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MEASURING UNDESIRABLE OUTPUT IN EFFICIENCY EVALUATION: THE CASE OF TANNERIES IN PAKISTAN

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Abstract

The present paper estimate efficiency for the Pakistani leather tanning industry under alternate assumptions of weak and sturdy disposability of undesirable outputs. Data envelopment technique (DEA) is used for modeling of undesirable outputs to individual tanning units in order to assess their relative efficiency using their production data. Data on the amounts of inputs (raw hide/skin, labor, capital, fuel), outputs (tanned leather) and water pollutants (BOD, COD, and chromium) for 50 leather tannery firms or decision-making units (DMUs) operating within the industrial estates of Karachi, Lahore and Multan basin drained by Malir, Ravi and Chenab rivers respectively, were collected. The efficiency measures of these DMUs reveal many inefficient firms reflecting low level of amenability with liquid effluents standards.

1. Introduction

This paper deliberates upon the pivotal role and importance of leather tanning sector in the tanning industry of Pakistan and its impacts on the environment. The economic support of this sector is highly significant in terms of international trade and foreign exchange earnings. This paper also discusses the economic importance of tanning industry and critical issue of environmental degradation due to leather tanning activity, which is a major source of trepidation for policy makers and other stake-holders; the extensive practice of chemicals and water in this industry generates large cantons of highly contaminated wastewater, solid waste, air pollution and to some extent noise pollution.

Leather industry is the second prevalent export earning sector after textiles (Pakistan Tanners Association Annual Report 2017-18) in Pakistan. Currently, this sector is adding around US$ 948.265 million (ICT Trade Map 2018-19). It adds 5% to GDP and 5.4% to the general export earnings. The leather tanning industry is associated with several environmental problems. The release of untreated effluents into water masses and soil is the main source of pollution. Liquid effluents from pre-tanning, tanning and finishing processes contain organic chemicals, inorganic chemicals and suspended solids (such as grease, hair, wool, and flesh). Effluents are hot, smelly, alkaline by chemicals used in liming method, acidic by chemicals used in pickling process and colored by substances used in dying process. Chromium salt used in chrome tanning is very toxic. The effluents have many impacts such as lower the dissolved oxygen points in receiving water masses, pressurize aquatic life and harm the quality as well as esthetic value of water masses.

In this paper we apply recently developed techniques to the analysis of efficiency scores for a sample of 50 tannery mills or decision-making units (DMUs) operating within the industrial estates of Karachi, Lahore and Multan basin drained by Malir, Ravi and Chenab rivers respectively. Data envelopment technique (DEA) can be used for efficiency measurement of manufacturing unit that practices several inputs and several outputs and by-products such as BOD, COD and Chromium. I offer a brief review of literature of the various models. According to this literature, efficiency quantities generally based on postulation that inputs must be curtailed, and outputs must be extended. Undesirable by-products (need to be curtailed) and desirable outputs are united into the production model in an increasing number of applications, over the last few years. The paper is planned as follows. We begin with a brief review of a detailed description of the concept of Data Envelopment Analysis (DEA) and its uses in section 2. This is followed by a discussion of importance of tanneries and their environmental impacts (section 3). Section 4 contains a discussion of methodology. In section 5, data is reported. Empirical results are informed in section 6. Conclusion is provided in section 7.

2. Review of Literature on DEA

Data envelopment analysis (DEA) is a comparatively novel ‘data oriented’, linear programming to build a non-parametric technique of efficiency estimation of decision-making units (DMUs) that produce several good and bad outputs using several inputs. Data envelopment analysis estimate the relative efficacies and non-efficacies of peer DMUs by constructing a non-parametric piecewise surface (frontier) assessed with the assistance of mathematical programming procedures (Cooper et al., 2000). Due to empirical alignment and absenteeism of a priori assumptions, Data Envelopment Analysis (DEA) have used in several studies involving efficient frontier (non-parametric piecewise surface) estimate. DEA has pragmatic to an extensive range of situations such as manufacturing, transportation, health care and education (Coelli et al., 2005).

Farrell (1957) planned a piece-wise-linear convex hull tactic to estimate a frontier, to accurate insufficiencies in production indexes, leading to the substitute of the perception of

productivity with the perception of efficiency, only a few writers considered it in the two decades subsequent to Farrell's research paper. Boles et al. (1995),Shephard (2015),and Afriat (1972) proposed mathematical programming approaches that could attain the task. applied to empirical data by Farrell (1957). Structuring on the valuation of individual DMUs by Farrell (1957), Charneset al. (1978, 1981) developed a non-parametric method that used the term DEA first time. Since then DEA methodology have applied and extended in many papers, because It examine the efficiency of single input and output to multiple input and output settings. DEA has no assumptions about functional form likened to the parametric approach. Relative efficiency scores of a DMU is examine by efficiency of other DMUs that placed on or below the frontier. Generally, an input oriented linear programming DEA model are purported by Charnes et al. (1978) and supposed constant returns to scale (CRS). In contrast, an output-oriented DEA model by Banker et al. (1984) are purposed, which dealings radial efficiency of manufacturing units, assume VRS (variable return to scale, and at the same time offers an efficiency score for all DMUs, and build the best practice frontier. Charnes et al. (1981), adopt in the traditional DEA framework that inputs hold to curtailed and outputs to expanded. Koopmans (1951) in his formative work had identified waste, pollution and smoke unwanted by-products produced in the manufacture procedure that need to be lessened. The non-parametric DEA approach employed by Fare et al. (1989) on data of 1976 of 30 US firms which practice wood pulp, energy, labor and capital in order to produce paper and four undesirable outputs such as Sulphur oxide (SO_x), BOD, particulates (PART) and total suspended solids (TSS). The efficiency scores of operating units are very sensitive when pollutants were incorporated according to the results shown by this study. Similar results are illustrated by many other studies as Pittman, 1983; Tyteca, 1996, 1997.
An environmental functioning indicator of Fare et al. (1996) is presented by decomposing total productivity into efficiency index and pollution index. DEA modeling methods are used which formerly developed by Fare et al. (1989) to construct environmental functioning indicator and assumed weak disposability for pollutants. Models were used to observe data set of US electric utilities which used fossil fuel-fired. The ranking of fossil fuel-fired electric utilities makes out using the environmental functioning indicator model was expressively different to efficiency scores of the traditional DEA model. Most of the manufacturing units are responsible for the joint production of desirable and undesirable output. When evaluating the performance of manufacturing units, then reward a unit in providing a desirable output and punish those who produce pollutants.

Several advantages of non-parametric DEA tactics over parametric stochastic tactics are evaluated by Seiford and Thrall (1990). One of the significant benefits is the robustness of mathematical programming procedures of non-parametric tactics used to solve DEA problems. According to Charnes and Cooper (1984), another advantage of DEA model is the possibility to enter an environmental variable. This environmental variable is the by-product of the production process. Performance estimation of effective processes are proven useful in DEA framework. Seiford and Zhu (2002) used spreadsheet model in DEA framework to evaluate performance of manufacturing units and benchmarking.

Scheel (2001) adopted different procedures to deal with undesirable outputs in DEA framework, these undesirable by-products hold to minimized. The performance of DMUs can be improved by expanding the desirable and curtailing the undesirable outputs in a standard DEA model as shown by Seiford and Zhu (2002). The production method and modeling for efficiency by indicating the environmental variable has gradually grown in recent years. James and Bennett (1995) emphasized that, environmental efficiency procedures are still in its early stages. and after

25 years, the statement of James is still valid. The scale of challenge in environmental performance measurement is that the small and simplest measures of actions are better than of no action, according to James and Bennett (1995). Any kind of instant action can lead to pollution control, make some serious resolution of environment performance, and improve the responses of customer, regulators and stakeholder.

Khalil (2011) measured the relative efficiency of the most polluting industry that is textile mills in relations of liquid effluences in Pakistan. The operating units of textile is a leading sub sector of the economy in relation to export earnings, employment generation, value added production and foreign exchange earnings. Textile operating units' relative efficiencies are estimated by applying the techniques of data envelopment analysis. The textile units use labor, capital, raw material (cotton or yarn) and fuel as an inputs to produce good output that is printed fabric and BOD and COD as a bad output to measure efficiency scores. The efficiency scores of all processing units of textile manufacturing display the consciousness of pollution abatement of some manufacturers that may be due to the strict regulations of state but overall the situation is not so good. Environmental instruments and effective measures are needed to regulate the liquid effluents discharged by decision making units of textile manufacturing in Pakistan.

We have extended the existing literature by evaluating the efficiency scores of tanning industries by incorporating undesirable outputs such as BOD, COD and chromium by using the non-parametric approach like DEA. No study has done it before.This study also provides the analysis of individualtanneries whether the tanneries are complying with the National Environmental QualityStandard? The findings of the research are helpful for the Government and Policymaker incorrecting and managing environmental quality of tanneries.

3. Importance of tanneries and their impact on environment

3.1 Importance of tanneries:

Leather industry is the second largest export oriented sector of the country. It is highly vibrant, job creating and value-added processing units in leather and leather products. The tanning unit employs about one million people directly, producing finished leather of fine quality for home and foreign markets. It adds 5.4% to export earnings and 5% to GDP. The major exporters of tanned leather to different countries of the world, Pakistan's rank is 20th as given in Table 1. Tanned leather is the most significant sector that plays an important role in restoring economic growth of the country.

Table 1: Economic Contribution of Leather Industry 2017-18

Exports	5.4% of total export (US$ 948.265 million)
Employment	One Million
GDP	5% of total GDP
Rank in the World	20^{th} as an exporter of tanned leather

Source: Annual Report 2017-18 Pakistan Tanners Association, ICT Trade map.

Tanning process is one of the most value-added and export-oriented sectors of the leather industry in Pakistan. Export of Tanned Leather holds a major share of 35% in Pakistan's total Leather & Leather Products with an export value of US$ 948.265 million as given in table 2. This is followed by 31% share of Leather Garments, Leather Gloves shares are 23%, Leather Footwear 10% and Other Leather Manufactures 1%.

Table 2: Product-wise Export performance of Leather industry during 2017-18

Commodities	Unit	July-June 2017-2018	
		Qty	Value
Tanned Leather	'000' SQM	26179	330209
	AUP/Sq.M		12.61
Leather Garments	'000' DOZ	861	294399
	AUP/Pcs		84.49
Leather Gloves	'000' DOZ	6032	215881
	AUP/Pair		5.96
Leather Footwear	'000' Pairs	6018	95150
	AUP/Pair		15.81
Other Leather Manufacturing	'000' KGS	1022	12626
	AUP/kg		12.35
Total			948265

Source: PTA, Annual Report, 2017-18. Values are in Thousands of US Dollars.

Leather Industry is engaged actively in production and geared-up of exports of fine quality of tanned leather and leather products to meets the international demand. This industry is playing positive role by strengthening the exports volume of the country to earn foreign exchange. The members of this industry are courageously prepared to uphold the spotless image of leather industry to meet the WTO's challenges and other global pressures with full sense of quality consciousness and responsibilities under the realm of national policies, rules & regulations and international conditionality.

3.2 The environmental challenge for the leather tanning industry

The leather tanning industry is associated with several environmental problems. The discharge of liquid effluents into the water masses and soil is the main source of pollution. Organic chemicals, inorganic chemicals and suspended solids (such as hair, wool, flesh and grease) are included in liquid effluents discharged from pre-tanning, tanning and finishing operations. Liquid wastes are hot, smelly, alkaline in liming process, acidic in pickling process and colored in printing process. Chromium salt used in chrome tanning is very toxic. The effluents have many impacts such as damage the quality and esthetic value of water bodies, threaten the aquatic life of downstream and lessen the quantity of dissolved oxygen in water masses. Two types of environmental costs are characterized as those that have effect on final consumer's health, and those that have effect on the local environment of the production process. The effects of final consumer's health are generally caused by persistent use of toxic chemicals in the production process (Hell-bent for leather, Labor conditions in the leather industry in Pakistan, 2016). Recent attention has focused on organic compounds, inorganic compounds, and heavy metals. Because the primary pollutants that finished leather industry in Pakistan creates are BOD, COD, TDS, SS, Nitrate, Sulphide and heavy metals (chromium, cadmium, copper, zinc, nickel, lead, etc.)

3.3 Adverse Impacts of wastewater

Liquid effluents generated from the leather tanning industry have two disposal routes, either waste water settled into large receiving water masses like a lake, canal, river or sea: or it is discharged in groundwater reservoirs. Depending on the disposal routes, effluents may contaminate in land too. The liquid effluents discharged from leather tanning units has vast impacts on environment. The detail of the impacts of different pollutants is presented in table 3.

Table 3: Adverse impacts of different pollutants

pH	Effluents directly discharged from tanning processing unit is usually varies between 3.5 to 13.5. liquid effluents with a low pH due to chrome tanning is acidic in nature in receiving water bodies and run metal liquifying in the water. Mounting in the sewers are due to high pH. Aquatic life survival is difficult in the change of pH of water body. The continuous discharge of non-neutral pH in the receiving body caused the alteration of the habitat. In other words, the alteration of pH causes extinction of some species while leads to dominance of others.
Organic pollutants	Liquid effluents from leather tanning units contains high value of BOD and COD. The amount of these two organic pollutants lessen the dissolved oxygen which are needed to chemical organic matter and biodegradable chemicals reactions. Dearth of oxygen in water masses could dangerous for the biological activity by altering the environment from aerobic to non-aerobic.
Particulate and Sediments	Usually suspended solids (SS) present in effluents of tanning units are partially organic in nature. Depending on the prevailing condition the suspended solid of effluents decompose aerobically and anaerobically when settled at the bottom of the water body. Dissolved oxygen of water body is consumed during aerobic activities and creating an adverse effects on the ecological systems of the water mass. Odors will generate by the anaerobic decomposition of organic matter. Additionally, particulate matters are the reason of turbidity in the receiving water masses.
Total Dissolved Solids (TDS)	Total dissolved solids concentration in tanning effluents is very high. Pickling and chrome tanning operations may cause high loads of TDS on effluents of tanning industry. The

	presence of dissolved solids is not good for the health of the aquatic life. Aesthetically displeasing color and odor in wastewater of tanneries are due to the presence of dissolved minerals organic compounds.
Color	Tanning effluent are dark in color due to the dyes and printing chemicals used in dying process. Turbidity increases due dyes which cause harm to the photosynthesis process which is necessary for certain botanical species for food synthesis and leads to habitat alteration.
Chromium	The toxicity of chromium is variable for flora and fauna. About the aquatic environment of the species, toxicity change the temperature, pH and the degree of hardness of the water. Due to the cumulative effects of chromium, this metal tends to climb up in the food chain. Leather tanning units use chrome-based tanning for water resistant, flexible and durable leather, thus waste water discharge from tanning units have chromium and being move into the environment.
Oil and Grease	Presence of grease and oil in liquid effluent of tanning industry may cause reduction in the re-oxygenating capability of the water mass, resulting deficiency of dissolved oxygen, turbidity and aquatic life be threatening.

Source: Pollutant in tannery effluents: United Nation Industrial Development Organization, 2016

4 Methodology

4.1. The technology set of undesirable output

Assume, a manufacturing unit uses an inputs vector $X \epsilon R^{+N}$ to produce an output vector of desirable $y^g \epsilon R^{+M}$, and undesirable $y^b \varepsilon R^{+Z}$: R^{+N}, R^{+M}, and R^{+Z} are non-negative N, M and Z-dimensional Euclidean spaces, respectively. Let feasible output set L(x) is for the specified input vector x and input requirement set $L(y^g, y^b)$ is for a specified output vector (y^g, y^b). Now the technology set of undesirable output is defined as:

$$T = \{(y^g, y^b, x) \varepsilon R^{N+M+Z}, (y^g, y^b) \varepsilon L(x), x \varepsilon L(y^g, y^b)\}. \quad (1)$$

The disposability of output is sturdily or weakly if

$$(y^g, y^b) \varepsilon L(x) \text{ and } (y^{g'}, y^{b'}) \leq (y^g, y^b) \rightarrow (y^{g'}, y^{b'}) \varepsilon L(x) \quad (2)$$

Which indicates that if an output vector which we observed is feasible, then any other output vector which is smaller than our observed vector is also feasible. The processing operations which creates unwanted by-products that are costly to dispose of are excluded from the above assumption. For example, worries about liquid effluents such as BOD, COD and cr, infer that these liquid effluents are costly to dispose of. In such cases weakly disposable assumption are considered.

$$(y^g, y^b) \varepsilon L(x) \text{ and } 0 \leq \Theta \leq 1 \rightarrow (\Theta y^g, \Theta y^b) \varepsilon L(x) \quad (3)$$

This indicates that pollution is not freely disposable and pollution abatement is not possible without distracting resources away from the creation of good outputs and makes lower desirable products with specified inputs.

4.2 Data Envelopment Analysis

The data envelopment analysis (DEA) of input oriented variable return to scale (VRS) model, where we reduce the input by keeping the output at its current level is written as:

$$\begin{aligned}
&\min_{\Theta} \Theta \\
&\text{subject to} \\
&\Sigma^n_{j=1}\phi_j x_i \leq \Theta x_{io} \qquad i = 1,2,\ldots,m \\
&\Sigma\, \phi_j y_r \geq y_{ro} \qquad r = 1,2,\ldots,s \qquad (4) \\
&\Sigma\, \phi_j = 1 \qquad j = 1,2,\ldots,n \\
&\phi_j \geq 0
\end{aligned}$$

In estimation, DMUo is one of the observed unit from the n DMUs. x_{io} is i^{th} input and y_{ro} is the r^{th} output of the observed DMUo. The feasible solution for model (4) is $\Theta = 1$. $\Theta^* \leq 1$ is the optimal value to model (4). $\Theta = 1$ indicate that DMUo is on the frontier and the current level of input cannot be proportionally reduced. $\Theta < 1$ indicate that DMUo is not on the frontier and input level can be reduced proportionally. Θ^* represents the efficiency score of DMUo.

The values of both input slack and output slack may exist in model (4) and after calculation we obtain as

$$\begin{aligned}
&si^- = \Theta x_{io} - \Sigma^n_{j=1}\phi_j x_{ij} \qquad (5) \\
&sr^+ = \Sigma\phi_j y_r - y_{ro}
\end{aligned}$$

Where si^- is the input slack and sr^+ represent output slacks. In model (4) when $\Theta^* = 1$ and $\phi^* = 1$ the value of the input slack and output slack is zero, because of optimal solutions. Model (5) does not provide all the non-zero slacks.

After solving model (4), following mathematical linear programming model is used to determine the possible non-zero inputs and outputs slacks.

$$\begin{aligned}
&\max \Sigma si^- + \Sigma sr^+ \qquad (6) \\
&\text{subject to} \\
&\Sigma^n_{j=1}\phi_j x_{ij} + si^- = \Theta^* x_{io} \\
&\Sigma\phi_j y_{rj} - sr^+ = y_{ro} \\
&\Sigma\, \phi_j = 1,\ \phi_j \geq 0
\end{aligned}$$

In fact, model (4) and (6) represent a two stage method of DEA, that can be displayed with the help of the following model:

$$\begin{aligned}
&\min \Theta - \varepsilon(\Sigma si^- + \Sigma sr^+) \qquad (7) \\
&\text{subject to} \\
&\Sigma^n_{j=1}\phi_j x_{ij} + si^- = \Theta^* x_{io} \\
&\Sigma\phi_j y_{rj} - sr^+ = y_{ro} \\
&\Sigma\, \phi_j = 1,\ \phi_j \geq 0
\end{aligned}$$

Non-Archimedean ε is present in the objective function of (7) permits to minimize the Θ to deter optimization when the slacks, si^- and sr^+ are involved. In model (7), inputs are maximum

decrease via Θ^* optimization from model (4) in the first step of the two stage DEA procedures. then movement on to the efficient frontier is realized through optimizing the slack behaviors in model (6) is required in second stage.
The DEA model of output oriented variable return to scale (VRS) is:

$$\max\lambda - \varepsilon(\Sigma s_i^- + \Sigma s_r^+) \qquad (8)$$
subject to
$$\Sigma\phi_j x_{ij} - s_i^- = \bar{x}_{io}$$
$$\Sigma\phi_j y_{rj} - s_r^+ = \lambda\, \bar{y}_{ro}$$
$$\Sigma\, \phi_j = 1,\ \phi_j \geq 0$$

In the first step of two-stage DEA procedure of the above model, λ^* be optimized by slacks ignoring and in second step slacks be optimized by λ^* fixing through the following mathematical programming problem.

$$\max\Sigma s_i^- + \Sigma s_r^+ \qquad (9)$$
subject to
$$\Sigma^n_{j=1}\phi_j x_{ij} + s_i^- = x_{io}$$
$$\Sigma\phi_j y_{rj} - s_r^+ = \lambda^*\, y_{ro}$$
$$\Sigma\, \phi_j = 1,\ \phi_j \geq 0$$

$\lambda^* = 1$ indicate that DMUo is on the frontier and is efficient. $s_i^- = s_r^+ = 0$ for all inputs and outputs. Slacks are obtained through:

$$s_i^- = x_{io} - \Sigma^n_{j=1}\phi_j x_{ij} \qquad (10)$$
$$s_r^+ = \Sigma\phi_j y_{rj} - \lambda^* y_{ro}$$

Model (7) and (8) are identified in the same frontier if $\lambda^* \geq 1$, $\phi^* = 1$ and $\Theta^* = 1$.

4.3 Invariance Classification

Let inputs altered into $\bar{x}_I = x_{ij} + u_i$ and outputs into $\bar{y}_{rj} = y_r + v_r$. The input oriented variable return to scale model with u_i and v_r nonnegative values are:

$$\min\Theta - \varepsilon(\Sigma s_i^- + \Sigma s_r^+) \qquad (11)$$
subject to
$$\Sigma^n_{j=1}\phi_j x_{ij} + s_i^- = \Theta^*\bar{x}_{io}$$
$$\Sigma\phi_j y_{rj} - s_r^+ = \bar{y}_{ro}$$
$$\Sigma\, \phi_j = 1,\ \phi_j \geq 0$$

And variable return to scale model of output orientation become

$$\max\lambda - \varepsilon(\Sigma s_i^- + \Sigma s_r^+) \qquad (12)$$
subject to
$$\Sigma\phi_j x_{ij} - s_i^- = \bar{x}_{io}$$
$$\Sigma\phi_j y_{rj} - s_r^+ = \lambda\, \bar{y}_{ro}$$
$$\Sigma\, \phi_j = 1,\ \phi_j \geq 0$$

If a DMUo is efficient in model (8) or model (9), the DMUo is also efficient and on the frontier in model (11) or (12) due to the assumption of convexity $\Sigma^n_{j=1}\phi_j = 1$ as depicted by Ali and Seiford (1990).

4.4 DEA model of Undesirable Outputs

Good output is illustrated by y^g_{rj} and bad with y^b_{rj}. To improve the performance of the manufacturing unit, y^g_{rj} to increase and y^b_{rj} to reduce. In output oriented variable return to scale model of standard BCC, for efficiency scores both good and bad output are supposed to increase. Following model is applied to curtail the undesirable by products:

First we multiply each pollutant by "-1" and a proper weight v_r is used to alter all negative environmental variables. $y^b_{rj} = -y^b_{rj} + v_r = 0$ obtained by $v_r = \max\{y^b_{rj}\} + 1$. The efficiency scores of the model which have undesirable outputs be get as:

$$\text{Max } h \quad (13)$$

Subject to

$$\Sigma^n_{j=1}\phi_j y^g_{rj} \geq h y^g_{ro} \qquad i = 1,2,\ldots,m$$
$$\Sigma\phi_j \bar{y}^b_{rj} \geq h\, \bar{y}^b_{ro} \qquad j = 1,2,\ldots,n$$
$$\Sigma\phi_j x_{ij} \leq x_{io}$$
$$\Sigma\, \phi_j = 1,\ \phi_j \geq 0 \qquad r = 1,2,\ldots,s$$

Model 13 is used to curtail the unwanted by-products.

Output oriented variable return to scale (VRS) envelopment is applied in the present study to inputs value of raw hide/skin, labor, capital and fuel and the desirable output value of tanned leather with the values of by-products of BOD, COD and chromium in the present study for the year 2019 for tannery processing units in Pakistan, based on the model of Seiford and Zhu (2002). In this study, three different tactics are used to treat the undesirable output. First, ignore the undesirable output, second a monotone transformation is applied, and the revised variables are used. In third model, unwanted outputs are used as an inputs.

5. Data

To evaluate the efficiency values of 50 tannery units for the year 2019, the data set is obtained from the 50 tannery units from the locality of Malir, Ravi and Chenab rivers, which run across the industrial areas of Karachi, Lahore and Multan and arrive finally at the Arabian Sea. A field survey of leather tanning units by using the structured questionnaire is conducted to collect the data on the variables of inputs, desirable outputs and undesirable outputs (questionnaire attached in appendix). The technology used for both the production of tanned leather and pollution abatement is comparable in all the observed leather tanning units. The manufacturing process of tannery produces a valuable output tanned leather together with by-products of BOD, COD and chromium. The average value of inputs, output and by-product of the year 2019 mentioned in Table 4.

Table 4: Descriptive statistics (sample size = 50)

Variable	Description	Units	Mean	Standard Deviation	Minimum	Maximum
LABR	Labor employed	No. of persons/year	212.1	115.6794	60	550
MATINP	Hide/skin	Million Square Feet	4.7678	6.4778	0.6	26.4
FUEL	Power and gas	Million Rupees	2.578	3.0085	0.34	12
CAPT	Total capital	Million Rupees	698.7128	231.2004	190.269	1500
Y (output)	Tanned leather	Million Square Feet	3.7357	3.7652	0.55	18

BOD	Pollutant	mg/l	942.4	207.0611	575	1277
COD	Pollutant	mg/l	2125.56	882.9708	1031	3480
Cr	Pollutant	mg/l	8.75	1.9604	5.7	11.34

Source: Field work, 2019

Pakistan Environmental Protection Agency (EPA) set the standard for liquid effluents. It is obligatory to pollution creating units to meet the national environmental quality standards set for liquid effluents. NEQS for BOD is 80 mg/l, for COD is 150 mg/l and for chromium is 1.0 mg/l. To make polluting units comply with the standards set by NEQS, regulatory authority used command and control instruments. Effluent treatment plants are operating in a very few units in our sample. Some DMUs in our sample are using the inputs which create less pollution or using process change in manufacturing to attain the NEQS for water pollution.

6. Discussion of Results

Different mathematical models are used to estimate the efficiency scores for benchmarking and to evaluate the performance of 50 leather tanning units. Zhu (2014) developed a software for DEA frontier. Zhu have no input and output limit and makes it easier to estimate efficiency through excel solver. Tables 5 presents the efficiency quantities for each leather tanning unit or DMU.

Efficiency score for performance evaluation are present in Tactic I. this tactic deals undesirable output by ignoring them. Tanned leather is the only output which is used in this model. Tactic I display that 22 tanning units are efficient while 28 are inefficient when undesirable output BOD, COD and cr are not involved. The DEA framework used for valuation of efficiency for performance of leather tannery units have invariance property. A translation vector is used in tactic II. This translation vector increases the desirable output and curtail the undesirable output. The estimated efficiency scores for performance of 50 tanning units of tactic II show that 25 tanning units are efficient. This obviously indicates that some manufacturing units consider the decrease in pollutants or operate in socially required manners. It is probable that some environment policies of state such as agreement to the NEQS (national environmental quality standards) present or tracked by some leather tanning units which allocate little resources for activities of pollution abatement. By comparing tactic I and tactic II, it is realized that inefficient tanning units in column 1 are less efficient than in column II. Several tanning units are inefficient according to Tactic II, realizing that units still manufacturing under restriction or some pollution abatement policy. Findings approve the results of Fare et al. (1989) and Seiford and Zhu (2002) and Khalil (2011). Figure 1 display efficiency scores across DMUs of Tactic II, more realistic efficiency scores for performance evaluation of leather tanning units are revealed in tactic II when some outputs are unwanted to performance extent.

Table 5: Efficiency scores of 50 leather tanning units

Tanning units	Tactic I	Tactic II	Tactic III
1	**1.000000**	**1.000000**	**1.000000**
2	1.170807	**1.000000**	1.170807
3	**1.000000**	**1.000000**	**1.000000**
4	**1.000000**	**1.000000**	**1.000000**

5	1.529282	1.005797	1.519523
6	1.446561	**1.000000**	**1.000000**
7	3.356723	1.015936	**1.000000**
8	1.44676	1.023868	1.094004
9	1.085648	1.014014	**1.000000**
10	**1.000000**	**1.000000**	**1.000000**
11	1.047837	1.00061	1.047837
12	1.312448	1.00216	1.312448
13	**1.000000**	**1.000000**	**1.000000**
14	1.022131	1.003662	1.011745
15	1.122141	1.007648	1.122141
16	1.086881	1.009011	1.086753
17	1.048077	1.01024	1.045903
18	**1.000000**	**1.000000**	**1.000000**
19	1.245801	**1.000000**	1.245801
20	1.00838	1.007837	**1.000000**
21	1.081684	1.053709	**1.000000**
22	**1.000000**	**1.000000**	**1.000000**
23	1.078721	1.045525	1.076579
24	1.107697	1.047987	**1.000000**
25	1.152923	1.057346	1.149107
26	**1.000000**	**1.000000**	**1.000000**
27	1.030129	1.014487	**1.000000**
28	1.167464	1.000371	1.167464
29	1.12204	1.012237	1.12204
30	1.080268	1.012157	1.080268
31	1.140399	1.000352	1.140399
32	1.004997	1.001502	**1.000000**
33	**1.000000**	**1.000000**	**1.000000**
34	**1.000000**	**1.000000**	**1.000000**
35	**1.000000**	**1.000000**	**1.000000**
36	**1.000000**	**1.000000**	**1.000000**
37	**1.000000**	**1.000000**	**1.000000**
38	**1.000000**	**1.000000**	**1.000000**
39	**1.000000**	**1.000000**	**1.000000**
40	1.409243	1.004118	1.407377
41	1.322104	1.018484	**1.000000**
42	**1.000000**	**1.000000**	**1.000000**
43	**1.000000**	**1.000000**	**1.000000**
44	**1.000000**	**1.000000**	**1.000000**
45	**1.000000**	**1.000000**	**1.000000**

46	**1.000000**	**1.000000**	**1.000000**
47	1.29687	1.002857	1.29687
48	**1.000000**	**1.000000**	**1.000000**
49	**1.000000**	**1.000000**	**1.000000**
50	1.080714	1.005815	1.080714

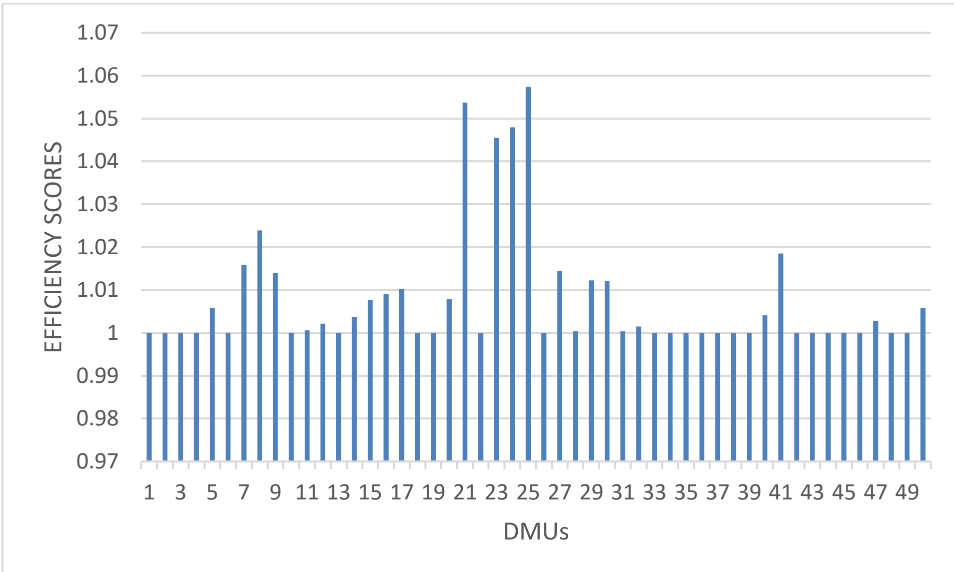

Figure 1: Efficiency scores across DMUs

Tactic III provides the estimated efficiency of leather tanning units when undesirable output is used as inputs. Though it does not imitate the reality of manufacturing method, the results specify that reduction of inputs move to better presentation in terms of effluent control. Yet, from the estimated efficiency of the leather tanning units, most units in the leather tanning industry are not much worried about liquid effluent control. Existing policies of government to pollution abatement are noticeably not as effective as to make all manufacturers comply with national environmental quality standards (NEQS).

6.1 CRS and VRS envelopment model:

The average product also relates to the concept of returns to scale. In production, Fried et al. (2008) have clearly share out the concept of returns to scale. In a single input/output case, AP is quickly expressed. A production unit which have level of input x and output level y, the average product of the unit is y/x. An average product would be affected by scale size in an under efficient operation of a return to scale scenario. If the production process is under efficient then it became difficult to separate out the effect of change in efficiency to the change in scale size.

In a Pareto-efficient case, a DMU with a single input (x)/ single output (y) context, the level of input scaled by a $\alpha \neq 1$, $\alpha \rightarrow 1$ to αx. The operation remnants Pareto-efficient by changing its level of output to βy. The average products (AP) has now become $(\beta y/\alpha x) = (\beta/\alpha)*(y/x)$. Thus, the scale of the average product (AP) has been the ratio of (β/α), if $(\beta/\alpha) > 1$, the average product of the unit has increased by $(\beta/\alpha)*(y/x) > (y/x)$. In such a situation, we have increasing return to scale (IRS) because the proportionate change of the output by β is larger than the proportionate change in input α. The depiction, increasing return to scale (IRS) is local because we measured only a marginal variation in the scale of the unit ($\alpha \rightarrow 1$). If $(\beta/\alpha) < 1$, we have local decreasing returns to scale (DRS) and if $(\beta/\alpha) = 1$, we have local constant return to scale (CRS). The significance of detecting and manipulating returns to scale for a processing unit becomes noticeable; if the manufacture unit is not functioning under constant return to scale (CRS), in theory, there would be gained to fluctuating scale size to manipulate returns to scale.

However, this may not be achievable in practice because scale size may not be in a control of a processing unit. In the multiple-input/ multiple-output case, the explanations of increasing return to scale (IRS), constant return to scale (CRS), and decreasing return to scale (DRS) in terms of the connection between the proportionate change in the level of input and proportionate change in the level of output can be generalized as follows.

Let DMU_j be Pareto-efficient and have level of input $x_j = \{x_{ij}, I = 1,2,\ldots,m\}$ and level of output $y_j = \{y_{rj}, r = 1,2,\ldots,s\}$. Let us rule its input to $\alpha x_j = \{\alpha x_{ij}, I = 1,2,\ldots,m\}$ where $\alpha > 0$. Let DMU_j now with level of input αx_j be competent in principle of becoming Pareto-efficient with level of output $\beta y_j = \{\beta y_{rj}, r = 1,2,\ldots,s\}$.

In building the production possibility set in a non-parametric data envelopment analysis (DEA) framework, we must choose plausible assumptions to maintain the terms of return to scale, portraying the technology under which the decision making units (DMUs) being evaluated operate. It is always probable to choose about the concept of constant return to scale (CRS) or variable return to scale (VRS) at the basic DEA model.

An examination of returns to scale in data envelopment analysis (DEA) is not the purpose of this study. However, it is relevant to briefly converse the results in Table 6 which are attained with the same data on inputs and outputs as in Table 4 in the light of Banker et. al. (1996) argument on alternative procedures for defining returns to scale in data envelopment analysis (DEA) framework. Banker et al. (1984) quantified that Charnes et al. (1978, 1981) presented the CCR model of non-parametric Data Envelopment Analysis (DEA) to assess the relative efficiency of operating units. These writers successively introduced the BCC model which split up technical and scale efficiencies. Subsequently, Banker et al. (1984) displayed how the CCR design can be employed to evaluate return to scale and most productive scale size (MPSS). Banker and Thrall (1992) displayed that the BCC and CCR methods of returns to scale valuation in Banker (1984) and BCC (1984) are equivalent. Fare et al. (1985) offered a substitute process for the valuation of returns to scale using non-parametric DEA. Numerous studies (e.g., Chang & Guh,1991) have observed their assessment of returns to scale as being theoretically different from Banker et al. (1984); Banker and Thrall, (1992); Chang and Guh (1991) and Khalil (2011) characterize the Banker et al. (1984) method as worthless.

Table 6: Efficiency comparison of CRS and VRS Models

Tanning units	VRS	CRS
1	**1.000000**	**1.000000**
2	**1.000000**	1.219986
3	**1.000000**	**1.000000**
4	**1.000000**	**1.000000**
5	1.005797	1.705437

6	**1.000000**	1.413519
7	1.015936	1.247588
8	1.023868	1.165269
9	1.014014	1.05956
10	**1.000000**	1.022727
11	1.00061	1.029388
12	1.00216	1.403621
13	**1.000000**	**1.000000**
14	1.003662	1.033248
15	1.007648	1.21116
16	1.009011	1.167514
17	1.01024	1.123186
18	**1.000000**	**1.000000**
19	**1.000000**	1.167621
20	1.007837	1.039101
21	1.053709	1.097773
22	**1.000000**	**1.000000**
23	1.045525	1.075425
24	1.047987	1.12408
25	1.057346	1.17048
26	**1.000000**	**1.000000**
27	1.014487	1.024693
28	1.000371	1.122164
29	1.012237	1.107084
30	1.012157	1.076584
31	1.000352	1.11598
32	1.001502	1.003877
33	**1.000000**	**1.000000**
34	**1.000000**	**1.000000**
35	**1.000000**	**1.000000**
36	**1.000000**	**1.000000**
37	**1.000000**	**1.000000**
38	**1.000000**	**1.000000**
39	**1.000000**	**1.000000**
40	1.004118	1.33311
41	1.018484	1.140107
42	**1.000000**	**1.000000**
43	**1.000000**	**1.000000**
44	**1.000000**	**1.000000**
45	**1.000000**	**1.000000**
46	**1.000000**	**1.000000**

47	1.002857	1.175734
48	**1.000000**	**1.000000**
49	**1.000000**	**1.000000**
50	1.005815	1.072062

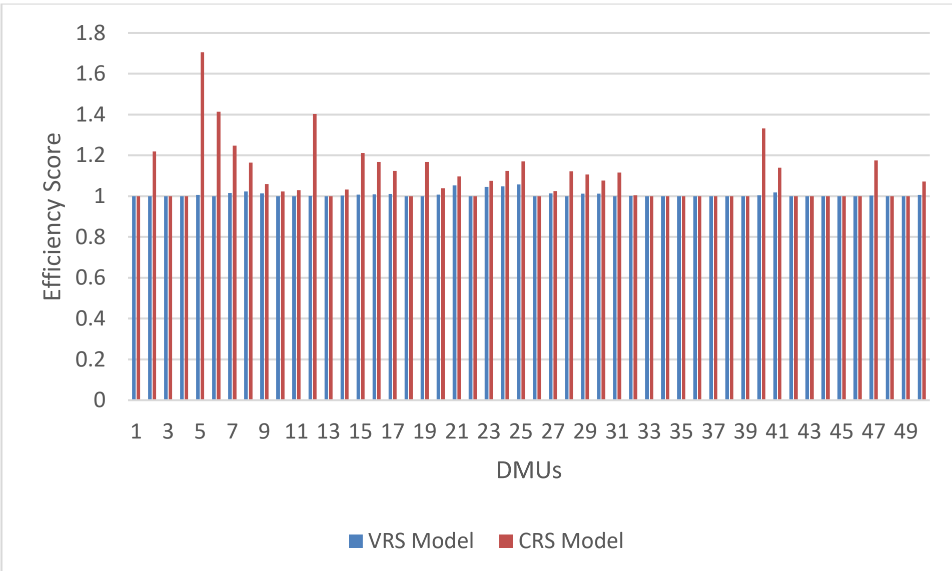

Figure 2: Efficiency comparison of VRS and CRS model

The efficiency scores of tanning units using constant return to scale (CRS) model and variable return to scale (VRS) model, are shown in Table 6 and in figure 2. CRS values of efficiency estimation are higher than values of VRS model for all DMUs supporting the theoretic explanation in this section. The findings in table 6 are reliable with the conclusions of Ahn et al. (1988), a processing unit is efficient in CRS model is also efficient in VRS model whereas the reverse is not essentially true. DMUs 1, 3, 4, 13, 18, 22, 26, 33, 34, 35, 36, 37, 38, 39, 42, 43, 44, 45, 46, 48, and 49 are efficient in the CRS model are also efficient in the VRS model, but DMUs 2, 6, 10, and 19 are efficient only in the VRS model.

7. Conclusion

This paper discusses the theoretical aspects of DEA method working to measure the comparative efficiency for performance evaluation of leather tanning units. Numerous inputs (labor, capital, raw material, fuel) uses to produce desirable (tanned leather) and undesirable outputs (BOD, COD and cr) in DEA framework. Modeling unwanted by products in the efficiency valuations using the non-parametric approach as DEA technique is a relatively new tactic in literature by means of invariance property. In framework of BCC model of variable return to scale, the invariance property applied, and a monotonic vector for variable transformation used to deal the unwanted by-products. BCC model of output oriented VRS permits amplification of good output and reduction of unwanted by-products. To empirically test three different models of efficiency scores, data is collected for inputs, desirable outputs and undesirable outputs from 50 leather tanning units in Pakistan for year 2019. The findings related to estimated values of efficiencies are coherent with findings of other studies. Estimated efficiency scores of leather tanning units confirm the indicator that some manufacturers having environmental realization due to monitoring actions in place but generally the situation is not so good. Effective actions and command and control instruments are still required to check the growing pollution levels in water masses discharged by leather tanning industry.

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Appendix

Measuring the Business Problems of Domestic Tanneries regarding their efficiency

Objective: this survey is the part of PhD thesis which is related to identify the business problems of domestic tanneries regarding their efficiency in Karachi, Lahore and Multan. Since this survey is the part of an academic research so all the information will be used only for academic purposes**.**

A. General Information:

Name of respondent (optional):

☐

Designation:

☐

Phone Number:

☐

E-mail Address:

☐

Name/ Location of tannery:

☐

Raw material used:

☐ Sheep/Goat
☐ Buffalo/ Cow
☐ Both

Types of tanning:

☐ Chrome Tanning
☐ Vegetable Tanning
☐ Aldehyde Tanning
☐ Synthetic Tanning

B. **Quantity of Input/output**:

1. Leather produced (million Sq. feet)

2019	2018	2017	2016	2015

2. Leather stock (million S. feet)

2019	2018	2017	2016	2015

3. Raw material (million Sq. feet)

2019	2018	2017	2016	2015

4. Quantity of chemicals used?

2019	2018	2017	2016	2015

5. Number of people employed (full time+ part time)

2019	2018	2017	2016	2015

C. **Cost of Input/output**

1. Cost of fixed capital: machinery building (rupee value in ‘000’)

2019	2018	2017	2016	2015

2. Cost of electricity (rupee value in ‘000’)

2019	2018	2017	2016	2015

3. Cost of diesel/fuel (rupee value in ‘000’)

2019	2018	2017	2016	2015

4. Cost of water (rupee value in ‘000’)

2019	2018	2017	2016	2015

5. Cost of raw material (rupee value in 000)

2019	2018	2017	2016	2015

6. Cost of chemical (rupee value in ‘000’)

2019	2018	2017	2016	2015

7. Annual cost of labor force (rupee value in ‘000’)

2019	2018	2017	2016	2015

8. Leather sales (rupee value in 000)

2019	2018	2017	2016	2015

D. **Pollution abatement**:

1. Have you installed any effluent treatment plant?

☐ Yes
☐ No

2. If yes, is this plant operative?

☐ Yes
☐ No

3. Cost of installation of this plant?

☐

4. Annual running cost of effluent treatment plant?

☐

5. Is there any combined effluent treatment plant?

☐ Yes
☐ No

6. Cost of installation you bear for this combined effluent treatment plant?

☐

7. Annual running cost you bear for this combined effluent treatment plant?

☐

8. Why do you decide to invest in effluent treatment plant?

☐

9. Does your tannery have any in-house laboratory?

☐ Yes
☐ No

10. If yes, then share your pollution level of followings

BOD

2019	2018	2017	2016	2015

COD

2019	2018	2017	2016	2015

Chromium

2019	2018	2017	2016	2015