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Assessment of Performance of Pharmaceutical Firms making Drugs for Specific Diseases Prevalent in India: A Data Envelopment Analysis Approach

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ABSTRACT

There exists a lot of diversity in Indian pharmaceutical environment in various aspects. We have applied Delphi Technique to arrive at specific prevalent diseases in India and identified 24 pharmaceutical firms making drugs for these diseases. We used data envelopment analysis (DEA) approach to find out the efficiency of firms and peers of inefficient firms. Tobit regression has been used to get the determinants of efficiency.

Indexing terms/Keywords

Data envelopment Analysis (DEA), Pharmaceutical firms, Delphi technique , BCC model, Tobit regression.

Academic Discipline And Sub-Disciplines

Management Science

SUBJECT CLASSIFICATION

Data Envelopment Analysis

TYPE (METHOD/APPROACH)

Qualitative approach used for assessment of opinions through Delphi technique and Quantitative inferential approach used through DEA.

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INTRODUCTION

India is rapidly growing to become a major and vibrant economic power, in spite of the wide disparities within its social milieu. There is increase, also in population of higher income group, who do not hesitate to afford branded costlier drugs in preference to cheaper alternatives (FICCI – Ernst & young study, 2010). India is now becoming a lucrative destination for global pharmaceutical giants. It is estimated that India may become a US$ 8 billion drug market by 2015 for the MNCs. Domestic pharmaceutical market is expected to touch USD 21 billion by 2015, from 7.1 billion in 2007 (www.moneyexpress.com/ business/33701.txthtml).

The management of pharmaceutical business includes marketing, quality assurance, R&D, finance, operations, wholesale and drug store management. The application of drug laws and/or intellectual property rights will be of necessary use for those in pharmaceutical business. Recent developments in pharmaceutical sector in India reveal many mergers and acquisitions (M&A) taking place, resulting in shooting up of revenues of the business. The Indian companies are getting involved in this M&A space as there is growing domestic market for cheaper versions of patent drugs. (i.e. generic drugs) which also will be able to serve developed markets abroad. Unlike in past, the Multi National Companies (MNCs) pharmaceutical companies are clearly shifting their strategies:- from giving out manufacturing contracts to Indian companies to owning them. Multi National Companies (MNCs) are attracted by the emerging markets in Indian scenario for generic drugs. This trend is noticed in the strategy of companies such as Pfizer, GSK, Abott and Sanofi. The pharmaceutical market has witnessed a strong double – digit growth ranging from 13.5 % to 17 % over the past four years (with the exception of the year 2008 when growth was relatively low at 10 %). So for those MNCs facing sluggish sales in their home markets, even a market share of 2-3 % in India could be attractive. (Mergers & Acquisitions in Pharmaceutical industry- News report Times of India:16.02.2011). Some of M&A in pharmaceutical industries are shown in Table-1.

The tendency of Indian pharmaceutical majors being bought by MNCs orients them away from Indian markets, and it may have adverse effect on drug pricing and affordability on the part of the average Indian consumer. In last four years, at least six big acquisitions of this kind took place.

Table-1 Mergers and Acquisitions in Pharmaceutical Industries:

Year	Indian Company taken over	Foreign Buyer	Deal size $ Million
June'08	Ranbaxy Lab	Daiichi Sankyo,Japan	4600
July'08	Shantha Biotech	Sanofi Aventis, France	783
Dec'09	Orchid	Hospira, USA	400
Aug'06	MatrixLab	Mylan Inc.	736
May'10	Piramal Healthcare	Abott, USA	3720
Dec'10	Paras Pharma	Reckitt Benckiser, USA	726

(source: Mergers & Acquisitions in Pharmaceutical industry- News report Times of India :16.02.2011: “Pharma sector injects fresh life into M &A space)

The biosimilar opportunity is also big, that big pharmaceutical giants don’t want to miss it. Merck has established a subsidiary and Pfizer has tied up with Biocon. A biosimilar is approximate copy of a patented biological drug. It is approximate copy because it is hard or impossible to make an exact copy of a biological at the moment. While generic drugs have made a big dent in the market, regulators had not allowed generics companies to make off-patent biological. They are relaxing their attitudes due to the high cost of patented biologicals. As in the generics, Indian companies are looking at a large global market in biosimilars. Big opportunity for Indian firms as several blockbusters goes off patent during year 2017 -2024. The size of the biosimilars market by 2020 is expected to be $ 11 Billion (: Economic Times, 1st March 2012).

In view of above discussed scenario, it is quite obvious that costly drugs, which are ordinarily beyond the reach of average Indian consumer and which are manufactured by pharmaceutical companies including MNCs, are still reigning the market and enjoying their share in a tough competitive market. Nevertheless, keeping larger public good in mind, it will be in the best interest of even these companies to tailor down their costs to meet needs of consumer,without any compromise on quality. Keeping wide spectrum of prevalent diseases in India in view, analysis may be conducted to assess the firms in making available of vital drugs on basis of certain criteria such as:

1. Generic formulations of single drugs or generic formulations of scientifically acceptable and rational combinations.
2. Assessment of these firms spends on R&D which eventually increases the cost of medicine.
3. Analyze if efficient firms are cost efficient. As cost efficient firm can provide drugs at affordable price.
4. Increase in marketing efforts by the firms supposedly improves the accessibility of drugs.

By such a study, it may be possible to understand clear picture of comparative assessment of the market place economics of drugs and of different firms at large to help the consumers. Like with improved cost efficiency may lead to scope of reduction of price.

Previous Studies

A number of studies have been published on different aspects pertaining to pharmaceutical firms. Some of the work done by authors throws lot of insights on pharmaceutical industry scenario in Indian context. Kotwani et.al. (2007) studied on prices & availability of common medicines at six sites in India. Sengupta (2010) worked on National Health System in India with regards to access to Health Care and Medicines. His work provided detail framework and policy pertaining to Indian pharmaceutical industry.

Sampath (2005) provided studies on “Economic Aspects of Access to Medicines after 2005: Product Patent Protection and Emerging Firm Strategies in the Indian Pharmaceutical Industry”. Dhar & Gopukumar (2006) provided detailed information on Post-2005 Trade Related Aspects of Intellectual Property Rights (TRIPS) scenario in patent protection in the pharmaceutical sector in particular to generic pharmaceutical industry in India. Kiran Ravi & Mishra Sunita (2011) also provided a post TRIPS analysis on pharmaceutical companies.
Some of the papers published based on financial statement analysis of the firms. We are focusing mainly on those studies that use frontier analysis or DEA to gauge performance of pharmaceutical firms.

Pannu et.al. (2010) studied on aspect of Innovation on performance of Indian Pharmaceutical Industry. Malhotra & Malhotra (2008) used DEA where it employs relative efficiency, a concept enabling comparison of companies with a pool of known efficient companies. The inputs considered are “days of sales outstanding, days cost of goods, sold in inventory, total debt/equity. The outputs considered are “cash flow per share, return on equity, return on assets, return on invested capital, inventory turnover, interest rate coverage, quick ratio”. Saranga (2007), Saranga and Phani (2004) used DEA to study the performance of pharmaceutical companies in order to determine the best practices in the Indian Pharmaceutical industry. Mazumdar et.al. (2010) used DEA efficiency score of a firm which provides an assessment of its performance based on measurement of output and input efficiencies for Indian pharmaceutical firms.

Identification of prevalent disease in India

Delphi Technique is used to arrive at specific prevalent diseases in India. Delphi technique used to form consensus after opinions from experts for specific prevalent diseases in Indian context. Study on these firms was arrived based on drugs (generic names) and older (Innovator) drugs, specific against the diseases, available in market.

The Delphi technique was developed during the 1950s by workers at the RAND Corporation while involved on a U.S. Air Force sponsored project. The aim of the project was the application of expert opinion to the selection – from the point of view of a Soviet strategic planner – of an optimal U.S. industrial target system, with a corresponding estimation of the number of atomic bombs required to reduce munitions output by a prescribed amount. More generally, the technique is seen as a procedure to ‘‘obtain the most reliable consensus of opinion of a group of experts . . . by a series of intensive questionnaires interspersed with controlled opinion feedback’’ (Dalkey & Helmer,1963). Delphi technique was earlier used for futuristic study, but currently it is being used extensively in social sciences to arrive at a consensus by a panel of experts (Chia & Sandford, 2007).

We used Delphi technique with a panel of seven judges, working at a distance, with all communication by email through a moderator. There are two separate stages, shortlisting and judging, each consisting of an initial round that elicits panelists’ comments on the entries, followed by three rounds in which panelists nominated their preferred entries. The number of rounds depends on how quickly a consensus emerges.

Panelists sent their responses to the author who was the moderator, which was collated and circulated to them anonymously after each round, as the basis for the next round. The panelists have at each stage a full record of what comments and nominations other panelists have made, but they do not know who made which comment or voted for which entry. Nor do they know the final result, till the same was disclosed after the consensus which was reached after 3 rounds for the widely prevalent diseases in Indian context fit for the studies. The following diseases and the relevant drugs are being considered for study out of the exhaustive list of widely prevalent and emerging diseases in Indian population. This study is further based on following diseases supported by expert opinion of Medical professionals as selected by the process cited above:-

Communicable diseases:

Tuberculosis

The treatment of Tuberculosis, world over, is based on WHO guidelines, according to which the first line drugs (categories I, II & III) for routine cases and second line drugs, which are given in drug-resistant cases i.e multi drug resistant tuberculosis (MDRTB) (source: 1. TB-A clinical manual for South -east Asia: Harries et.al., World Health Organization (WHO), Geneva,1997, 2. Guidelines for the management of drug- resistant Tuberculosis Crofton et.al.WHO, Geneva,(1997)

The treatment of the disease is done based on the category of patient affected by the infection. The treatment can be done based on administration of First line Drugs or 2nd Line drugs for MDRTB, as the case may be. The list of I st Line drugs and manufacturers is provided in Table -2. Similarly for 2nd line drug is illustrated in Table-4.

Human immunodeficiency virus infection / acquired immunodeficiency syndrome (HIV/AIDS)

Anti Retroviral drugs used for treatment of HIV-AIDS is provided in Table 3.

Non communicable diseases

Diabetes mellitus

The treatment for Diabetes based on the severity is done through administration of oral hypoglycemic agents as Shown in Table-5. The treatment done through administration of Biguanides and its combinations are provided in Table-7. Table-6 provides the list of companies into different types of Insulin used for treatment of Diabetes.

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Table-2 – 1st line drugs for Tuberculosis and Medicine Company name

Disease	Tuberculosis (Ist line drugs)								
Medicine	Rifamycin (RIFA)	Isonicotonic acid Hydrazide (INH)	Pyrazinamide (PZA)	Etham butanol (ETB)	ETB + INH	RIFA + INH	RIFA + INH +PZA	RIFA + INH +PZA + ETB	Streptomycin (injectible)
Company name	Aristo	Park Davis	Novartis	Lupin	Lupin	Unichem	Novartis	Novartis	SPPL-Ethical Div
	Lark Labs	Albert David	Macleods	Macleods	Plethico	Ovearseas HC	Unichem	Larks Lab	
	Lupin	IPCA	Lark Labs	RPG lifesciences	Cadilla Pharma	Biological E	Biological E	Lupin	
	Macleods	Pfizer	Taurus	Panacea Biotech	Le Sante	Merind	Platheco	Unichem	
	Plathico	Macleods	Lasante	Samarth Pharm	Themis	Aristo	Merind	Biological E	
	Concepts		Overseas HC	Concepts		Alkem	Aristo	Merind	
	IDPL		PCI	Emcure		Zydus Cadilla	Alkem	Alkem	
	Le Sante		Emcure	Pharmed		Emcure	Emcure	Zydus Cadilla	
	Overseas HC		Aristo	Plethico		IDPL	Lark Labs	Macleods	
	Biochem		Le Sante	Larks Labs		Lark Labs	IPCA	Platheco	
	Zydus Cadilla		Pharmed	Le Sante		IPCA	Macleods	Le Sante	
	Novartis		Lupin	Overseas HC		Biochem	Le Sante	Suniz	
	Themis		Novartis	Taurus Labs		Pharmed	Lupin	Overseas HC	
	Taurus labs		Themis	Themis		Macleods	Suniz	Indoco	
			Taurus			Platheco	Overseas SC	Concepts	
						GSK	Concept	Themes	
							Indoco	Rextar	
							Aventis	Wockhardt	
							Kresp	GSK	
							Novartis		
							Pharmed		
							Rextar		
							Themes		
							GSK		

(Source: Industry Drug Review)

Table-3. Antiretroviral drug for HIV/AIDS

Disease	AIDS (HIV +) Antiretroviral drug (ARV)									
	1. Nucleoside reverse transcriptase inhibitors (NRTI) (Nucleoside Analog)									
Medicine	Zidovudine (ZDV)	Abacavir (ABC)	Didanosine (ddi)	Emtricitabine (FTC)	Lamivudine (3TC)	Stavudine (d4T)	Tenofovir (TDF)			
Company Name	GSK	Cipla	Cipla		GSK	Cipla				
	Cipla				Zydus Biogen					
	Le Sante				Zydus Alidac					
	Samarth Pharma				La Sante					
	BHB lifesciences									
	Zydus Biogen									
	2. Protease Inhibitor (PI)									
Medicine	Amprenavir (APV)	Atazanavir (ATV)	Darunavir	Fosamprenavir (FPV)	Indinavir (INV)	Lopinavir (LPV)	Nelfinavir	Ritonavir (RTV)	Saquinavir (SQV)	Tripanavir (TPV)
Company					Cipla		Cipla	Cipla		
					Genix Pharma			Genix Pharma		
	3. Non nucleoside reverse transcriptase inhibitor (NNRTI) effective for HIV-1 & HIV-II									
Medicine	Efavirenz (EFV)	Nevirapine (NVP)	Delavvirdine (DLLV)							
Company	Cipla	La Sante								
		Cipla								

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Table-4. 2nd Line drugs for Multi drug resistant Tuberculosis and company name

Disease	Tuberculosis (2nd line drugs for Multi drug resistant Tuberculosis (MDRTB))									
Medicine	**Amikacin**	**Ciprofloxacin**	**Ofloxacin**	**Kanamycin**	**Paraminosalicylic acid (PAS)**	**Ethionamide**	**Prothionamide**	**Cycloserine**	**Capriomycin**	**Clofazimine**
Company name	Cadilla Pharma	Sarabhai	Anichem Labs	Macleods	Macleods	Lupin	Le Sante	Macleods	Macleods	Atra Zeneca
	NPIL	Alkem	Aquilla Labs	Samarth Pharma	Lupin	Overseas HC	Macleods	Lupin		SPPL
	Neon labs	Aquilla	Bestochem	Alembic	USV limited	Themes	Themis	BHB pharma		
	Biochem	Otsira genetica	Kee Pharma			Macleods		Panacea		
	Comed	Bayer	Biochem			BHB Lifesciences		Samarth		
	Lupin	NPIL	Biodrug			Le Sante				
	Indoco	Biochem	Claris Lifesciences			Panacea Biotech				
	Samarth Pharma	Plathico	Divus Labs			Samarth Pharma				
	Alkem	Blue Cross	Mimec pharma							
	Indswift	Memec Pharma	Ethicare							
	Plathico	Warren	Medico labs							
	Global Medical sciences	Eglomed	Emcure							
	Brown and Burk	Ranbaxy	Dey's							
	Syntheko	Albert David	Neu Foreva							
	Mapra Lab	Biological E	MarK remedies							
	Aristo	Anichem Labs	Zenith HC							
	Troikaa	Cipla	Merind							
	Emcure	Indoco	Monochem							
	Novamed	Core	e Merck							
	Secure HC	Zydus Cadilla	Brussels							
	Taurus	Emcure	Seagull Labs							
	Cachet	Cadilla Pharma	Blue Cross							
		Glenmark	Khandelwal							
		Lark Labs	Concepts							
		Dr. Reddy's Labs	Oglamed							
		Lupin Pharma	Zydus Cadilla							
		Alembic	Macleods							
		Claris Lifesciences	Suniz Pharma							
		Mankind	Medley Pharma							
		Sun Pharma	Emcure							
		GSK	Aventis							
		Macleods	Vales							
		Concept	Indswift							
		Dey's	Taurus Lab							
		HAL (Hindustan Antibiotic limited)	Balpharma							
		Formed	Mankind							
		Karnataka Antibiotic ltd (KAPL)	FDC							
		NPIL	Stancare							
		Biddle Sawyer								
		Torrent								
		Dabur								
		Hygeia								
		Khandelwal								
		Indswift								
		Taurus								
		Balpharma								
		Wyeth Laderly								
		FDC								

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Table-5 – List of Oral Glycemic Agents used for treatment of Diabetes Mellitus

Disease	Diabetes mellitus (Oral Hypoglycemic agents)								
	1. Sulphonyl ureas								
Medicine	Chloropropamide	Tolbutamide	Glibenclamide	Glipizide	Gliclazide	Glimepride	Rosilglitazone + Glicazide	Rosilglitazone	Pioglitazone
Company	Dey's Pharma		Cadilla Pharma	Emcure	Torrent	Aventis	Aristo	Torrent (psycan)	Biochem
			Zydus Medica	Bal Pharma	Comed	Torrent		Dr. Reddy's Lab	Unisearch
			Sarabhai	Microlabs	Bal Pharma	Panacea		Sun Pharma	Medley
			Aventis	Otsira Genetica	Serdia	BioChem		Aristo	Indswift
			Inga	Franco Indian	Carsyon	Microlabs		Healtheon	Zydus Medica
			NPIL	Modi Mundi Pharma	RPG Lifesciences	Emcure		Microlabs	Panacea
			Bal Pharma	RPG lifesciences	Argus	Medley		RPG Lifesciences	Wockhardt
			Sun Pharma	Alembic	Inga	Argus		Emcure	Healtheon
			USV	Wallace	Alkem	Comed			Systopic
			Otsira Genetica	Jenburkt	Khandelwal	RPG Lifesciences			Ranbaxy
				USV	Modi Mundi Pharma	Otsira Genetica			Sun Pharma
				Stadmed	JKDPL	Ranbaxy			Emcure
				Dey's	Stadmed	Wallace			KAPL
					Panacea	Sun Pharma			Alembic
					Raptakos	Cadilla Pharma			Intas
					Medley	Win Medicare			Life Medicare
					Indoco	Kopran			Comed
					Aristo	Bal Pharma			Karsyon
					IPCA	Life Medicare			Balpharma
					USV	Intas			Otsira Genetica
					Protec				Aglomed
					Cadilla Pharma				RPG Lifesciences
					Novartis				Kopran
					Alembic				Argus
					Jagsonpal				IPCA
					Dey's				Indoco
					Intas				NPIL
					Dr.Reddy's labs				Franco Indian
									Cadilla Pharma
									E.Merck

Table-6 List of company making Insulin for treatment of Diabetes

Disease	Diabetes mellitus (Insulin)					
Medicine	Neutral Insulin (Soluble)	Isophane Insulin (NPH)	Insulin Zinc suspension (Lente Insulin)	Pre mixed biphasic Insulin	Insulin Lispro	Insulin Glargine
Company	Novo Nordisc	Biocon	Novo Nordisc	USV	Eli lily	Aventis Pharma
	USV	USV	Eli-Lily	Novo Nordisc	Ranbaxy	
	Sarabhai	Novo Nordisc	Ranbaxy	Sara Bhai		
	Eli lily	Sara Bhai	Sarabhai	Eli-lily		
	Ranbaxy	Eli-lily	Cadilla Pharma	Ranbaxy		
	Aventis	Aventis		Aventis		
	Cadilla Pharma	IRM Pharma		Cadilla Pharma		

(Source: Drug Today)

Table-7 List of company making Biguanides for treatment of Diabetes

	Biguanides and it's combinations								
Medicine	**Phenphormine**	**Metphormine**	**Metphormine + Glibenclamide**	**Phenphormine +**	**Metphormine + Glipizide**	**Metphormine + Gliclazide**	**Metphormine + Glimpride**	**Metphormine + Rosiglitazone**	**Metphormine + Pioglitazone**
Company	USV	Ostira Genetica	RPG Lifesciences	Cadilla Pharma	Nucron Pharma	Torrent	Novartis	Torrent	Unisearch
		Aventis	NPIL		Bal Pharma	Comed	Torrent	Aztec	Stancare
		Argus	USV		Novartis	Bal Pharma	Panacea	Aristo	Sunpharma
		CFL	Bal Pharma		Microlabs	Carsyon	Otsira Genetica	Healtheon	Emcure
		Torrent	Sun Pharma		Franco Indian	Argus	Cadilla Pharma	Panacea	Intas
		Bal pharma	Modi Mundi Pharma		Aztec	Alkem	NPIL	Microlabs	Carsyon
		Novarts	Win Medicare		Zenburkt	Biochem	Unisearch	Emcure	Otsira genetica
		Stadmed	NPIL		USV	Khandelwal	Intas		NPIL
		IPCA	Argus		Dey's Pharma	Modi Mundi			Cadilla Pharma
		Dey's			Otsira Genetica	Win Medicare			
		Alkem			Taurus Labs	Stadmed			
		Alembic			Tridoss	Panacea			
		NPIL				Raptakos			
		Protec				Medlay Pharma			
		Franco Indian				Indoco			
		Emcure				Aristo			
		Cadilla Pharma				IPCA			
		Microlabs				Cipla			
		Comed				Mankind Pharma			
		Panacea				Cadilla Pharma			
		Zenburkt				Novartis			
		PIL				Alembic			
		Ranbaxy				Dey's			
		RPG lifesciences				Jagsonpal			
		Wallace				Intas			
		Healtheon				Dr. Reddy Labs			
		Raptakos				Wallace			
		Intas				PIL			
	Others								
Medicine	**Acarbose**	**Repaglinide**	**Nateglinide**						
	Emcure	Torrent	Healtheon						
	Wockhardt	Azitec (Sun)	Alembic						
	Cardicare	Wallace	Intas						
	Balpharma		Emcure						
	Otsira Genetica								
	Healtheon								
	Medley								
	Arian, Sun								

From the above work we came across 87 pharmaceutical firms relevant for the study. The data was collected from the Annual report of companies and was also gathered from Bloomberg, Mar, 2013.

"Many companies manufacturing or distributing a range of products will find that the Pareto Law will apply and can be exploited to determine supply strategy. Typically an analysis of the business will show that the 80/20 (or similar) rule holds. In other words, 80% of total volume will be generated from just 20% of the total product line."(Martin Christopher and Denis Towill (2001). Considering the above stated Pareto's approach we have considered 24 pharmaceutical firms which contribute to more than 80 % of the business. We could get the data for 24 companies which are listed in stock exchange and for those companies whose websites were having the Annual report for the year 2012.

Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric method of measuring efficiency of any Decision Making Unit (DMU) like firms, retail stores, public sector agency etc (Ramanathan, R. (2003). It was first introduced into the operation research by Charnes, Cooper and Rhodes in 1978 which is known as CCR model. This model has an assumption of constant returns to scale. Then, in 1984, Banker, Charnes and Cooper introduced a new model, known as BCC model. This model was an extension of the CCR model to accommodate the variable return to scale into consideration while analyzing the efficiency or performance of any DMU.

CCR model takes n DMUs into consideration, using m inputs to secure s outputs. The notations which are used in the model are as follows-

m: number of inputs (i=1,2,…m)

s: number of outputs (r=1,2,…s)

n: number of DMUs (j=1,2,…n)

x_{ij} : i^{th} input of j^{th} DMU

y_{rj}: r^{th} output of j^{th} DMU

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & \cdots & . \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix} \quad Y = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ . & . & \cdots & . \\ y_{s1} & y_{s2} & \cdots & y_{sn} \end{pmatrix}$$

$u = (u_1,u_2,\ldots u_s)$ $\quad$ $v = (v_1,v_2,\ldots v_m)$

The efficiency of each DMU is measured once and hence we need n optimization problem to be solved, one for each DMU_j. Let the DMU_j to be evaluated on any trial be designated as DMU_o, where"o"ranges over 1,2,….,n. We solve the following LP to obtain values for the input weights $v_1,v_2,\ldots v_m$ and output weight $u_1,u_2,\ldots u_s$ as variables.

max $u_1y_{1o} + u_2y_{2o} + \ldots\ldots + u_sy_{so}$

s.t. $v_1x_{1o} + v_2x_{2o} + \ldots\ldots + v_mx_{mo} = 1$

$u_1y_{1j} + u_2y_{2j} + \ldots. + u_sy_{sj} \le v_1x_{1j} + v_2x_{2j} + \ldots\ldots + v_mx_{mj}$ (j = 1,2,....,n)

$v_1,v_2,\ldots v_m \ge 0$

$u_1,u_2,\ldots u_s \ge 0$

The dual of LP helps in recognizing the reference set for the inefficient DMUs. These reference sets then help us in identifying the inadequacies existing in the inefficient units. The dual of the above model can be given in the following form-

min $\theta = \theta^*$

s.t. $Y\lambda \ge y_o$

$X\lambda \le \theta x_o$

$\lambda \ge 0$

The BCC model differs from the CCR model only in the adjunction of the condition $\sum_{j=1}^{n} \lambda_j = 1$ which we also write $e\lambda = 1$ where e is a row vector with all elements unity and λ is a column vector with all elements non-negative.

The above model provides technical efficiency (θ) of any DMU.

Phase – I

Min $\theta = \theta^*$

s.t. $Y\lambda \ge y_o$

$X\lambda \le \theta x_o$

$e\lambda = 1$

$\lambda \ge 0$

We solve phase-I to get θ^*. Then using our knowledge of θ^*, we solve phase-II.

Phase-II

Min $\sum s_i^- - \sum s_r^+$

s.t.

$Y\lambda - s_r^+ = yr_0$, r =1,2,3, …. s

$X\lambda + s_i^- = \theta^* x_{i0}$, i =1,2,3, …. m

$e\lambda = 1$

$\lambda \ge 0, s_i^-, s_r^+ \ge 0$

Data Variables

The variables selected for the study are categorized as input-output in the following manner

Inputs

The inputs considered are Expenditure on Research and development (R&D), Cost of Materials, Weighted Average cost of capital (WACC).

To state, "Without a dramatic increase in R&D productivity, today's pharmaceutical industry cannot sustain sufficient innovation to replace the loss of revenues due to patent expirations for successful products." (Paul et.al, 2010,). Expenditure on Research and Developments (R&D) is needed for innovation and considered as a key input.

Cost of materials (CM) is the cost of the raw materials consumed to make the finished goods.

The cost of capital is a standard tool of practical finance, so it's worth writing out the formula. Let r_D, and r_E, be the cost of debt and the cost of equity-that is, the expected rates of return demanded by investors in the firm's debt and equity securities. The overall (weighted-average) cost of capital depends on these costs and the market-value ratios of debt and equity to overall firm value.

Weighted Average Cost of Capital = r_A, = r_D,D/V + r_E,E/V

The weighted average cost of capital r_A, is the expected return on a portfolio of all the firm's outstanding securities. (Myers, 2001).

A calculation of a firm's cost of capital in which each category of capital is proportionately weighted. All capital sources - common stock, preferred stock, bonds and any other long-term debt - are included in a WACC calculation. All else equal, the WACC of a firm increases as the beta and rate of return on equity increases, as an increase in WACC notes a decrease in valuation and a higher risk. The WACC equation is the cost of each capital component multiplied by its proportional weight and then summing:

Weighted Average Cost Of Capital (WACC)

$$WACC = \frac{E}{V} * Re + \frac{D}{V} * Rd * (1 - Tc)$$

Where:

Re = cost of equity, Rd = cost of debt, E = market value of the firm's equity, D = market value of the firm's debt,

V = E + D, E/V = percentage of financing that is equity, D/V = percentage of financing that is debt, Tc = corporate tax rate

Businesses often discount cash flows at WACC to determine the Net Present Value (NPV) of a project, using the formula: NPV = Present Value (PV) of the Cash Flows discounted at WACC.

Outputs

Outputs are Sales in million INR, Net Profit, Earning per Share (EPS), Export %

Earnings per share (EPS) is the amount of earnings per each outstanding share of a company's stock.The portion of a company's profit allocated to each outstanding share of common stock. Earnings per share serves as an indicator of a company's profitability.

$$Earnings\ per\ share(EPS) = \frac{Net\ Income - Dividends\ on\ preferred\ stock}{Average\ outstanding\ Share}$$

When calculating, it is more accurate to use a weighted average number of shares outstanding over the reporting term, because the number of shares outstanding can change over time. However, data sources sometimes simplify the calculation by using the number of shares outstanding at the end of the period. Diluted EPS expands on basic EPS by including the shares of convertibles or warrants outstanding in the outstanding shares number.

We are dropping Sales from output as Sales and Profit are highly correlated as stated in Table-8.

Table-8. Correlations of outputs

	O1 Sales	O2 Profit	O3 Earning / Share	O4 Export
O1 Sales	1			
O2 Profit	.776**	1		
O3 Earning / Share	.201	.219	1	
O4Export	.040	.009	.007	1

The descriptive statistics for the outputs and inputs considered are presented in Table 9. The efficiency of DMUs, their peers, possible reductions of inputs in percentage, possible increase in outputs in percentage are presented in Table 10.

Table-9 Descriptive Statistics of outputs and inputs

	N	Minimum	Maximum	Mean	Std. Deviation
Profit	24	9	25873	4866.75	5802.790
Earning per Share	24	.51	76.76	26.0029	19.99184
Export	24	2.73	86.90	33.0217	21.15355
R&D	24	3	6243	1591.67	1920.518
CM	24	314	23264	9167.79	7705.955
WACC	24	6.34	10.82	9.3254	.86017
Valid N (listwise)	24				

Table 10 Efficiencies, Peers and Projections

Phase -I			Phase-II					
			Output % to increase			Input % to decrease		
DMU #	BCC effi.	Benchmark DMU #s	Net Profit (O2)	EPS (earning per share) (O3)	Export % (O4)	R&D Spent (I1)	Cost of Material, cogs (I2)	Weighted Average cost of capital WACC (%) (I3)
1	0.73	8,13,19	107	538	0	53	27	27
2	0.85	13,19,21	23	0	360	15	36	15
3	0.75	8,19,22	0	151	0	61	46	25
4	0.87	8,19,22	0	28	0	76	47	12
5	0.98	8,19,22	0	153	0	50	55	1.5
6	0.94	13,21	6	111	21	5	84	5
7	1		0	0	0	0	0	0
8	1		0	0	0	0	0	0
9	1		0	0	0	0	0	0
10	0.89	13,19	19	0	239	11	64	11
11	1		0	0	0	0	0	0
12	0.76	8,19,22	0	152	0	74	66	23
13	1		0	0	0	0	0	0
14	0.9	13,19,21	118	547	0	9	64	9
15	0.91	8,19	43	92	0	56	34	8
16	0.72	8,19	258	74	0	76	42	27
17	1		0	0	0	0	0	0
18	0.94	8,19,22	0	98	0	79	53	5
19	1		0	0	0	0	0	0
20	0.85	19,22	0	76	0	43	60	14
21	1		0	0	0	0	0	0
22	1		0	0	0	0	0	0
23	0.81	8,19,22	0	30	0	73	38	18
24	0.85		0	38	0	82	64	14

In order to clearly examine the determinants of efficiency, we further applied Tobit regression model regressing the BCC efficiency (as shown in second column of Table 10) as dependent variable. As per DEA literature Coelli(1998), Tobit regression model is suitable when the dependent variable is censored. The Tobit regression model is represented as-

$$\theta_i = \alpha_i + \beta_1(\mathrm{Profit})_i + \beta_2(EPS)_i + \beta_3(Export)_i + \beta_4(R\&D)_i + \beta_5(CM)_i + \beta_6(WACC)_i + \varepsilon_i$$

Where, θ_i is the efficiency score for the pharmaceutical company, i computed from the BCC model.

The BCC efficiency statistics are as shown below.

Table 11: BCC efficiency statistics

	Minimum	Mean	Maximum	SD
BCC efficiency	0.72	0.9062	1.0000	0.09753

The χ^2 test statistics (=244.8) with five degrees of freedom associated with p value (= 0.0) shows that the model is a good fit for the data. Also we find that the value of constant 2 ($e^{-2.52}$= 0.08046) from the Tobit model is less that the standard deviation of θ_i (=0.09753) which again shows that the models appears to fit the data well. The results of Tobit regression are presented in Table 12.

Table 12: Tobit regression model

Variable	Value	Std. Error	z-value	p-value
Constant	1.6600000	0.27800000	5.95493	
Profit**	0.0000432	0.00001680	2.57840	0.004963
Earning per Share	0.0003140	0.00134000	0.23538	0.406957
Export**	-0.0022300	0.00123000	1.80903	0.035223
R&D**	-0.0000519	0.00001745	-2.98381	0.004123
CM**	-0.0000112	0.00000701	-1.60411	0.054345
WACC**	-0.0086300	0.03030000	-2.84309	0.002234

** Significant

Recommendations and conclusions

DEA was useful to find out the benchmark DMU / companies. It was found that all companies are above 70 % BCC efficient. The benchmark companies for each are cited in Table 10. There is a tremendous scope to reduce the R&D spent. It can be inferred that even though the spent on R&D is more but it is not yielding enough. The cost of materials also needs to be reduced. The inference is that these firms are using cost plus margin system and there is good scope for backward negotiations with the vendor to reduce the cost of raw materials which can help society in large to produce drugs at affordable prices. The results derived through Tobit regression analysis highlights that the efficiency of pharmaceutical firms is mainly impacted either by output variables namely profit and export or by input variables i.e. R&D and WACC.

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