which is the second largest contributor to global warming after carbon dioxide [UNEP (2009); Chung, *et al.* (2005); Ramanathan and Carmichael (2008)]. Black carbon absorbs radiation and warms the atmosphere at regional and global scales. Increased concentration of black carbon and other pollutants, observed in the high Himalayas, is expected to enhance glacier melting. Black carbon emissions and other types of aerosols have also given rise to atmospheric brown clouds (ABCs) in Asia [Nakajima (2009)]. The aerosols in ABCs decrease the amount of sunlight reaching the earth's surface by 10 to 15 percent and enhance atmospheric solar heating by as much as 50 percent. In general, ABCs and their interactions with greenhouse gases significantly affect climate, hydrological cycle, glacier melting, agricultural and human health [UNEP.RRC.AP (2012)]. Thus, all it indicates that open field burning of crop residue is the most undesirable treatment of crop residue from the perspective of environmentalists. This treatment of crop residue also worsens the problem of global warming.

Rice-wheat cropping system is dominant in the Indo-Gangetic Plain (IGP) which comprises of parts of Pakistan, India, Bangladesh, and Nepal. IGP is producing enormous quantity of rice straw and it is usually not used as feed for animals [Badarinath, *et al.* (2006)]. Consequently, rice residues are generally burnt and it is often questioned, why farmers burn it? Research work done shows that burning of rice residues increases the short-term availability of some nutrients i.e. P and K [Erenstein (2002)] it also results in the loss of plant nutrients [Biederbeck, *et al.* (1980); Gupta, *et al.* (2004); Heard, *et al.* (2006); IRRI-CIMMYT Alliance Cereal Knowledge Bank (2007)] in addition, it also creates health and environmental problems [The Lung Association (2009); Nori (2005); Graham, *et al.* (1986); Prasad and Power (1991)]. Burning of crop residues also reduces microbial population [Raison (1979)] and organic carbon [Rasmussen, *et al.* (1982); Heard, *et al.* (2006)]. However, incorporation of crop residue increases organic carbon and nutrient contents of soils and crop yield [Sharma, *et al.* (1985); Sidhu and Beri (1989); Ganwar, *et al.* (2006); Hartley and Kessel (2005); Kessel and Horwath; Prasad, *et al.* (1999); Hooker, *et al.* (1982); Bhatnagar, *et al.* (1983); Garg (2008); Surekha, *et al.* (2006); Prasad, *et al.* (1999); Tripathi, *et al.* (2007)].

There is an increasing interest in converting crop residues to energy products due to new emerging technologies and rising energy prices [Idania, *et al.* (2010); Scarlat, *et. al.* (2010)]. There are number of studies that indicate the existence of potential of electricity generation through the usage of crop residue as a fuel in power generation plants [Freedman (1983); Ergudenler and Isigigur (1994); Shyam

(2002); Jingura and Matengaifa (2008); Karaj, *et al.* (2010); Hiloidhari and Baruah (2011); Nguyen, *et al.* (2013)]. Liquid or gaseous biofuel can be produced from crop residues like cereals and corn, by using thermo-chemical or biological techniques [Elmore, *et al.* (2008)]. Hiloidhari and Baruah (2011) found 16 different types of crop residue in Sonitpur district of Assam, India. They found rice crop as a dominant source of residue and about 0.17 million tonnes of residue biomass has a potential to produce about 17MW power. According to them, decentralised crop residue based power generation can solve the problem of acute shortage of grid connected power supply. Similarly, Nguyen, *et al.* (2013) estimated the electricity generation from wheat straw instead of coal and natural gas. Their study also indicates that usage of straw will reduce global warming and use of non-renewable energy. Hence, there is an increasing recognition that interrelations between agriculture, biomass production, bio-energy and climate should be better understood in order to estimate the realistic bioenergy potential [Haberal, *et al.* (2011)]. According to Freedman (1983), a huge potential of biomass energy is available in rural areas in the form of rice crop residue. Potential amount of energy that can be obtained from this residue is 3.70×10^{10} J/ha/year under traditional methods, $7.93 \text{ X } 10^{10}$ J under labour intensive and $8.36 \text{ X } 10^{10}$ J under capital intensive methods. Accurate estimates of the amounts of produced crop residues, their disposal pattern (quantity used as feed for animals, quantity used as fuel for cooking, quantity incorporated into soil, quantity burnt to clear the field in order to improve the performance of farm machinery for bed preparation for the next crop, etc.) and the potential amount of crop residue that can be saved from burning and used for bioenergy generation on sustainable basis is very important. According to Jingura and Matengaifa (2008), biomass can provide 47 percent of the energy consumption in Zimbabwe and crop residue is its major component. According to them, estimated annual amount of crop residue in Zimbabwe is 7.805 Mt and it has an energy potential of 81.5 PJ per year. Thus crop residue can be used for energy generation besides feeding of animals and improvement of soil fertility. Moreover, environmental advantage connected with burning of residue for electricity generation can be revealed from the fact that this usage does not compete with food or cash crops and no land use change is required [Barz and Delivand (2011)]. Shyam (2002) identified crop residue as a sustainable source of energy supply and suggested establishment of decentralised electricity supply system based on crop residue in rural areas. Likewise, Karaj, *et al.* (2010) analysed the existence of potential of electricity generation in Albania through biomass (bioenergy crops, agricultural and forestry residues and wastes). They considered generation of steam and biogas from the biomass to run steam generators and turbines for the generation of electricity. Energy content in biomass was estimated theoretically by estimating biomass using statistical reports, literature review and personal investigations. For Albania, it is found that 4.8 million tons of dry biomass was produced in year 2005 with energy content 11.6 million MWh/a. This energy content has technical potential of 3 million MWh/a of electrical energy production. This amount of electrical energy is equal to 45.8 percent of total electrical consumption of Albania. Study of Ergudenler and Isigigur (1994) identified agricultural residue as a potential fuel for sustainable electricity generation in Turkey.

According to them, usage of agricultural residue in power plants has less environmental impacts and results in the reduction of net emissions of CO_2, SO_2 and NO_x as compared to thermal power plants in which lignite is major source of fuel. Open field burning of residue has adverse impact on the soil fertility [Malhi and Kutcher (2007)] and on the environment because of greenhouse gas emissions. So by using this residue for electricity generation, one can avoid the problem of greenhouse gas emissions and intensity of electricity shortage problem. As in Pakistan, no comprehensive study has been carried out to identify the factors influencing the rice crop residue burning decision by the farmers and the potential of burnt rice residue for electricity generation, so this study is conducted to answer this question. The specific objectives of the study are:

(1) To determine the factors, which influence farmers to make decision of burning of rice crop residue, and
(2) To find out the quantity of electricity that can be produced by using the rice straw that is currently being burnt.

The rest of paper is organised as follows. Section 2 describes the methodology along with model specification and description of data set. Section three discusses the results of models and key determinants of the rice crop residue burning decision by the farmers along with potential of the burnt residue for electricity generation. Last section deals with summary and suggestions for the generation of electricity.

2. METHODOLOGY

The first part of the methodology presents a model to answer the question why the farmers burn the rice residue. The second part is concerned with the methodology used in estimating the potential electricity that can be generated from the residue, which is being burnt by farmers. Finally, procedure used for data collection is presented.

2.1. Logit Model of Residue Burning Decision

Adoption of burning or non-burning (i.e. complete removal/incorporation) residue management practice essentially involves a choice by the farmer. Binary choice models are more appropriate when a choice is made between the two alternatives [Judge, *et al.* (1980); Pindyck and Rubinfeld (2000)]. The linear probability model suffers from a number of deficiencies i.e. variance of the disturbance is heteroscedastic—the distribution of this term is not normal and it does not constrain the predicted values to lie between 0 and 1- [Amemiya (1981); Capps and Kramer (1985)]. Problems of the linear probability model can be overcome through the monotonic transformation (Probit or logit specification), which guarantees that predictions lie in the unit interval [Capps and Kramer (1985)]. The choice of model i.e. probit or logit is mainly a question of convenience [Hanushek and Jackson (1977)]. In this paper, logit model is used. A farmer will make his choice based on the rule of utility maximisation. According to this rule, farmer i selects the alternative from the choice set that maximises his utility U_i. Since the researcher does not have complete information about all the factors that are considered important in the decision making process by farmers while making a choice, so the utility function U_{ij} is broken down into two components [Guadagni and Little (1983)], i.e.

$U_{ij} = V_{ij} + \varepsilon_{ij}$ Where, U_{ij} is the overall utility of *i*th farmer for *j*th choice,

V_{ij} is a systematic utility component of *i*th farmer for *j*th choice,
ε_{ij} is a stochastic component of *i*th farmer for *j*th choice.

The decision maker chooses the alternative from which he gets the maximum utility. In the binomial or two alternatives case, farmer chooses alternative 1 if and only if.

$$U_{i1} \geq U_{i2} \quad \text{or} \quad U_{i1} + \varepsilon_{i1} \geq U_{i2} + \varepsilon_{i2}$$

In probabilistic terms, the probability that alternative 1 is selected is given by

$$\Pr(1) = \Pr(U_{i1} \geq U_{i2}) = \Pr(V_{i1} + \varepsilon_{i1} \geq V_{i2} + \varepsilon_{i2}) = \Pr(\varepsilon_{i2} - \varepsilon_{i1} \leq V_{i1} - V_{i2})$$

It states that the probability of choosing alternative 1 is equal to the probability of the difference in stochastic utility of choice 1 and 2 being less than or equal to the difference in systematic utility of choice 1 and 2. Assuming that $\varepsilon_{i2} - \varepsilon_{i1}$ has a logistic distribution, the probability (P_i) that farmer *i* burns residue is a function of an index variable (Z_i) summarising a set of farmer attributes, which can be written as:

$$P_i = F(z_i) = \frac{e^{Z_i}}{1+e^{Z_i}} \text{ Where } Z_i = X_i^{/}\beta$$

Where β is a vector of coefficients; X_i is a vector of the *i*th farmer attributes and *e* is the base of natural logarithm. Z_i is a dichotomous variable, it takes the value of one if a farmer has adopted the practice of residual burning and takes the value zero otherwise.
The change in P_i with respect to change in X_i is given by:

$$\frac{\partial P_i}{\partial X_i} = (\frac{\partial F}{\partial z_i})(\frac{\partial z_i}{\partial x_i}) = f(z_i)\beta = \frac{e^{x_i^{/}\beta}}{1+e^{x_i^{/}\beta}}\beta_k$$

Where β_k is the *k*th element of the parameter vector β.

As P_i is equal to one if a choice is made and zero otherwise so the correct estimation procedure is maximum likelihood. The probability that the farmer burns the rice residue depends upon various attributes like farm size, number of farm fragments, livestock strength, age, education, farming experience and caste of farmer, ownership of farm, soil type, use of rice residue as feed, fuel, cost of collection and transportation of rice residue etc. Therefore, the following model is used to analyse the decision of rice residue burning:

$$\begin{aligned} BURN_i = {} & \beta_0 + \beta_1 AGE_i + \beta_2 EXP_i + \beta_3 PRIM_i + \beta_4 UPMAT_i + \beta_5 AMATR_i + \beta_6 JAT_i \\ & + \beta_7 ARIAN_i + \beta_8 RAJPUT_i + \beta_9 SIZE_i + \beta_{10} ONWER_i + \beta_{11} OWNCT_i + \beta_{12} FRAGM_i \\ & + \beta_{13} SILTL_i + \beta_{14} CLAY_i + \beta_{15} ANIMAL_i + \beta_{16} TCBURN_i + \beta_{17} WHTSOWN_i \\ & + \beta_{18} MACH + \beta_{19} FEED_i + \beta_{20} FUEL_i + \beta_{21} PBASM_i + \beta_{22} INSECT_i \\ & + \beta_{23} REDTURN_i + \beta_{24} CONMACH_i + \beta_{25} COLTRAL_i + \beta_{26} GUJRAN_i + \varepsilon_i \end{aligned}$$

Where, the variables are defined in Table 1.

Table 1

Variable Definitions

Variable Name	Description
BURN	1 if farmer adopted the practice of rice crop residue burning; 0 otherwise
AGE	Age of farmer in years
K2EXP	Farming experience of farmer in years
PRIM	1 if farming is the primary occupation; 0 otherwise
UPMAT	1 if educational level of farmer is up to matric; 0 otherwise
AMATR	1 if education level of farmer is above matric; 0 otherwise
JAT	1 if caste of farmer is Jat; 0 otherwise
ARIAN	1 if caste of farmer is Arian; 0 otherwise
RAJPUT	1 if caste of farmer is Rajput; 0 otherwise
SIZE	Operational size of farm in acres
OWNER	1 if farmer is owner operator; 0 otherwise
OWNCT	1 if farmer is owner-cum-tenant; 0 otherwise
FRAGM	Number of places where the farm land is situated
SILTL	1 if the dominant soil type is silt loam; 0 otherwise
CLAY	1 if the dominant soil type is clayey; 0 otherwise
ANIMAL	Number of animal units on the farm
TCBURN	Total cost associated with the handling the residue and preparation of wheat field after rice
WHTSOWN	1 if wheat is sown before the end of November; 0 otherwise
MACH	1 if farm machinery is available for incorporation; 0 otherwise
FEED	1 if rice residue is used as feed for animals; 0 otherwise
FUEL	1 if rice residue is used as fuel; 0 otherwise
PBASM	Proportion of rice acreage allocated to super basmati and 385 basmati to total rice acreage
INSECT	1 if the intention of respondent is to control insects, weeds and diseases; 0 otherwise
REDTURN	1 if the intention of respondent is to reduce turnaround time between harvesting of rice and sowing of wheat; 0 otherwise
CONMACH	1 if burning of residue results in convenience in use of farm machinery; 0 otherwise
COLTRAN	Total cost associated with collection and transportation of rice residue
GUJRAN	1 if farm is located in Gujranwala district; 0 otherwise

2.2. Methodology for Determining the Potential of Electricity Generation from Rice Residue

Following steps are involved for calculating the generation of electricity from rice residue.

2.2.1. *Determining the Total Yield of Rice Crop and Residue*

Availability of accurate data about the crop residue is very essential for determining the potential of bioenergy in any country. Previous studies estimated the straw produced from the main product like grain and used a specific ratio of main product to straw to estimate the straw produced. Such a ratio of main product to straw varies from variety to variety and sometime even for a specific product because of differences in climatic and agronomic conditions under which the main product is produced. Consequently, the estimate of amount of crop straw produced either overestimated or underestimated the actual amount of straw produced. This study uses primary data collected from the farmers for the assessment of the quantity of straw produced and its disposal pattern. In this study in to order obtain the yield of rice crop and its residue, farmers were asked about the variety grown, area under each variety, yield of paddy and straw. This information was used to calculate the paddy yield and straw yield which came to 1624 kg and 1602 kg, respectively. Thus the ratio of paddy to straw was 1:0.99. This ratio was quite comparable with the ratio of 1:1 reported by Jiang, *et al.* (2012).

2.2.2. *Rice Area under Various Residue Management Practices*

In the study area, farmers were following different practices to manage the rice residue. Therefore, farmers were asked about the rice area managed under various residue management practices i.e. area from which residue was removed 100 percent (REMV), area from which pural was removed and lower parts of rice plant were burnt (RPBL), area from which pural was removed and lower parts of stem were burnt (BPLP), area from which pural was removed and lower parts of stem were incorporated (RPINC) and the area where the entire residue was incorporated (INC). The area where traditional manual method was used for harvesting, the residue was removed 100 percent and was used mainly as feed for animals.

2.2.3. *Estimation of Quantity of Rice Residue Burnt*

In two practices (i.e. RPBL and BPLP), burning of residue is involved. Moreover, there is not complete burning of residue in these practices as the lower parts of rice plant are not dry enough to catch fire. Consequently, we asked farmers about the proportion of rice residue burnt in these practices. This proportion was used to determine the quantity of rice residue burnt from the straw yield produced for each variety grown under these two practices. A weighted average quantity of residue burnt was obtained by weighting the quantity of straw burnt with the acreage of each variety for the practice RPBL and BPLP. Finally, quantity of residue burnt per acre under various residue management practices was weighted according to the acreage under each practice to determine the quantity of residue burnt per acre of rice harvested. This quantity of residue per acre was multiplied with the rice acreage in the rice wheat cropping system of Punjab, to estimate the total quantity of residue burnt. Assuming the same quantity of residue burnt per acre for the rice-wheat cropping system area, we estimated the total quantity of burnt residue in Punjab, Pakistan.

2.2.4. *Estimation of Biomass Power Potential*

Conversion of biomass to energy can be done by using various technologies i.e. thermo-chemical and bio-chemical [Jiang, *et al.* (2012)]. Thermo-chemical conversion technology is specifically suitable for loose biomass [Nussbaumer (2003)]. The most common process involves the direct combustion of fuels to produce thermal energy, which is used to produce steam and further to generate electricity by using steam turbines, steam engines or other energy converters [Barz (2008)]. Biomass power plants with different sizes of combustion can generate electricity from a few kilowatts to 100 MW with net conversion efficiency from 20 to 40 percent [Mckendry (2002); Nussbaumer (2003)].

In order to estimate the power potential, following expression is used.

$$RRPP_J = \frac{K \times ACR_J \times WAQRB \times LHVR}{T}$$

Where $RRPP_J$ is the rice residue biomass power potential of the J-th area; K is the overall energy conversion efficiency assuming a value of 20 percent [Hiloidhari and Baruah (2011)]; ACR_J is the rice acreage in acres in the J-th area; $WAQRB$ is the weighted average quantity of rice residue burnt per acre; $LHVR$ is the lower heating value of the rice straw. It is taken to be 15.03 (G) t^{-1} [Singh, *et al.* (2008)]; T is the annual operating duration in seconds.

2.3. Data

The data for this study were collected during the year 2010 from the two most important districts (i.e. Gujranwala and Sialkot) having share of maximum acreage in the rice-wheat system of the Punjab [Punjab (2009)]. Ten villages were selected randomly from the 36 villages already selected by the Federal Bureau of Statistics from each of the districts for the estimation of acreage and yield of various crops. These villages were considered as primary sampling units (PSU). Farmers within the PSUs were taken as secondary sampling units. A list of farmers was prepared in each village and then 20 farmers were randomly selected from different sizes in proportion to their number. Total sample comprised of 400 respondents. For the collection of data, a comprehensive questionnaire was constructed, which was modified after pre-testing. The data were collected by using personal interview method.

3. RESULTS

3.1. Influence of Different Factors on the Decision of Burning of Residue

Descriptive statistics of the variables used in the model are exhibited in Table 2.

The means of the qualitative variables refer to the proportion of respondents taking on particular qualitative attributes. For example, approximately 77 percent of the respondents are owner operators, roughly 20 percent of the respondents are owner-cum-tenants. Similarly, approximately 57 percent of the respondents are Jat, 13 percent Rajput and 6 percent Arian. The continuous variables indicate that each farm has, on average about 11.93 acres of land and the collection and transportation cost per acre of rice residue is Rs 485.84 (Rs 104 = 1 US$).

Table 2

Descriptive Statistics for the Variables Used in Logit Analysis

Variable	Mean	Std. Dev.	Minimum	Maximum
AGE	47.49	15.637	17	80
EXP	27.63	15.978	1	70
PRIM	0.923	0.268	0	1
UPMAT	0.403	0.491	0	1
AMATR	0.088	0.283	0	1
JAT	0.570	0.496	0	1
ARIAN	0.063	0.242	0	1
RAJPUT	0.128	0.334	0	1
SIZE	11.929	14.934	0.62	100
OWNER	0.765	0.425	0	1
OWNCT	0.198	0.399	0	1
FRAGM	1.508	0.779	1	4
SILTL	0.623	0.485	0	1
CLAY	0.348	0.477	0	1
ANIMAL	8.921	11.406	0	130
TCBURN	3061.639	1246.474	0	7850
WHTSOWN	0.835	0.371	0	1
MACH	0.103	0.304	0	1
FEED	0.740	0.439	0	1
FUEL	0.120	0.325	0	1
PBASM	73.551	38.001	0	100
INSECT	0.330	0.417	0	1
REDTURN	0.095	0.294	0	1
CONMACH	0.580	0.494	0	1
COLTRAN	485.835	478.800	0	4556.794
GUJRAN	0.50	0.501	0	1

The maximum likelihood estimates of the logit model are presented in Table 3. Likelihood ratio indicates that the amount of variation explained is significantly different from zero. Pseudo R^2 value is 0.433. The probability of burning rice residue was significantly associated (at 20 percent level) with fourteen variables out of twenty six variables included in the model. These factors were: (a) Farming experience of the farmer (EXP), (b) Rajput caste (RAJPUT), (c) Farm size (SIZE), (d) Farmer is owner operator (OWNER), (e) Farmer is owner-cum-tenant (OWNCT), (f) Soil type is silty loam (SILTL), (g) livestock strength on the farm (ANIMAL), (h) Total cost associated with the handling of the residue and preparation of wheat field after rice (TCBURN), (i) Farm k2 machinery availability for incorporation (MACH), (j) Use of residue as feed for animals (FEED), (k) Use of residue as fuel (FUEL), (l) Intention of the respondent to reduce turnaround time between harvesting of rice and sowing of wheat (REDTURN), (m) Burning of residue results in convenient use of farm machinery (CONMACH) and (n) The geographic location of farm in Gujranwala (GUJRAN) district.

Table 3

Maximum Likelihood Estimates for Logit Model

Variable	Estimate	Change in Probability	Z statistic
AGE	–0.0191	–0.0048	–1.100
EXP	0.0398*	0.0099	2.290
PRIM	–0.5552	–0.1357	–0.910
UPMAT	0.2375	0.0593	0.710
AMAIR	–0.4940	–0.1219	–0.720
JAT	0.0191	0.0048	0.050
ARIAN	–0.5119	–0.1260	–0.780
RAJPUT	0.9857[a]	0.2332	1.680
SIZE	0.0766**	0.0191	4.400
OWNER	–2.8688*	–0.5587	–2.240
OWNCT	–2.7415*	–0.5349	–2.070
FRAGM	–0.0493	–0.0123	–0.220
SILTL	1.1686[b]	0.2832	1.310
CLAY	0.9606	0.2341	1.080
ANIMAL	–0.0261[b]	–0.0065	–1.540
TCBURN	0.0002[a]	0.0001	1.820
WITHSOWN	0.4141	0.1028	0.940
MACH	–0.8701[b]	–0.2089	–1.550
FEED	–2.7507**	–0.5530	–6.300
FUEL	–0.9806*	–0.2335	–2.020
PBASM	0.0026	0.0007	0.640
INSECT	0.1035	0.0259	0.220
REDTURN	1.3046*	0.2945	2.280
CONMACH	1.7715**	0.4149	4.090
COLTRAN	–0.0001	–0.0001	–0.160
GUJRAN	0.6672*	0.3186	2.090
CONSTANT	0.7673	1.9147	0.400

The farming experience (EXP) had positive influence on the probability of burning rice residue. The probability of burning increased by one percent for each one percent increase in farming experience. A possible explanation for this behaviour is that 53.75 percent and 15.15 percent farmers perceive that residue burning improves the physical properties and increase soil nutrients of soil, respectively. Moreover, the results of the study show that 70.50 percent and 64.75 percent of the farmers perceive that burning of rice residue increases the yield of wheat and rice, respectively. The increase in the yield of both wheat and rice crops is due to substantial and ready availability of nutrients through ash to plants due to incomplete burning of rice residue as the temperature desired for complete burning is not achieved during the burning of residue [Kumar and Goh (2000)]. Further there is rapid conversion of nutrients from organic form to inorganic form N, P, K, Ca and Mg [Surekha, *et al.* (2006)].

The probability of burning of rice residue was increased by 1.91 percent for each percent increase in farm size (SIZE). This results from the fact that livestock strength per unit area decreases with increase in farm size and consequently the use of rice residue as feed falls.

Total cost associated with the preparation of field for wheat crop after rice was significantly related with the increase in probability of rice residue burning. The survey results show that the total cost associated with the preparation of wheat field after rice was Rs 3536.79 where the rice straw was burnt in the field compared with Rs 4097.83 for the incorporation of rice residue practice. This shows that farmers are adopting the burning practice as the cost associated with burning practice was substantially less than non-burning practice. Under the prevailing cost conditions, farmers will not stop rice residue burning practice unless they are compensated appropriately by other measures.

Tenure type i.e. owner operator (OWNER) and owner-cum-tenant (OWNCT) were significantly associated with the decrease in probability of rice residue burning by 55.87 percent and 53.49 percent, respectively. This shows that owner operators and owner-cum-tenant have long-term planning horizon and are concerned more with the sustainability of land resource.

The probability of burning of rice residue was decreased by 0.65 percent for each 1 percent increase in animal strength (ANIMAL). Because the effect of animal strength on the use of rice residue is positive, therefore, farmers have adopted less burning practice.

Availability of farm machinery for incorporation (MACH) of rice residue in the soil was significantly associated with the decrease in probability of rice residue burning by 20.89 percent. This suggests that ensuring the availability of farm machinery for incorporation can help in reducing the practice of burning.

Use of rice residue as feed (FEED) and fuel (FUEL) were both significantly associated with decrease in probability of rice residue burning by 55.30 percent and 23.35 percent, respectively. Thus the farmers can reduce the adoption of burning practice by utilising the residue for domestic purposes.

The probability of burning of rice residue was increased by 29.45 percent with the intention of the producers to reduce turnaround time between harvesting of rice and sowing of wheat (REDTUURN). Delay in sowing of wheat reduces its yield by 30 kg/day [Akhtar, *et al.* (1992)] and in order to sow on time farmers are burning residue to clear the field. Intention of the farmers to burn rice residue for the convenient use of farm machinery had positive and significant impact on the probability of residue burning by 41.49 percent. Thus farmers used burning practice for the convenient use of farm machinery for the preparation of fields for the wheat crop. Thus the reduction of turnaround time between harvesting of rice and sowing of wheat and convenient use of farm machinery demand the proper disposal of rice residue for obtaining better wheat yield.

Not surprisingly, producers in the Gujranwala district exhibited higher probability of rice residue burning than Sialkot district, the calculated change in probability was 16.53 percent. Larger farm size in Gujranwala district compared to Sialkot district probably contributed to this difference.

3.2. Potential for Electricity Generation

If one looks at the overall area of rice allocated to different residue management practices, then the full burn method ranks as first and removal ranks as second (Table 4). 58 percent of area under rice is fully burned, while 25 percent of rice area has full removal of residue. The remaining area is either partially burnt or a small portion is incorporated into the field. We observed a similar pattern of adoption of different residue management practices for different varieties of rice (see Table 4).

Table 4

Proportion of Rice Area with Various Varieties under Different Residue Management Practices

		Pattern of Residue Management (Percent of Total Rice Area)				
Variety	Area (Acres)	Complete Removal of Residue	Removal of *pural* and Burning of Lower Parts of Rice Plant	Burning of *Pural* and Lower Parts of Rice Plant	Removal of *pural* and Incorporation of Lower Parts of Rice Plant	Complete Incorporation
Super Basmati	2677	25	12	59	3	1
Basmati 386	810	26	12	53	9	0
Other Varieties	303	23	12	62	3	0
All Varieties	3790	25	12	58	4	1

The results of logit model indicate that total cost associated with the handling of residue and preparation of field for wheat crop after rice was significantly related with the increase in probability of rice residue burning. The survey results show that the total cost associated with the handling of rice residue and preparation of the wheat field after various rice residue management practices was the highest at Rs 4585.72 for the REMV practice and the lowest at Rs 3423.94 for the BPLP practice. The total cost was higher for RPBL, RPINC and INC by 25.56 percent, 26.51 percent and 19.68 percent, respectively, in comparison with BPLP. Thus, the burning of residue is the most economical method for handling rice residue and preparing the wheat field. Under the prevailing cost conditions, farmers will not stop rice residue burning unless they are compensated appropriately by other measures.

The proportion of the straw burnt for various varieties; ranged from 53.75 to 58.12 percent for the practice of removal of *pural* and the burning of the lower parts of rice plant; from 63.48 to 69.26 percent for the practice of burning the *pural* and the lower parts of the rice plant. In terms of quantity 931 kg and 1034 kg of rice straw per acre was burnt under these practices, respectively. On overall basis, 712 kg of rice straw per acre was burnt in the study area. Of the total surveyed respondents, 61 percent were of the view that the trend in rice residue burning was increasing although 31 percent thought it was decreasing. About eight percent thought there is no change. As reported by 46 percent and 65 percent of the respondents, respectively, the short turn-around time between the harvesting of the rice crop and the sowing of the wheat crop and inconvenience in the use of farm machinery were the major reasons for the burning of rice residue. Major reasons for not burning the residue included its use as feed for animals and for home cooking as reported by 95 percent and 24 percent of respondents, respectively.

On the basis of results of survey conducted in rice-wheat cropping system, total quantity of rice residue burnt is estimated at 1704.91 thousand tonnes. Using same basis as used for rice-wheat cropping system, total quantity of rice residue burnt is estimated at 3106.68 thousand tonnes for Punjab and 4159.05 thousand tonnes for Pakistan, which could be used for electric power generation.

On the basis of the quantity of rice residue burnt, the potential for electric power generation is estimated as 162.51 MW, 296.13 MW and 396.44 MW for the rice-wheat cropping system, areas of Punjab and Pakistan, respectably. The power scenario in the rice-wheat cropping area and in other areas in Punjab and Pakistan is characterised by fluctuating voltage, load shedding and unreliable supply. However, demand for electricity is increasing over time and is expected to increase many folds in coming years in Pakistan. Electricity is required for improving health facilities, education system, living standard and for other economic activities including running of tubewells for meeting the water requirements of rice and other crops. Major part of the demand is met through fossil fuels. Diminishing fuel reserves, mounting oil prices and Green House Gases emission from burning of fossil fuels resulting in global environment problems demand to look for renewable energy for meeting future energy requirement. Thus significant part of future energy must be met from renewable energy sources to meet the rising demand and to reduce Green House Gases emission. According to World Bioenergy Association (2010), reasonable and sustainable use of world biomass energy can meet energy demand globally. The European Commission has set an overall target of 20 percent share of renewable energy and a 10 percent share of renewable energy in transport for the year 2020 [Dam and Junginger (2011)]. U.S. Department of energy has set a target that biomass will supply energy equivalent to 30 percent of current petroleum consumption [Fengxiang, *et al.* (2011)]. Similarly, targets have been fixed by Romania [Scarlat, *et al.* (2011)] and Australia [Herr and Dunlop (2011)]. Demirbas (2011) has reported that biomass energy can meet half of the present global energy consumption by the year 2050. In view of the haulage cost associated with rice crop residue, installation of crop residue biomass power plants at the village level would be an attractive option for improving electricity supply. Such decentralised units can benefit the rural population in many ways. First, these can generate income for farmers from rice residue, which is presently being burnt by them. Second, these can generate employment through involvement of rural population in collection, transport, loading and other activities. Third, decentralised power units at the village level can stimulate economic activities through assured power supply [Hiloidhari and Baruah (2011)].

4. CONCLUSIONS

This paper addresses two very important issues i.e. why farmers burn rice residue and what is the potential of electricity generation from the residue being burnt? Burning of rice crop residue has significant effect on the yield of crops, physical properties of soil and environment. The results obtained by using logit model provide policy-makers with additional insight into the relations between the adoption of rice residue burning practice and the various factors which influence its adoption. There will not be significant decline in rice residue burning under prevailing government policies as the other practices are costly in terms of handling of rice residue and preparation of wheat field after rice. Application of choice logit model has identified farming experience, farm size, farmer's caste, soil type, tenure type, animal strength, use of residue as feed and fuel, cost of preparation of wheat field after rice, reduction in turnaround time between harvesting of rice and sowing of wheat, convenience in use of farm machinery, availability of machinery for incorporation and geographic location of farm as key explanatory variables of rice crop residue burning decision.

The present study also attempted to estimate the quantity of burnt rice residue, which could be used for the generation of electricity. The results indicate that 58 percent of area under rice is fully burnt, while in 12 percent area, pural is removed and lower parts of rice plant are burnt. The proportion of the straw burnt ranged from 53.75 to 58.12 percent of the total straw produced for various varieties of rice when the farmer removed the pural and burnt the lower parts of rice plant, while this proportion varied from 63.48 to 69.26 percent when the farmers burnt both pural and lower parts of rice plant. On overall basis, 712 kg per acre of rice straw was burnt in the study area. The overall quantity of rice straw burnt is estimated to be 1704.91 thousand tonnes for the rice-wheat cropping system area, 3106.68 thousand tonnes for Punjab and 4159.05 thousand tonnes for Pakistan. The rice straw burnt has the potential to generate 162.51 MW, 296.13 MW and 396.44 MW electric power in the rice-wheat cropping system area, Punjab and Pakistan, respectively. In order to minimise the cost of haulage of rice straw, installation of decentralised power plants at village level would be a good option. Further, use of rice crop residue as an energy source can help in reducing foreign exchange requirements as four kg of crop residue can substitute one litter of furnace oil or one m^3 of natural gas [Dubey, *et al.*]. Moreover, power generation from crop residues would be a source of income for the farmers from the rice residue along with generation of additional employment opportunities and economic activities on sustainable basis.

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Mitigating Vulnerability to Oil Price Risk—Applicability of Risk Models to Pakistan's Energy Problem

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The paper examines the prospects of reducing the price risk of Pakistan's oil imports through hedging in the oil futures market. The paper evaluates the ex-ante cross hedge strategies over the 1990–2013 period using 1–4 months futures NYMEX in order to see how to reduce price risk? Our results indicate that in all cases except one, ex-ante hedging would have been effective in reducing price risk. We provide quantitative estimates of the return/risk trade-offs from hedging Pakistan's oil imports, and find that futures hedging offers the country significant risk-reduction potential.

Keywords: Risk-return Trade-off, Hedging, Oil Prices
JEL Classification: G100, G130

I. BACKGROUND

Since the early 1970s oil price shocks have been a major concern of the policy-makers around the world because of their adverse impacts, particularly, on the net oil-importing economies. In general, rising oil prices lead to deteriorating trade and fiscal balances, and generate inflation pressures, which in turn reduce the nation's competitiveness [Bielecki (2002)]. Oil price volatility leads to investment uncertainty and raises the associated project costs affecting economic growth. Therefore, any strategy for ensuring energy security must also address oil price volatility through adopting structural measures and use of the financial instruments [Bacon and Kojima (2008); Yépez-García and Dana (2012)].

Given the volatility of oil prices, many oil exporting countries have sought to achieve export revenue stabilisation through International Commodity Agreements. Such arrangements are, however, not available to oil importing countries. Other methods such as stabilisation funds, contingent financing and import diversification have also not been successful in stabilising import expenditure. An alternative approach to stabilise import expenditure is to use market based risk management tools such as futures hedging. Though futures hedging does not protect from a long-term secular increase in oil prices, they can be effective in managing short-term price risk. This approach in mitigating a country's vulnerability to oil price risk utilises the risk hedging instruments traded in the financial markets or the over-the counter markets contracts [Wu and Cavallo (2012)].

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Using futures markets for hedging price risk is an established practice in business, but not widely used by governmental agencies, particularly in the oil importing developing countries [Devlin and Sheridan (20040; Satyanarayan (1997), and Satyanarayan, *et al.* (1993)]. Daniel (2001) and Hotz and Unterschultz (2001) address issues in hedging risks at the national level. Claessens and Varangis (1995) noted, however, that since the first Gulf war, countries like Mexico, Brazil and Chile are regular users of the oil derivatives markets, and reported that, "the New York Mercantile Exchange (NYMEX) estimates that developing countries are increasingly holding a higher percentage of the total open interest in crude oil futures."

Since the energy sector deregulation and emergence of markets in energy products, the significance of energy price risk management has increased manifold. There has been a considerable amount of work done in the development of risk assessment models. For example, Fan, *et al.* (2008), Cabedoa and Moya (2003), He, *et al.* (2011), Huang, *et al*. (2007), Hung, *et al*. (2008), Marimoutou, *et al.* (2009) and Žiković (2011) have extended risk assessment using Extreme Value Theory. However, there are relatively fewer studies on the application of advanced risk model, especially to developing countries, such as Pakistan, which pose special challenges.

Development of oil price risk mitigation strategies is important for Pakistan for a number of reasons. The country's energy sector is heavily dependent on imported oil and related products, and therefore, is highly exposed to oil price volatility. Country's exchange rate is also closely linked to oil prices, which exacerbates country's vulnerability. In addition, the dynamic processes underling the oil prices in local currency return are characterised by spikes and extreme values, and may also not be stable due to frequent structural shifts in the institutional and regulatory environment. In general, the nature of oil price exposure would be specific to each country, and it would be instructional to examine and document it for Pakistan's policy development.

There have been a number of academic studies drawing attention to the link between the Pakistan's energy sector and economic growth. Ansar and Asghar (2013) show that there are positive relationships among oil prices, CPI and the KSE-100 Index. Basher and Sadorsky (2006) find strong evidence that oil price risk impacts stock price returns in emerging markets, including Pakistan. Malik (2008) points out that Pakistan's dependence on imported fuels is expected to increase even further in future given the depleting gas resources, which will have a negative impact on Pakistan's foreign reserves. Ghayur (2007) proposes a new energy modelling process, "Decube Framework," designed to help the policy and decision-makers by forecasting future energy demands and then assisting them in drafting a plan for energy supplies. He then develops a policy and finally an action plan for policy-makers. Siddiqui (2004) focuses on the issue of causality between energy use and economic growth and shows that energy expansion is expected to lead to higher growth and its shortage may retard the growth process. Malik (2010) finds that oil prices and output are found to be strongly related, and to a great extent this relationship is non-linear. However, the important issue of hedging in Pakistan has been largely unexplored; this paper seeks to fill this gap.

The objective of this paper is to assess the prospects for hedging Pakistan's exposure to oil price risk by evaluating risk hedging strategies using oil futures. The following section discusses Pakistan's exposure to high and volatile oil prices. It is followed by an overview of the oil price volatility. In the next section, we elaborate the basic hedging strategy. Section V presents a framework for evaluating the costs and benefits of alternative hedging strategies. We show, using quoted spot prices for Dubai crude, that these are effective strategies for reducing risk for Pakistan. Section VI further evaluates the hedging strategy taking the specific case of prices of imported furnace oil by Pakistan from September 2005 to June 2012. Section VII summaries and concludes the paper.

II. PAKISTAN'S OIL EXPOSURE

The volatility of the world oil market since the OPEC oil price shocks of the 1970s has exposed the oil import dependent countries like Pakistan to a considerable degree of macroeconomic risk. The country since its birth in 1947 has been importing crude oil, however, over the last decade, the oil sector has emerged as the country's Achilles' heel.

Table 1 presents some summary statistics on the role of oil to underscore its critical position in the Pakistan's economy. Over the last ten years, the oil imports have increased from 2.7 percent of the GDP in constant 2005 US$ to about 9 percent, and from about 2 percent of the country's GDP in current US$ to about 6 percent in recent years. More importantly, from the early 2000s, oil import expenditure has increased from 18 percent to 57 percent as a percentage of exports, and the share of energy produced from oil sources has increased from about 16 percent to over 35 percent, rendering the economy more vulnerable to external shocks originating in the world oil market.

Table 1

Petroleum and Products Imports as a Percentage of Key Items

Year	As % of Exports	As % of Imports	As % of GDP (Constant 2005 US$)	As % of GDP (Current US$)	Electricity Production from Oil Sources, %
2003-04	18.3	16.6	2.4	2.7	15.7
2004-05	24.5	18.7	3.5	3.6	15.9
2005-06	36.0	23.8	5.4	5.4	20.3
2006-07	42.5	27.2	6.3	5.8	28.6
2007-08	51.4	29.7	8.5	7.3	32.2
2008-09	52.5	31.6	8.0	6.1	35.4
2009-10	53.2	33.5	8.1	6.5	38.0
2010-11	48.6	34.3	9.2	7.0	35.2
2011-12	58.2	35.5	10.4	6.8	35.4
2012-13	56.8	35.3	9.8	6.1	n.a.

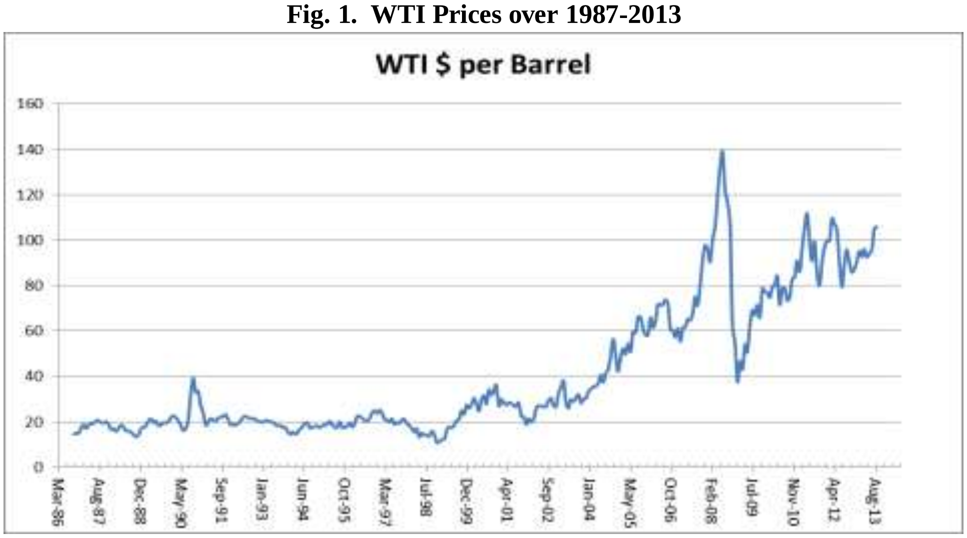
Source: State Bank of Pakistan, World Development Indicators and authors' calculations.

The oil sector is of great importance to government from many dimensions. The performance of the energy sector critically affects Pakistan's macroeconomic performance and any external shocks relating to this sector have economy-wide repercussions. Its performance affects the pace of economic growth, and rising oil prices create hardships for the consumers leading to political unrest and a backlash against the government. In consideration of equity and the unpalatable political consequences, the government has been subsidising the sector to a great extent. Volatility of oil prices is of major concern from the government's fiscal management perspective, as it can significantly affect the forecasts of oil imports and the subsidies built into the government budget. Pakistan's heavy dependence on imported oil for electricity generation renders it especially vulnerable to high and volatile oil prices, affecting its economy both at the macro and the micro level. The sharp increase in the world oil prices over 2008-2010 period has been a major cause of large public sector deficits and a worsening balance of payments situation. Following the oil price increase over 2003-2012, the expenditure on oil imports increased fivefold. Pakistan's dependence on oil has increased to such an extent that even minor oil price increases have a substantial adverse impact on its macroeconomic performance.

III. OIL PRICE VOLATILITY

The yearly price per barrel of crude over the 1987–2013 period shows an upward secular rise but with wide fluctuations, as shown in Figure 1. Table 2 contains annual average spot prices for West Texas Intermediate (WTI), along with standard deviation and the coefficients of variation for each year. The rise in oil prices over time and the price volatility is clearly seen from the Table; the coefficient of variation has been as high as 32.2 percent, but also as low as 5 percent over 1987–2013. The sharp increase in the oil prices in 2007-08 followed by an equally sharp drop is remarkable. It is the steep price increase since 2004 that has been a major factor responsible for Pakistan's energy crisis in the recent years.

Fig. 1. WTI Prices over 1987-2013



Pakistan imports crude oil from the Gulf and Arab countries under various bilateral agreements of different terms. It is likely that the exporters bear much of the price risk by offering long-term contracts, charge a premium to the importers, but themselves hedge their own short positions. The actual amount paid per unit, therefore, is not reflective of the spot price obtaining at the time, or its price volatility. A direct comparison of the WTI and Pakistan's import prices and volatility would, therefore, not be valid. Moreover, since procurement is mainly done through a public corporation, Pakistan State Petroleum, actual data on the amounts and volumes of imports is not publically available. Therefore, for the current analysis, we take the quoted spot prices for Dubai Crude (Dubai Fateh 32 API, fob Dubai) to be the relevant spot prices for Pakistan's imports. Dubai Crude is a light sour crude oil extracted from Dubai and is one of only a few Persian Gulf crude oils available immediately. Dubai Crude is generally used for pricing Persian Gulf crude oil exports to Asia. The crude spot price data for 1986–2013 was obtained from Datastream (Thomson Reuters).

Table 2

Yearly WTI Price USD per Barrel

Year	Average Price	Standard Deviation	Coefficient of Variation
1987	18.97	1.22	6.4%
1988	15.97	1.51	9.5%
1989	19.55	1.26	6.5%
1990	25.07	7.49	29.9%
1991	21.12	1.69	8.0%
1992	20.57	1.30	6.3%
1993	18.42	1.88	10.2%
1994	17.22	1.51	8.8%
1995	18.48	0.93	5.0%
1996	21.95	2.25	10.3%
1997	20.31	1.50	7.4%
1998	14.28	1.95	13.7%
1999	19.70	4.97	25.2%
2000	30.19	3.36	11.1%
2001	25.71	3.59	14.0%
2002	26.65	3.46	13.0%
2003	30.84	3.24	10.5%
2004	41.79	6.71	16.1%
2005	56.99	5.87	10.3%
2006	65.92	5.87	8.9%
2007	73.98	14.35	19.4%
2008	99.00	31.87	32.2%
2009	63.57	12.31	19.4%
2010	79.38	5.47	6.9%
2011	95.18	9.00	9.5%
2012	94.14	9.25	9.8%
2013	97.04	5.26	5.4%

The futures hedge involves buying futures contract to off-set possible adverse price movements in the spot market. The world's predominant oil futures market is the New York Mercantile Exchange (NYMEX), listing one of the most active futures contracts on the West Texas Intermediate (WTI) crude. Besides the NYMEX, crude futures are also traded on other futures exchanges around the world. However, an important question in considering large size hedging strategies involves market liquidity, i.e., if there is sufficient depth and trading in the listed contract. For liquidity consideration among others, the NYMEX futures contracts are considered preferable as the exchange is also the most liquid of the futures markets in oil.[1] We use four different nearby futures contracts, i.e., with deliveries one, two, three and four months ahead of the placing of the hedge. The futures prices for these contracts were obtained from the US Energy Information Agency.[2] Before hedging strategies can be evaluated, the time series properties of the spot and futures prices need to be examined. The prices of most commodities are typically generated by non-stationary stochastic processes, which creates an econometric problem since estimated parameters are unstable and can lead to spurious results [see Granger and Newbold (1974)]. Therefore, a non-stationary series needs to be transformed into a stationary series before further analysing and drawing inferences. The logic for requiring stationarity is that models inferred from stationary series are also stationary or stable. In general, a non-stationary series can be transformed into a stationary series by differencing. Here the focus is on the stationarity or otherwise of the series and not on estimating short term and long term effects of one time series on another, as can be studied employing models such as the Error Correction Models (ECMs).

Tables 3a and 3b report the results of Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for non-stationarity on the levels and first differences of the spot and futures price series.[3] The ADF and PP test results confirm that both spot and futures prices are non-stationary at levels but stationary in the first differences. Thus, the model must be constructed in terms of the stationary, first differenced variables.

Table 3a

Stationarity Tests for Prices at Levels (Sep 1986-Aug 2013)

Price	ADF Test Statistic	PP Test Statistic
Dubai Spot Price (P_{DS})	–1.04 (16 lags)	–0.709
WTI Spot Price (P_{WS})	–0.87 (16 lags)	–1.206
WTI 1 Month Futures (P_{WF1})	–1.16 (16 lags)	–1.170
WTI 2 Months Futures (P_{WF2})	–1.12 (16 lags)	–1.119
WTI 3 Months Futures (P_{WF3})	–1.10 (16 lags)	–1.040
WTI 4 Months Futures (P_{WF4})	–1.09 (16 lags)	–1.032

[1]Some other exchanges that trade crude oil and petroleum futures are the IPE (International Petroleum Exchange), SIMEX (Singapore International Monetary Exchange) and ROEFEX (Rotterdam Exchange). Liquidity is however highest in the NYMEX. Besides, DME Oman Crude Oil Futures Contract (OQD) was launched by the Dubai Mercantile Exchange (DME) in June 2007 which trades on the CME Globex.

[2]Available from EIA web page: http://www.eia.gov/dnav/pet/pet_pri_spt_s1_d.htm

[3]The ADF test for any series X_t is based on the regression: $\Delta X_t = \alpha + \beta X_{t-1} + \sum_{t=0}^{p} \delta_i \Delta X_{t-i} + \varepsilon_t$.

If β is significant, the null hypothesis of non-stationarity is rejected. The ADF test accounts for for higher order serial correlation by modeling the series as an AR(p) process. The Phillips-Perron test is similar to the ADF test but uses a non-parametric robust correction for serial correlation. For details, see Diebold (2000).

Table 3b

Stationarity Tests for First-order Difference in Prices (Sep 1986-Aug 2013)

Price Difference	ADF Test Statistic	PP Test Statistic
Dubai Spot Price (ΔP_{DS})	–13.91*(16 lags)	–13.47*
WTI Spot Price (ΔP_{WS})	–15.95*(16 lags)	–15.96*
WTI 1 month Futures (ΔP_{WF1})	–15.37*(16 lags)	–15.28*
WTI 2 months Futures(ΔP_{WF2})	–15.31*(16 lags)	–15.15*
WTI 3 months Futures(ΔP_{WF3})	–15.24*(16 lags)	–15.08*
WTI 4 months Futures (ΔP_{WF4})	–15.17*(16 lags)	–14.97*

Note: The MacKinnon 1 per cent level critical value is –3.45. *Indicates significance at 1 percent level.

Table 3c

Tests of Basis Risk (Sep 1986-Aug 2013)

Regression	α	β	R^2	Durbin-Watson
ΔP_{DS}= α+ β(ΔP_{WF1})	0.046	0.8799*	0.88	1.63
	(0.51)	(47.89)		
ΔP_{DS}= α+ β(ΔP_{WF2})	0.040	0.9084*	0.89	1.60
	(0.47)	(51.65)		
ΔP_{DS}= α+ β(ΔP_{WF3})	0.038	0.9269*	0.90	1.62
	(0.46)	(52.82)		
ΔP_{DS}= α+ β(ΔP_{WF4})	0.037	0.9428*	0.90	1.63
	(0.45)	(52.96)		

Note: t-statistics are in parentheses.

IV. HEDGING STRATEGY

The bulk of international trade in crude oil takes pace in light to medium grades (API gravity of 30 to 40). The composition of the Pakistan's crude oil imports is quite different from the commodities underlying the NYMEX futures contacts. If the quality of the spot (cash) commodity is identical to the quality of the commodity specified in the futures contract, the usual recommendation is to hedge all of the quantity to be transacted since the spot and futures prices in this case tend to be perfectly correlated or to place a 'naïve' hedge. But due to the difference of quality between the Pakistan's imports and the WTI crude underlying the NYMEX contracts, the effectiveness of *cross-hedging* Pakistan's crude import prices using the WTI futures contract needs to be determined. Moreover, the NYMEX crude oil futures contract is based on pipeline delivery of 1,000 barrels of West Texas Intermediate (WTI) crude in Cushing, Oklahoma. Since, a cross-hedging strategy would necessitate closing futures contracts before the delivery dates, there will be some divergence in the futures prices and the spot prices at the delivery date resulting in the *basis risk,* which needs to be evaluated.

In general, the higher the correlation between spot and futures prices, measured as the R-square (R^2), the more effective is the hedge. Hedging effectiveness is measured by R^2 and the basis risk is measured by $1–R^2$. Table 3c reports the results of a regression of spot price changes on four futures contracts available on the NYMEX, one for the nearby month and three with delivery in following second, third and the fourth month. As the table shows, the R^2 lies between 0.88 and 0.90 and the basis risk ranges from 0.12 to 0.10. This indicates that Pakistan's crude imports can be effectively cross-hedged using the **WTI** futures contract.

V. A FRAMEWORK FOR HEDGING

In this section, a simple framework is presented for placing the hedge and determining the optimum proportions of un-hedged (spot) and hedged (futures) output.[4] Taking the point of view of an oil importer, we consider only the use of a 'long-hedge' (i.e., the hedger buys futures contracts) to insure against price increases. In a long hedge, a short position in the spot market ($Q_s < 0$) is offset by a long position in the futures market ($n > 0$). At the initial time the hedger knows the spot and the futures current prices, P_{s0} and $P_{f\,0}$ but their one period ahead price, P_{s1} and P_{i1}, are unknown and are thus random variables. The expected (dollar) cost on the portfolio (EC) can then be represented as:

$$EC = Q_s E[P_{s1} - P_{s0}] - nQ_f E[P_{f1} - P_{f0}] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where,

Q_s = Quantity needed to be purchased
$E[P_{s1} - P_{s0}]$ = Expected change in the spot price from time 0 to 1
n = Number of futures contracts to be bought
Q_f = Notional value of one futures contract
$E[P_{f1} - P_{f0}] = \Delta P_f$ = Expected change in the futures price from time period 0 to 1.

Dividing (1) throughout by Q_s yields the expected dollar cost on the portfolio per spot unit ($EC/Qs = EC_p$) for a long hedger as: $EC_p = \Delta P_s - h\Delta P_f$

The ratio $h = (nQ_f / Q_s)$, is defined as the hedge ratio—the percentage of the spot or cash position that is hedged in the futures market.

If each unit in the spot market is hedged with a unit of futures, then $h = 1$ (termed as the naïve hedge), the portfolio is completely hedged. If there is no hedging, $h = 0$, then gains/losses in the value of the portfolio are simply equal to the change in the value of the spot position. The risk of the portfolio measured as the variance of portfolio values (Var_p) in (2) is given as:

$$Var_p = Var(\Delta P_s) + h^2 Var(\Delta P_f) - 2h\,cov((\Delta P_s, \Delta P_f) \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where $Var(\Delta P_s)$ and $Var(\Delta P_f)$ are the variance of spot price changes and futures price changes and $cov((\Delta P_s, \Delta P_f)$ = covariance between spot price changes and futures price changes.

Following the mean-variance model [attributed to Markowitz (1959)], the optimal hedge ratio that maximises expected utility for infinite degree of risk aversion and also minimises portfolio variance, is:[5]

$$h^* = cov((\Delta P_s, \Delta P_f) / var(\Delta P_f) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

[4]The model here is similar to Raju (2005).

[5]The mean-variance model implicitly assumes that the hedger has a quadratic utility function, or that the returns are normally distributed. For explanation of hedging effectiveness, basis risk and derivation of hedge ratio, see, among others, Hull (2012).

The *h**, the risk-minimising hedge ratio, thus equals the slope coefficient of an Ordinary Least Squares (OLS) regression of spot price changes (dependent variable) on futures price changes (independent variable).

Since the contracts on NYMEX expire on 25th of the delivery month and stop trading three trading days before, we assume that positions are opened on the 26th of each month and closed on the 20th of the next month. There is a loss (gain) on the spot price equal to $S_1–S_0$, but a gain (loss) on the bought futures equals to $F_1–F_0$; which are added to get the portfolio gain or loss as per Equation (3): $P_{S1}–P_{S0} – h(P_{f1}–P_{f0})$. Hedge ratios for the year (t), h^*_t are computed using three years' data prior to the year of hedge. The h^*, the risk-minimising hedge ratio equals the slope coefficient of an Ordinary Least Squares (OLS) regression of spot price changes (dependent variable) on futures price changes (independent variable). The 1990 hedge ratio is estimated using data from January 1987 to December 1989. Thus, the hedge ratios are estimated using information available only up to the year in which the hedge is placed. We compute the gains/loss on the hedged portfolios using four different nearby futures contracts, i.e., one, two, three and four months ahead of the month in which the hedge is placed. The issue to be determined is, if the country is better off not hedging as compared to hedging.

Table 4 reports ex-ante (before the resolution of uncertainty) risk minimising hedge ratios for each year over 1990–2013 and contrasts the performance of unhedged portfolio with four ex-ante hedged portfolios. The table shows that in all hedges, except one in 1996 employing one month futures contract, the variance of the unhedged position exceeded the variance of the ex-ante hedged position. The benefits through risk reduction from the ex-ante hedges range from a reduction in risk of 98 percent for the 2010 (four month futures) hedge to 27 percent for the 2004 (four month futures) hedge, ignoring the 1996 hedge using one month futures contract. The results indicate that there could be substantial risk reduction benefits from hedging Pakistan's oil imports. For the 1996 hedge, a strategy employing one month futures contract would have actually led to an increase rather than a decrease in portfolio variance. This result simply underscores the fact that the expected benefits from ex-ante hedges based on hedge ratios estimated from the historical data may not actually materialise because of the basis risk.

Taking a hedged position carries an opportunity cost in terms of foregone returns or increase in costs. Therefore, typically a reduction in risk would be accompanied by lower returns or increased costs, reflecting the risk-return tradeoff. Whether the hedger considers these incremental costs acceptable or not depends upon the hedger's degree of risk aversion. As an illustration, the portfolio returns and variances for hedge (*h*) ratios between 0 and 1 are calculated for the year 2012 and reported in Table 5. These are also graphed in Figure 2, which is in the familiar mean-standard deviation space and draws the portfolio opportunity frontier, showing the return and risk trade-offs from hedging Pakistan's oil imports. When the portfolio is unhedged ($h = 0$) we observe the highest return (0.53) and the highest risk (standard deviation, 7.37). The minimum risk portfolio corresponds to the Point M with an associated (dollar) return of –0.23 (US $/barrel) and a standard deviation of US $/barrel of 2.85. For the hedge ratios ranging between 0 and 0.83, portfolios carry lower risk but also lower return. We can ignore the portfolios lying on the negatively sloped portion of the opportunity set as these portfolios are inefficient; for the same level of risk, the portfolios on the positively sloped segment are dominant as they yield a higher return.

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Table 4

Performance of Hedged and Unhedged Portfolios (1990-2013)

Hedge Year	Unhedged Position		One Month Hedged Portfolio				Two Month Hedged Portfolio				Three Month Hedged Portfolio				Four Month Hedged Portfolio			
	Expected Cost	Portfolio Variance	Expected Cost	Hedge Ratio, h	Portfolio Variance	Risk Reduction	Expected Cost	Hedge Ratio, h	Portfolio Variance	Risk Reduction	Expected Cost	Hedge Ratio, h	Portfolio Variance	Risk Reduction	Expected Cost	Hedge Ratio, h	Portfolio Variance	Risk Reduction
1990	1.35	31.03	0.91	0.75	10.71	65%	1.03	0.83	11.10	64%	1.07	0.86	11.59	63%	1.08	0.87	12.08	61%
1991	0.70	6.95	0.26	1.06	0.68	90%	0.33	1.18	0.82	88%	0.35	1.28	0.74	89%	0.40	1.39	0.78	89%
1992	–0.11	0.35	-0.09	1.06	0.19	44%	–0.03	1.17	0.20	44%	0.00	1.27	0.18	48%	0.03	1.38	0.18	50%
1993	0.38	1.03	–0.47	1.07	0.15	85%	–0.40	1.17	0.16	84%	–0.35	1.26	0.15	86%	–0.33	1.38	0.15	86%
1994	–0.21	0.81	0.04	1.02	0.62	24%	–0.10	1.05	0.40	51%	–0.16	1.11	0.34	58%	–0.20	1.18	0.34	58%
1995	–0.27	0.69	0.09	0.88	0.16	77%	0.07	0.96	0.16	77%	0.02	1.03	0.16	77%	–0.02	1.08	0.18	73%
1996	–0.26	0.76	0.88	0.91	1.32	–74%	0.69	1.03	0.48	37%	0.64	1.13	0.33	57%	0.55	1.21	0.28	63%
1997	0.47	2.05	0.11	0.80	0.51	75%	0.12	0.96	0.28	86%	0.15	1.10	0.27	87%	0.19	1.21	0.29	86%
1998	0.76	1.03	–0.18	0.85	0.56	46%	–0.22	0.98	0.44	58%	–0.27	1.11	0.41	60%	–0.30	1.23	0.41	60%
1999	–0.97	2.35	–0.22	0.83	0.39	83%	–0.03	0.94	0.38	84%	0.07	1.04	0.40	83%	0.13	1.13	0.46	80%
2000	0.18	10.63	1.21	0.92	1.58	85%	0.99	1.01	1.29	88%	0.98	1.11	1.21	89%	0.99	1.20	1.11	90%
2001	0.06	2.22	–0.13	0.85	0.94	58%	–0.12	0.98	0.86	61%	–0.04	1.11	0.91	59%	0.02	1.24	0.88	61%
2002	–0.92	2.84	–0.19	0.84	1.16	59%	–0.17	0.97	0.84	70%	–0.12	1.07	0.69	76%	–0.10	1.19	0.70	75%
2003	–0.20	5.21	0.37	0.79	1.01	81%	0.44	0.89	0.54	90%	0.56	0.99	0.57	89%	0.61	1.10	0.50	90%
2004	–1.14	9.18	0.02	0.72	3.41	63%	0.15	0.80	4.09	55%	0.33	0.88	4.41	52%	0.17	0.97	6.72	27%
2005	–0.51	15.00	–0.55	0.59	2.22	85%	–0.54	0.63	1.59	89%	–0.41	0.66	1.23	92%	–0.32	0.70	1.00	93%
2006	0.19	30.04	–0.46	0.66	3.44	89%	–0.45	0.69	2.20	93%	–0.32	0.70	1.92	94%	–0.22	0.72	1.78	94%
2007	–1.23	21.16	–0.19	0.77	3.19	85%	–0.22	0.78	2.55	88%	–0.21	0.78	1.96	91%	–0.25	0.79	1.65	92%
2008	4.93	159.29	0.12	0.83	19.89	88%	0.47	0.84	9.32	94%	0.67	0.85	6.69	96%	0.82	0.87	5.07	97%
2009	–2.26	32.12	–1.04	0.93	5.30	84%	–1.42	0.96	4.56	86%	–1.15	0.97	2.90	91%	–0.94	0.98	2.41	92%
2010	–1.10	34.41	–0.91	0.93	1.68	95%	–0.97	0.95	1.49	96%	–0.88	0.97	1.05	97%	–0.77	0.98	0.86	98%
2011	–0.70	40.09	–1.51	0.95	14.13	65%	–1.49	0.97	14.24	64%	–1.41	0.97	13.99	65%	–1.35	0.98	14.12	65%
2012	0.53	54.38	–0.18	0.79	10.25	81%	–0.22	0.81	9.79	82%	–0.21	0.82	9.42	83%	–0.17	0.83	8.99	83%
2013*	0.16	11.66	1.06	0.84	5.88	50%	1.12	0.85	5.32	54%	1.10	0.86	4.34	63%	1.05	0.87	3.68	68%

* Hedged position for 2013 is from January to August; Expected cost is defined as per equation (1), EC = $Q_s E[P_{s1} - P_{s0}] - nQ_f E[P_{f1} - P_{f0}]$.

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Figure 2 illustrates the basic risk-return trade off faced by the hedger. The basic question is whether it is worthwhile to incur additional cost (or to accept a lower rate of return) by hedging and insuring against possible oil price increase. This decision to hedge (and to what extend) vs. not to hedge is affected by the level of risk aversion.

Fig. 2. Return-Risk Trade-offs from Hedging

Following Raju (2005) we calculate the explicit costs of hedging Pakistan's oil imports by comparing the decrease in risk with the increase in the cost of acquiring oil (or decrease in return) in the spot market. A cost elasticity measure can be computed by comparing the return and variance of the unhedged and hedged positions as follows:

Cost elasticity of hedging = (% Reduction in Return) / (% Reduction in Variance)

Where,

% Reduction in Return = 1 – [(Return of Hedged) /(Return of Unhedged)]
% Reduction in Risk = 1 – [Variance (Hedged)/Variance (Unhedged)]

These cost elasticities are reported in the last column of Table 5 and range between 0.98 and 2.27, with larger values implying higher costs of risk reduction. The cost associated with the minimum-variance portfolios are: 1.64, 1.72, 1.68, and 1.58 respectively for one to four month futures contracts respectively. For the one month contract, for example, cost elasticity of 1.64 implies that a 1 percent reduction in risk will result in a 1.64 percent reduction in return. The hedger would need to make a judgment if this is an acceptable cost for achieving risk reduction? which will depend upon the hedger's degree of risk aversion.

Table 5

Risk-Return Trade-offs (for Year 2012)

Hedge Ratio, h	Portfolio Return	Portfolio Variance	Increase in Cost	Reduction in Risk	Cost Elasticity
Hedging with One Month Futures					
0.0	0.5283	54.3816	–	–	
0.1	0.4397	45.6440	17%	16%	1.04
0.2	0.3510	37.8230	34%	30%	1.10
0.3	0.2623	30.9185	50%	43%	1.17
0.4	0.1737	24.9307	67%	54%	1.24
0.5	0.0850	19.8594	84%	63%	1.32
0.6	–0.0037	15.7047	101%	71%	1.42
0.7	–0.0923	12.4666	117%	77%	1.52
0.79*	–0.1761	10.2487	133%	81%	1.64
0.8	–0.1810	10.1450	134%	81%	1.65
0.9	–0.2697	8.7401	151%	84%	1.80
1.0	–0.3583	8.2517	168%	85%	1.98
Hedging with Two Month Futures					
0.0	0.5283	54.3816	–	–	
0.1	0.4369	45.5749	17%	16%	1.07
0.2	0.3455	37.7006	35%	31%	1.13
0.3	0.2541	30.7587	52%	43%	1.19
0.4	0.1627	24.7492	69%	54%	1.27
0.5	0.0712	19.6720	87%	64%	1.36
0.6	–0.0202	15.5273	104%	71%	1.45
0.7	–0.1116	12.3149	121%	77%	1.57
0.8	–0.2030	10.0350	138%	82%	1.70
0.81*	–0.2159	9.7882	141%	82%	1.72
0.9	–0.2944	8.6874	156%	84%	1.85
1.0	–0.3858	8.2722	173%	85%	2.04
Hedging with Three Month Futures					
0.0	0.5283	54.3816	0%	0%	
0.1	0.4392	45.5819	17%	16%	1.04
0.2	0.3500	37.7060	34%	31%	1.10
0.3	0.2608	30.7541	51%	43%	1.17
0.4	0.1717	24.7261	68%	55%	1.24
0.5	0.0825	19.6219	84%	64%	1.32
0.6	–0.0067	15.4417	101%	72%	1.41
0.7	–0.0958	12.1853	118%	78%	1.52
0.8	–0.1850	9.8529	135%	82%	1.65
0.82*	–0.2067	9.4244	139%	83%	1.68
0.9	–0.2742	8.4443	152%	84%	1.80
1.0	–0.3633	7.9597	169%	85%	1.98
1.1	–0.4525	8.3989	186%	85%	2.20
Hedging with Four Month Futures					
0.0	0.5283	54.3816	0%	0%	
0.1	0.4450	45.6042	16%	16%	0.98
0.2	0.3617	37.7357	32%	31%	1.03
0.3	0.2783	30.7762	47%	43%	1.09
0.4	0.1950	24.7255	63%	55%	1.16
0.5	0.1117	19.5838	79%	64%	1.23
0.6	0.0283	15.3510	95%	72%	1.32
0.7	–0.0550	12.0271	110%	78%	1.42
0.8	–0.1383	9.6121	126%	82%	1.53
0.83*	–0.1670	8.9919	132%	83%	1.58
0.9	–0.2217	8.1060	142%	85%	1.67
1.0	–0.3050	7.5089	158%	86%	1.83

VI. HEDGING EFFECTIVENESS WITH IMPORTED PRICES

As noted above the price data on Pakistan's actual procurement prices of oil and oil products is not publically available. However, the authors found limited data on the prices of furnace oil (PSO sale price ex-Karachi for imported oil) reported in the *Energy Year Book*, HDIP (2012) from September 2005 to June 2012. Based on this data the correlation coefficients between the monthly PSO imported prices and the Dubai spot and WTI futures are reported in Table 6.

Table 6

Correlation With PSO Ex-Karachi Imported Furnace Oil Prices

Price Series in 1st Differences	Correlation Coefficient
ΔDubai Spot	0.7287
ΔWTI Spot	0.6496
ΔBrent Spot	0.6929
ΔWTI Futures 1 Month	0.6515
ΔWTI Futures 2 Month	0.6558
Δ WTI Futures 3 Month	0.6576
Δ WTI Futures 4 Month	0.6586

As expected the correlations between PSO import prices and international spot and futures prices are not as high as between Dubai spot and WTI futures contracts. However, the correlation seems to be in a range where effective hedges may be placed.

In order to judge the effectiveness of hedging PSO imported oil prices using WTI futures contracts, monthly hedges were simulated, as per hedging framework explained in the earlier section. The hedge ratios were computed using prior three year rolling window; i.e., the hedge placed in August 2008 is based on hedge ratio computed over September 2005 to July 2008 periods, and so on for the following months. The results obtained from such ex-ante hedges over the August 2008 to June 2012 period are reported in Table 7.

As the table shows, the hedging achieves about 45 percent reduction in the variance. There is an increase in cost of 4.8–7.5 cents per gallon per month. The increase in cost of purchase is, however, a small percentage (0.06 percent to 0.10 percent of the average purchase price of oil. The results thus point out to a significant scope in price risk reduction at a relatively small cost.

Table 7

Results of Ex-ante Monthly Hedging PSO Import Prices

	Unhedged Position	Hedged Positions with WTI Futures			
		1 Month	2 Month	3 Month	4 Month
Expected Cost ($) *	0.0251	0.0730	0.0781	0.0891	0.0999
Variance	53.0864	29.5312	29.2523	29.2074	29.2276
%Δ in Variance	–	–44.37%	–44.90%	44.98%	–44.94%
Increase in Cost over Unhedged Position ($)		0.0478	0.0530	0.0639	0.0747
Increase in Cost as % of Average Oil Price		0.064%	0.070%	0.085%	0.099%

*Expected costs is as per Equation (1), $EC = Q_s E[P_{s1} - P_{s0}] - nQ_f E[P_{f1} - P_{f0}]$.

VII. SUMMARY AND CONCLUSIONS

In this paper we investigate the prospects of reducing oil price risk for Pakistan's oil imports through hedging in the oil futures market. We simulate ex-ante cross hedges for 1990–2013 and find that in all cases except one, ex-ante hedging was effective in reducing price risk. The estimated return and risk trade-offs from hedging indicate that for a risk minimising long hedger, a 1 percent reduction in risk would have cost a reduction in return of 1.58 to 1.72 percent. The results establish that there are risk reduction benefits from hedging Pakistan's oil imports, which together with the estimates of the opportunity costs of hedging should help in the hedging decision.

Besides the cost of hedging, there are other important considerations in the hedging decision from the country's perspective, which involve the cost of the structural adjustments (fiscal and budgetary adjustments) that are often necessitated as a consequence of unexpected price increases or declines. We have not included transaction costs into our analysis, which include brokerage fees and the opportunity cost of holding a margin account. However, the former are similar in magnitude to the fees for the spot transactions, and the latter costs are likely to be minimal considering that margin can be posted by depositing interest bearing securities.

Pakistan is reported to have considered hedging its oil import bill in 2005, but no decision was made. In 2009 there were fresh initiatives to opt for oil hedging, and the then Advisor to the Prime Minister on Finance hinted that such a programme may be put in place, and the Economic Coordination Committee (ECC) was to consider it. However, no final decision was taken. In 2009, September, the Securities and Exchange Commission of Pakistan (SECP) allowed trading in futures contracts of crude oil on the National Commodity Exchange Limited (NCEL). "The SECP while granting approval had also advised the NCEL to ensure that appropriate level of awareness, regarding risks associated with and significant matters of futures trading, was communicated amongst all futures market participants specially prospective individual investors," as reported in *Dawn* (2009). Perhaps there is a need to raise awareness on the benefits and costs of hedging. We hope that this paper advances such awareness.

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