Estimating Efficiency and Productivity Growth of the Grain Silos and Flour Mills Organisation in Saudi Arabia

Jaber Salem Alyami

Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy

February 2015

ABSTRACT

The Grain Silos and Flour Mills Organisation (GSFMO) is the responsible authority monopolising the Kingdom's milling industry. However, the organisation has recently been facing financial problems. The aim of this study is to estimate the technical, cost and allocative efficiency (TE, CE and AE) of the flour mills of the GSFMO (1988-2011), using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) approaches. In addition, it seeks to explain variation in efficiency levels between the mills and conduct further analysis through the second stage regression to estimate the effect of managerial variables. Productivity growth over time was also estimated in this study using DEA (2008-2011) and SFA (1988-2011) approaches. Both primary data and secondary data (1988-2011) to cover the nine milling branches were utilised.

Using DEA under constant return to scale (CRS), average TE ranged from 91.72% in Khamis branch to 97.63% in Almadinah. Average TE under input-orientated variable return to scale (VRS) was lower than TE estimated under output-orientated VRS. The older branches had the lowest TE compared to newer branches. Under VRS, TE was greater than TE for the same branches under CRS. TE results using SFA were quite analogous to the results using DEA. Regarding productivity growth, using DEA for the 2008-2011 data, no consistent patterns were found across the GSFMO branches in the mean total factor productivity growth (TFPG), technical change (TC), and efficiency change (EC). When using SFA to estimate productivity growth over the period 1988 to 2011, there was a decrease in productivity growth for most branches.

With regards to the results of the second stage regression, branch managers' age, local temperature and 'bad' infrastructure have a significant negative relationship with TE, while manager's experience did not seem to have any significant relationship with TE. However, new and mix machine conditions and number of mills in each branch have a significant positive relationship with TE. In terms of CE and AE using the DEA approach, the results show that major losses incurred by the organisation

were partly due to the significant decrease in CE and AE and that there is a significant scope to reduce inputs costs in the production process.

ACKNOWLEDGEMENTS

I would like to extend my gratitude to many people who helped to bring this thesis to fruition. First, I would like to thank my main supervisor Dr. Paul Wilson who provided me with the opportunity to pursue this doctoral program. Not only has he been a source of inspiration throughout the period of study but he has also provided valuable guidance and moral support throughout this thesis and through my entire program of study.

I would also like to thank my second supervisor Dr. Stephen Ramsden whose guidance and feedback have been extremely helpful. I really do not have enough words to express my deep and sincere appreciation and respect for Dr. Paul, Dr. Stephen and Dr. Dev.

I would also like to acknowledge the former Minister of Agriculture Dr. Fahad Balghunaim who offered me the opportunity to finish my postgraduate program in the UK. I would also want to appreciate the contribution of the former director of the GSFMO Engineer Walid Al-Khuraiji who gave me the go ahead to access the data of the organisation. Also important is to mention Ahmad Al-Fares (Assistant General Director of the GSFMO) and other colleague in the GSFMO for their help and support during the data collection process. I would not go without mentioning Saudi Arabia's Minister of Agriculture Abdulrahman Al Fadley for his continuous support for the ministry's employees on an overseas scholarship.

I cannot find the words to express my deepest thoughts and gratitude for my father, mother and siblings for their continuous support during my entire academic journey and for my wife and my children whose endurance with me have finally paid off with this academic endeavor. Finally, I must thank the United Nations represented in the Food and Agriculture Organisation (FAO), as well as the FAO's personnel based in Saudi Arabia for their financial support during the period of my study. I would also want to include all other people directly or indirectly involved in this research process. This thesis would not have been possible without the contribution of any of the above. Thank you all.

PUBLICATIONS AND PRESENTATIONS RELATED TO THIS THESIS

Published Papers:

Two papers have already been published in the conferences' proceedings Official Book:

1- Estimating Efficiency and Productivity Growth of the Flour Mills of the Grain Silos and Flour Mills Organisation (GSFMO) in Saudi Arabia (See the proceeding book, p. 171).
   Edited by: Banker R., A. Emrouznejad, H. Bal, I. Alp, M. Ali Cengiz (2013), Data Envelopment Analysis and Performance Measurement: Proceedings of the 11th International Conference of DEA, June 2013, Samsun, Turkey.
   It is now available at:
   <http://www.deazone.com/en/wp-content/uploads/2014/05/DEA2013-Proceedings.pdf>

2- Estimating Cost Efficiency (CE) and Allocative Efficiency (AE) of the Flour Mills of the Grain Silos and Flour Mills Organisation (GSFMO) in Saudi Arabia ((See the proceeding book, p. 182).
   Edited by: Ali Emrouznejad, Rajiv Banker Susila M. Doraisamy and Behrouz Arabi (2014), Data Envelopment Analysis and Performance Measurement: Proceedings of the 12th International Conference of DEA, April 2014, Kuala Lumpur, Malaysia.
   It is now available at:
   <http://www.deazone.com/proceedings/DEA2014-Proceedings.pdf>

Oral Presentations:

Part of the academic assessment, I delivered four oral presentations; three at the Biosciences school and one at the Business School at the University of Nottingham.

Poster Presentations:

A total of six posters were presented throughout the academic process; the first was part of my university assessment at the University of Nottingham (27-03-2013). The second was part of the 87th annual conference held by the Agricultural Economics Society at the University of Warwick (08-10 April 2013). The third was during the 11th international conference on DEA2013 (27-30 June 2013) in Samsun, Turkey. The forth was during the 7th Saudi Student Conference (SSC2014) held at Edinburgh International Conference Centre (EICC) in Edinburgh, UK on the 1st -2nd of February 2014. The fifth was during the university assessment (April 2014). The sixth was during the 12th international conference on DEA2014 (14-17 April 2014) at the University of Malaya in Kuala Lumpur, Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ADF	Agricultural Development Fund
AE	Allocative Efficiency
BBS	Bangladesh Bureau of Statistics
BC	Battese-Coelli
BCC	Banker, Charnes, Cooper
CBS	Central Bureau of Statistics
CCR	Charnes, Cooper and Rhodes
CE	Cost Efficiency
COLS	Corrected Ordinary Least Squares
CRS	Constant Returns to Scale
CSA	Central Statistical Authority
DEA	Data Envelopment Analysis
DEETYA	Department of Employment, Education, Training and Youth Affairs
DMUs	Decision Making Units (DMUs)
DRS	Decreasing Returns to Scale
EC	Efficiency Change
EE	Economic Efficiency
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GLSS	Ghana Living Standards Survey
GMPMF	Grain Mill Products Manufacturing Firms
GSFMO	Grain Silos and Flour Mills Organization
Ha	Hectares
i/l	imaging/laboratory
ICT	Information Communication Technology
ICUs	Intensive Care Units
I-O VRS	Input-Orientated VRS
IRS	Increasing Returns to Scale
JMLS	Jump Markov Linear System
KSA	Kingdom of Saudi Arabia
LDA	landing distance available
Mha	million hectares
MI	Malmquist Index
MOA	Ministry of Agriculture
MOLS	Modified Ordinary Least Squares
MSC	Mumias Sugar Company
NAERI	Norwegian Agricultural Economics Research Institute
NHS	National Health System
NLSS	Nepal Living Standards Survey
O-O VRS	Output-Orientated VRS
RTS	Returns to Scale
s/e	scheduled/emergency
SEERAD	Scottish Executive Environment and Rural Affairs Department
SFA	Stochastic Frontier Production Function
SFAS	Scottish Farm Account Survey

SRTUs	State Road Transport Undertakings
t/ha	tonnes per ha
TC	Technical Change
TE	Technical Efficiency
TFPG	Total Factor Productivity Growth
TODA	Take off Distance Available
VHLSS	Vietnam Household Living Standard Survey
VIF	Variable Inflation Factor
VRS	Variable Returns to Scale

1. BACKGROUND CHAPTER

1.1. Introduction

Saudi Arabia has always been thought of as a desert where agriculture is impossible. However, the government has succeeded in attracting technology which can change the desert into a productive agriculture area. As wheat is one of the significant staple grains in Saudi Arabia, it has been increasingly taken into consideration to such an extent that the Grain Silos and Flour Mills Organization (GSFMO) was established. The GSFMO is thus one of the most prominent governmental organisations specialising in the production of some of the most important food industries that are dependent agricultural produce, including flour.

This study focuses upon improving the efficiency of the milling industry production in the kingdom. This chapter provides a brief overview of the agriculture sector and the policy support and subsidies for it from the government. The main focus in the study will be on the GSFMO and its production from its flour mills between the years 1988 to 2011. Furthermore, the study will provide information about the current situation of the flour mills such as storage capacity of the wheat silos individually in order to examine the balance between the storage capacity of silos and the amount of wheat used, and the variation in machine and human productivities for all branches. The study also examines the cost of a tonne of flour from salaries and wages, operating costs and maintenance and hygiene contract costs.

The chapter includes a summary of key issues which have been identified after close scrutiny of the current situation of the flour mills, and upon which the objectives of the research have been drawn.

1.2. Agricultural sector in the Kingdom of Saudi Arabia

Since the establishment of the Ministry of Agriculture (MOA) in 1925, the Kingdom of Saudi Arabia (KSA) has focused on the development of the agricultural sector and has always sought to achieve particular goals, including; first encouraging the private sector to be a major actor in overall agricultural development; second, contributing to food security; third, taking advantage of the comparative advantage of different production areas in the Kingdom, and transferring modern technologies from outside the kingdom, in addition to achieving a balanced development between all production regions (MOA, 2002).

The progress of the agricultural sector has been aided by development infrastructure through major dam-building projects to maintain water resources. The kingdom has also undertaken the construction of state and private wells and other projects including desalination plants and sewage treatment facilities, established the GSFMO, created agricultural roads linking production areas and delivery centres and the introduction of mechanical, chemical and biotechnical technologies. This has led to higher growth rates of agricultural production and contributed to the diversification of sources of income and increased rates of self-sufficiency in food, especially wheat, dates, milk, eggs and some vegetables (MOA, 2010).

In 1968, the state issued a fallow land distribution system for individuals and agricultural companies. This system resulted in an increase in the number of agricultural holdings from 212,160 in 1982 to 250,690 in 2010. Moreover, the area of agricultural holdings increased from 2.14 million hectares (mha) in 1982 to 4.36 mha in 2010. As such, the average size of the agricultural holdings increased from 10.0 hectares (ha) in 1982 to 17.3 ha in 2010.

It became apparent, given the achievements of the agricultural sector in Saudi Arabia during the period spanning from 2000 to 2010, that there had been an increase in the value of agricultural output from 35.76 billion Saudi riyals in 2000 to 39.96 billion

Saudi riyals in 2010, while there had been a decline in the contribution of the agricultural sector in terms of the total domestic output from 5.7% in 2000 to 4.6% in 2010. This means that the contribution of the agricultural sector to total domestic output fell at a rate of 1.9% per annum during from 2000 to 2010 (MOA, 2011).

Even though there have been advancements made in the agricultural sector, it still faces several challenges, including most importantly: the imbalanced regional distribution of agricultural loans and subsidies amongst the production areas; the scarcity of water resources; and decline in the area of land cultivated during recent years from 1.22 million ha in 1999 to about 806.68 thousand ha in 2010 (*ibid*). All these variables have led to a decrease in the relative share of the agricultural sector in terms of the total domestic income.

1.2.1. Policy Support and Agricultural Subsidies

The Saudi government has pursued a policy to support and encourage the agricultural sector to achieve its national goals. For example, after the Kingdom was founded by King Abdul Aziz Al Saud in 1932, the government encouraged citizens to engage in economic activities, including agriculture, with the state importing agricultural machinery and equipment and distributing them among farmers at discounted prices, combined with low repayment schemes. It also issued a decree exempting all the equipment and machinery from customs duties in 1944. The Saudi Government distributed agricultural land in the form of grants among citizens, while other state lands were leased or sold at nominal prices to farmers in a number of regions in the Kingdom. In addition, the government supervised the drilling of several water wells and contracted with several technical experts to train and guide farmers to implement modern techniques and methods of agricultural productivity (Agricultural Development Fund, 2010).

Government support for the agricultural sector can be classified as either direct, by providing financial help, or indirect, through covering aspects such as advice to farmers. The government adopted direct support related to specific products on wheat, barley, dates, palms and specialised animal feed production projects. This direct financial support includes various subsidies and affordable loans, which are offered by the MOA, the Agricultural Development Fund (ADF), and the GSFMO.

With regard to the direct support not related to specific products, this includes agricultural loans and subsidies for the production inputs, such as supplying mechanisms, machinery, irrigation pumps, beekeeping equipment, and fishing and agricultural variable inputs like fertilisers, seeds and pesticides. The ADF provides the aforementioned support in all its forms and domains. Indirect support integrates with the direct support. In many cases, investors in the agricultural sector may not need direct support as such; rather, they may require technical services which they either cannot afford or are unable to use (Al-Obayd, 2002).

To increase agricultural activity, the government set up the ADF (previously known as the Saudi Arabian Agricultural Bank) in 1963 to financially support farmers and specialised agricultural enterprises such as those related to wheat, barley, feed, fruit and greenhouses used to produce vegetables, as well as projects associated with livestock production (broilers, dairy, sheep and veal fattening, and fish projects) (ADF, 2010).

The MOA also plays a major a role in providing direct agricultural subsidies, mostly via grain, palm and dates subsidies. As shown in Table 1.1, it is noted that the total value of direct agricultural subsidies for grain reached 68.04 million Saudi Riyals over an 11 year period, representing 13.90% of the total 489.33 million Saudi riyals of direct agricultural subsidies granted by the MOA. The total value of direct agricultural subsidies for palm and dates was 53.58 and 367.71 million Saudi riyals respectively, representing 10.95% and 75.14% of the total value of direct agricultural subsidies granted by the MOA. In addition, it can be seen that the total value of direct agricultural subsidies has increased by 33.49% from 2000 to 2010 (Table 1.1).

Table 1.1: Value of agricultural subsidies granted by the Ministry of Agriculture in million Saudi riyals during the period 2000-2010 by crop type

Year	Grain	Palm	Dates	Total	Index Number
2000	7.38	7.44	22.62	37.44	100
2001	12.54	12.72	14.58	39.84	106.41
2002	10.20	11.58	23.22	45.00	120.19
2003	4.74	5.88	39.42	50.04	133.65
2004	3.48	7.80	6.45	17.73	133.49
2005	5.10	8.16	36.78	50.04	133.65
2006	10.08	0.00	39.30	49.38	131.89
2007	4.92	0.00	44.94	49.86	133.17
2008	2.64	0.00	47.40	50.04	133.65
2009	3.60	0.00	46.38	49.98	133.49
2010	3.36	0.00	46.62	49.98	133.49
Total	68.04	53.58	367.71	489.33	-
%	13.90	10.95	75.14	100	-

Source: Ministry of Agriculture, Department of Studies, Planning, and Statistics, various issues of the Agricultural Statistical Yearbook (2000-2010).

1.3. Wheat Production in Saudi Arabia (2006-2010)

Wheat is one of the most important commodities and holds a strategic economic significance for Saudi Arabian agriculture. Table 1.2 shows that the mean area planted with wheat in the Kingdom of Saudi Arabia represented an average of 332.03 thousand hectares during the period 2006-2010. Wheat cultivation is concentrated in six production areas; namely, Aljouf (28.37% by area), Riyadh 21.12%, Qassim 16.82%, Hail 12.69%, Eastern 11.62%, and Tabuk 8.05%. These six production areas accounted for 98.67% of total wheat cultivation area. In addition, the mean local annual production of wheat crop in Saudi Arabia was 1.94 million tonnes during the period 2006 to 2010. The production of wheat is concentrated in the same six production regions; however, production output does not directly correlate with production areas. In terms of total production, the six main regions account for the following: Aljouf (34.57% by production tonnes), Riyadh 17.87%, Hail 14.69%, Qassim 14.36%, Eastern 8.95%, and Tabuk 8.79%. This indicates that these six cultivation areas accounted for 99.23% of total wheat production.

The mean wheat productivity in Saudi Arabia was 5.83 tonnes per ha (t/ha) during the period 2006 and 2010. The region of Aljouf occupied top position producing 7.1 tonnes per ha (t/ha), followed by Hail (6.74 t/ha), Tabuk (6.36 t/ha), and then followed by Qassim and Riyadh producing 4.98 and 4.93 t/ha respectively. Relative to the national mean production, productivity in each of the Aljouf, Hail, and Tabuk regions exceeds national averages by 21.8%, 15.7% and 9.2% respectively. By contrast, the mean productivity of wheat in the remaining regions ranged from 14.7% to 44.9% lower than the national average (Table 1.2).

Table 1.2: The relative importance of area and production of wheat for the various production areas during the period between 2006 and 2010

Region	Area (thousand ha)	%	Production (thousand tonnes)	%	Production (tonne/ha)	Order	Rate Number	Rate of change
Riyadh	70.12	21.12	345.86	17.87	4.93	5	84.6	-15.4
Makkah	0.27	0.08	0.87	0.05	3.28	11	56.2	-43.8
Almadinah	0.46	0.14	1.83	0.09	4.01	7	68.8	-31.2
Qassim	55.84	16.82	277.85	14.36	4.98	4	85.3	-14.7
Eastern	38.58	11.62	173.12	8.95	4.49	6	77	-23
Asir	2.78	0.84	8.93	0.46	3.21	12	55.1	-44.9
Tabuk	26.72	8.05	170.04	8.79	6.36	3	109.2	9.2
Hail	42.15	12.69	284.28	14.69	6.74	2	115.7	15.7
North border	-	-	-	-	-	-	-	-
Jazan	0.02	0.01	0.07	-	3.61	9	62	-38
Najran	0.67	0.2	2.58	0.13	3.84	8	65.9	-34.1
Albaha	0.25	0.07	0.88	0.05	3.56	10	61	-39
Aljouf	94.18	28.37	668.93	34.57	7.1	1	121.8	21.8
Kingdom	332.03	100	1935.26	100	5.83	-	100	-

Source: Collected and calculated using: The Ministry of Agriculture, Department of Studies, Planning and Statistics, the Annual Agricultural Statistics Handbook. Vol. 24 (2011)

1.3.1. Government Contribution to the Wheat Storage and Milling Industry

The expansion of agricultural production over recent years has been one of the success factors contributing to the achievement of a comprehensive development in the Kingdom. At a time when wheat trade has been characterised by fluctuations in terms of prices and supply in global markets, the government's policy has been geared towards encouraging local cultivation of wheat to reach self-sufficiency in wheat given its strategic importance. This support has taken various forms such as providing farmers with direct and indirect financial support, including the purchase of their produce at subsidised prices far exceeding world market prices, and the provision of affordable loans for needy farmers (GSFMO, Annual Report, 1988).

The state has spared no effort in the last few years to increase the acreage of wheat and to improve and multiply production through the provision of financial support, enabling farmers to use easy repayment plans to utilise modern agricultural machinery, erect dams and wells, import modern irrigation equipment, and reclaim agricultural lands and prepare them for cultivation.

Due to the importance of wheat as a strategic crop and being one of the basic ingredients of food, providing flour to citizens, the Kingdom embarked on the establishment of a governmental body in charge of purchasing wheat from farmers and storing this in accordance with the latest internationally recognised methods. This organisation would also be entrusted with the task of milling wheat, for which the GSFMO was created in 1972 (GSFMO, Annual Report, 2004).

One of the most prominent objectives of the GSFMO was to provide and store adequate amounts of wheat and keep a reserve stock to be used in emergency circumstances. The organisation has traditionally adhered to this policy, by developing an annual schedule to clarify the mechanisms, arrangements and time designated to receive wheat from farmers. This schedule is published and distributed to all branches of the organisation. For this purpose, silos were constructed for each of 11 branches throughout the kingdom. The total amount of wheat received from farmers was 8,686 tonnes in 1978, while the amount of wheat received from farmers in 2010 was 1.279 million tonnes (GSFMO, Annual Report 2010).

The GSFMO provides support for both wheat and barley. The support policy for wheat started in 1973 with a subsidy of 250 Saudi Riyals per tonne. Afterwards, the government fixed a promotional fund of 3,500 Saudi Riyals per tonne in 1978-79. There had been a constant decline in the support for several years until support reached 1000 Saudi riyals per tonne in 2004, which has carried on to the present time (GSFMO, 2011).

1.3.2. Policy Framework of Wheat Production

Despite the importance of wheat, and in light of the scarcity of water resources, the Council of Ministers Resolution No (335) was issued on the 22nd of September 2007, stipulating that the GSFMO would first stop buying wheat produced locally, in a maximum period of eight years at an annual rate of decline of 12.5%, and secondly prevent the export of locally produced wheat. Third, the MOA would prevent the issuing of licences for the production of wheat, barley and fodder (Secretariat of the Council of Ministers, 2007). In light of these governmental decisions issued in respect to wheat, the production and importation policy has changed, leading to a gradual decrease in the local production and self-sufficiency ratio on the one hand, and an increase in the amount of Saudi imports of wheat on the other.

As shown in Table 1.3, these data reflect the variations in production and consumption, as well as the proportion of self-sufficiency and Saudi imports of wheat. The local production of wheat decreased from 2.56 million tonnes in 2007 to 1.35 million tonnes in 2010, which represents an annual decrease of 15.8%, while local consumption saw an annual growth rate of 5.2%; thus a decreased self-sufficiency ratio from 100% in 2007 to 45.5% in 2010, an annual self-sufficiency decrease of 18.2%.

Table 1.3: Production, consumption, the ratio of self-sufficiency and wheat net imports during the period 2007-2010

	2007	2008	2009	2010	Rate of annual change
Local production (Thousand tonne)	2558	1985.6	1152	1349	-15.8
Available for consumption (Thousand tonne)	2565.1	2200.9	2650.7	2966.2	5.2
Wheat imports	7.1	215.3	1498.7	1617.2	7559.2
The ratio of self-sufficiency	100	90.2	43.5	45.5	-18.2

Source: Ministry of Agriculture, the Annual Agricultural Statistics Handbook, various issues (2007-2010)

1.4. The Grain Silos and Flour Mills Organisation (GSFMO)

The Grain Silos and Flour Mills Organisation (GSFMO) is responsible for the milling industry in Saudi Arabia, according to the Royal Decree No. 14 issued on the 08/05/1972 and amended by the Royal Decree No. 3/m issued on the 26/10/1985. The milling industry is considered as one of the strategic manufacturing industries, and aims to prepare wheat for human consumption.

The main aims of the GSMFO include the establishment and operation of flour mills to produce flour; the creation and operation of factories in order to produce feed for animals and other poultry; the construction and operation of silos to store grain in several locations that are close to agricultural and residential communities; and the purchase and importation of grain, as well as the provision of a supplementary stock of wheat to use at times of emergency (GSFMO, 1999).

To accomplish these aims, the organisation established the first major branches in Riyadh, Dammam and Jeddah in 1975, followed by the Qassim branch in 1976, then Khamis Mushayt in 1979. At the outset, five branches were established in Riyadh, Dammam, Jeddah, Khamis Mushayt and Qassim; the organisation then launched the remaining six branches in 1982 in each of Hail, Aljouf, Wadi Aldawasir, Alkharj, Almadinah and Tabuk (GSFMO, Annual Reports, 2011; see also Figure 1.1).
As shown in Table 1.4, the grain silos capacity varies across 11 branches from the largest Riyadh branch with a storage capacity of 535 thousand tonnes of wheat, representing 21.23% of the total storage capacity of grain silos in the Kingdom, to Khamis Mushayt branch with only 40 thousand tonnes wheat capacity (1.59% of the total).

The organisation had also established six industrial estates for the mills since its inception in 1972 until 2007 in the regions of Riyadh, Makkah, the Eastern Province, Qassim, Asir and Tabuk. There are a total of 19 flour mills with a daily production capacity of 5,715 tonnes of flour. In 2008, the organisation created mills in each of

Almadinah, Hail and Aljouf, bringing the total number of branches with mills to nine (Figure 1.1). These branches accommodated 22 mills with a daily production capacity of 10,980 tonnes of flour. The largest daily production capacity is in the five mills of Riyadh (2,550 tonnes of flour per day; 23.22% of the total production capacity of the mills in the Kingdom) compared to Hail, Tabuk, Aljouf and Almadinah branches, with each having a production capacity of 600 tonnes of flour per day. The organisation also established five factories for the production of animal feed with a total capacity of 2,100 tonnes per day in Riyadh, Jeddah, Dammam, Qassim, and Khamis Mushayt as shown in Table 1.4.

Table 1.4: Number of mills, production capacity for flour and feed mills, and the number of wheat silos and their storage capacity

Branch	Number of Flour Mills	Capacity of Flour Mills(tonne/day)	%	Capacity of Feed Mills(tonne/day)	Number of Wheat Silos	Capacity of Wheat Silos (thousand tonnes)	%
Riyadh	5	2550	23.22	300	1	535	21.23
Alkharj	0	0	0	0	1	200	7.94
Wadi Al Dawasir	0	0	0	0	1	500	19.84
Qassim	2	900	8.2	600	1	485	19.25
Hail	1	600	5.46	0	1	300	11.9
Jeddah	5	2430	22.13	300	1	120	4.76
Tabuk	1	600	5.46	0	1	100	3.97
Aljouf	1	600	5.46	0	1	100	3.97
Dammam	3	1050	9.56	300	1	80	3.17
Almadinah	1	600	5.46	0	1	60	2.38
Khamis Mushayt	3	1650	15.03	600	1	40	1.59
Total	22	10980	100	2100	11	2520	100

Source: Collected and calculated using: GSFMO, Annual report (2011).

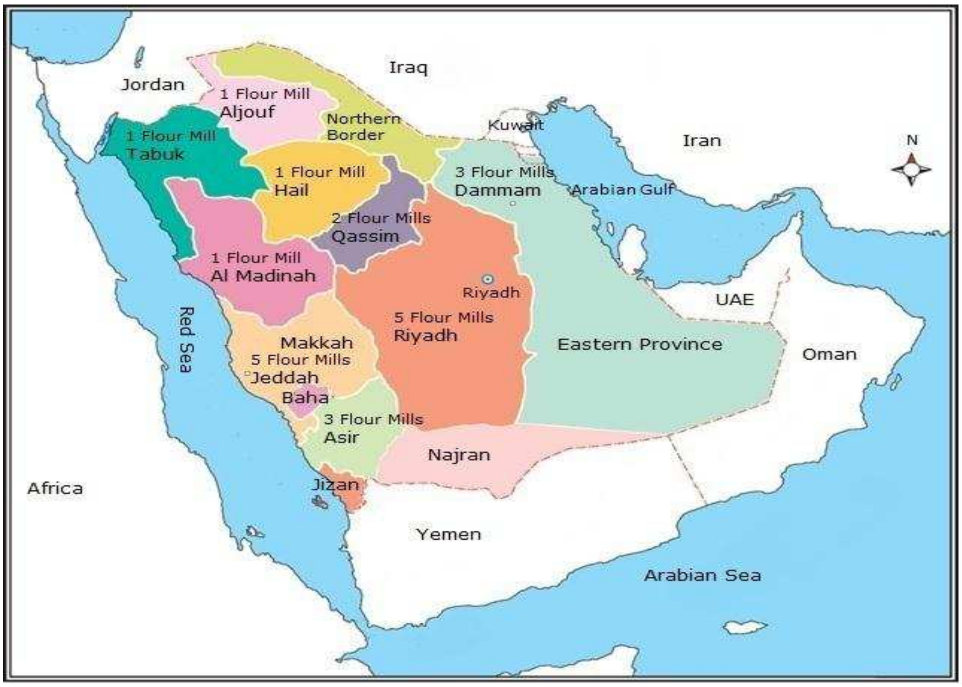

Figure 1.1: Distribution of GSFMO's Flour Mills by Regions in Saudi Arabia
Source: Adapted from Google maps (2011).

According to the budgets and profit and loss accounts of the GSFMO from 1996 to 2011, it can be noted that the revenues ranged from a minimum of 1,106.22 million Saudi riyals in 2001 to a maximum of 3,280.92 million Saudi riyals in 1997. On the other hand, the expenditure of the organisation ranged between a minimum of 1,755.18 million Saudi riyals in 2008 and as much as 3,671.88 million Saudi riyals in 2002. Based on these data, it is clear that the GSFMO has suffered losses, and despite the financial support provided by the Saudi government, these losses ranged from 210.6 million Saudi riyals in 1997 to 2,458.68 million Saudi riyals in 2002.

1.4.1. The Flour Mills of the GSFMO (1988-2011)

1.4.1.1. Variations in machine productivity GSFMO branches (1988-2011)

Studying the disparities in machine productivity for the various branches of the GSFMO, it can be seen in Figure 1.2 that there is a clear variation in the machine productivity between the various branches of the GSFMO. The mean machine productivity ranged between a minimum of 11 tonnes per hour in the Dammam branch to a maximum of 23.74 tonnes per hour in the Almadinah branch during the period 1988-2011 (Appendix 1).

By calculating the rate of change of mean machine productivity of the various branches to the mean machine productivity of the Dammam (the least productive with respect to machine productivity), it is clear that the productivity of the Almadinah, Hail, Aljouf and Tabuk branches was respectively, 115.8%, 84.9%, 84.5 %, and 79.2% greater than Dammam. The machine productivity for Khamis Mushayt, Riyadh, Qassim and Jeddah was also greater than Dammam, however at relatively lower rates of improvement at 42.8%, 18.1%, 17.9%, and 12.3% respectively.

In addition to variations in mean machine productivity, variation exists in the amount of wheat used and the number of hours of mills operation. Consequently, the standard deviation of machine productivity also ranges between 0.06 (Aljouf) and 5.42 (Almadinah).

Examining the data over the time period presented there are clear variations between the minimum and maximum machine productivity in the GSFMO branches in different years, with a minimum of 9.46 tonnes per hour in the Dammam branch (1990) and a maximum of 31.86% tonnes per hour in Almadinah branch in 2008 (Appendix 1), which stands as an outlier in the data; therefore, it was removed from the Figure 1.2.

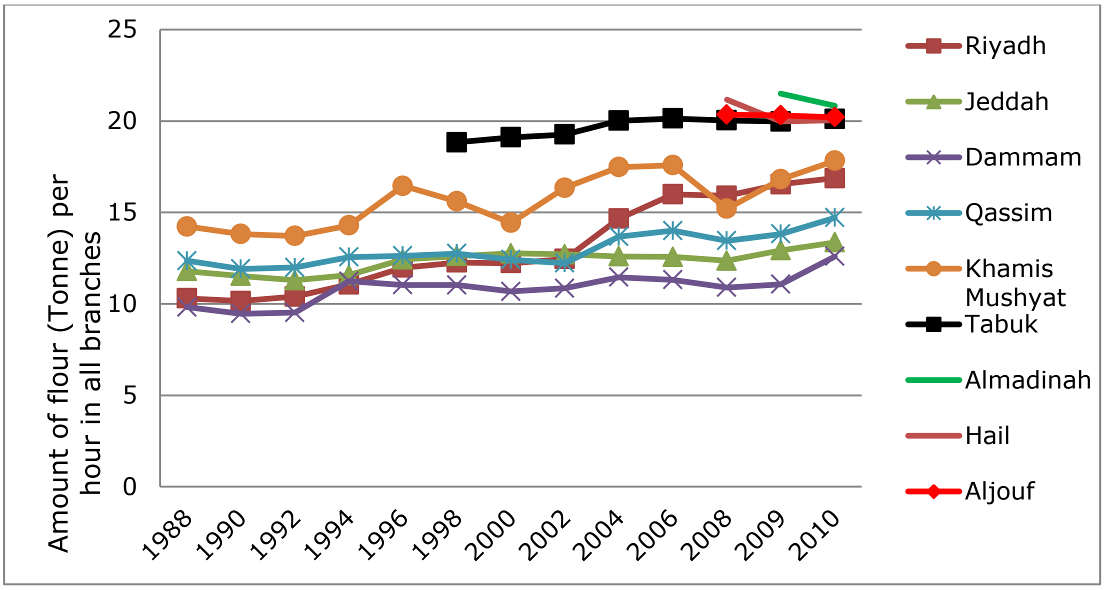

Figure 1.2: Machine productivity in the GSFMO branches (1988-2011)

1.4.1.2. Variations in human productivity GSFMO branches (1988-2011)

Figure 1.3 shows the variation in human productivity for the GSFMO branches. There is a clear disparity in the mean human productivity between the various branches, with the mean reaching a minimum of 478.6 tonnes per worker (Aljouf) and a maximum of 1355.4 tonnes per worker (Khamis Mushayt).

Calculating rate of change of mean human productivity relative to the mean human productivity of the Aljouf branch, it is can be seen that the human productivity in Khamis Mushayt, Riyadh, Jeddah and Tabuk exceeds productivity in Aljouf branch by 183.2%, 161.3%, 152.2% and 143.5%, respectively; human productivity for the branches of Dammam, Qassim, Almadinah and Hail, exceeded that of Aljouf with 103.4%, 64.9%, 62.3% and 25.3%, respectively.

The minimum and maximum levels of human productivity over time and across branches varied from 27.8 tonnes per worker for Aljouf branch (2008) and a maximum of 1993.6 tonnes per worker in the Riyadh branch (2005) (Appendix 2).

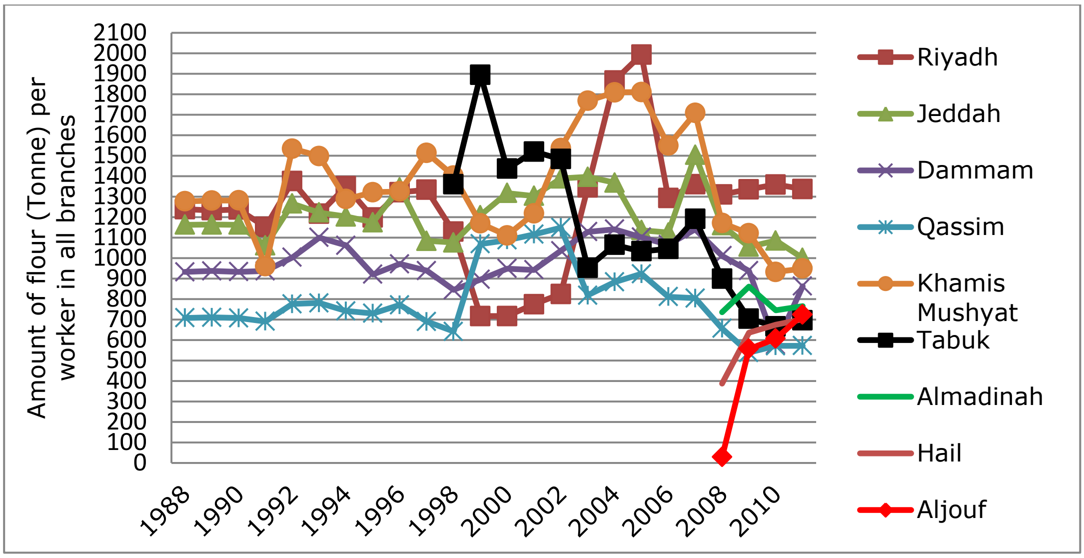

Figure 1.3: Human productivity in the GSFMO branches (1988-2010)

1.4.1.3. Manufacturing yield of the mills

A wheat: flour manufacturing yield was calculated by dividing the amount of flour produced as a proportion of the amount of wheat used in each mill. Figure 1.4 shows the manufacturing yield of the mills in all branches, with very small differences between the branches. The mean manufacturing efficiency of the mills ranged between a minimum of 0.77 tonnes of flour per one tonne of wheat used in the Khamis Mushayt branch and a maximum level of 0.83 tonnes of flour per one tonne of wheat used in the milling industry of the Jeddah and Tabuk branches during the 1988-2011 periods.

By calculating rate of change of mean manufacturing yield for the various branches relative to the mean manufacturing yield of the Khamis Mushayt branch, manufacturing yield of the Jeddah and Tabuk branches exceeded that of the Khamis Mushayt branch by 8.1% for each branch. Almadinah, Qassim, Aljouf, Hail, Riyadh and Dammam branches, outperformed that of the Khamis Mushayt by 7.0%, 6.7%, 5.2%, 4.8%, 4.4% and 3.6%, respectively.

From the data presented in Appendix 3, it can be argued that the Almadinah branch is the most stable branch with respect to manufacturing yield, with the standard deviation of manufacturing yield, ranging between a minimum of 0.02 (Almadinah) and a maximum of 0.14 (Qassim). There is also a conspicuous disparity between the minimum and maximum levels of yield manufacturing in the various branches of the GSFMO, with as low as 0.71 in the branches of Qassim and Khamis Mushayt, and as high as 0.86 in the branch of Tabuk (Appendix 3). Wheat: flour manufacturing yield therefore varies by 15% from the least efficient to the most efficient. The relative stability of the manufacturing yield of the mills in comparison to machine and human productivity can be attributed to the fact that all the mills produce the same brands of flour with almost fixed extraction rates.

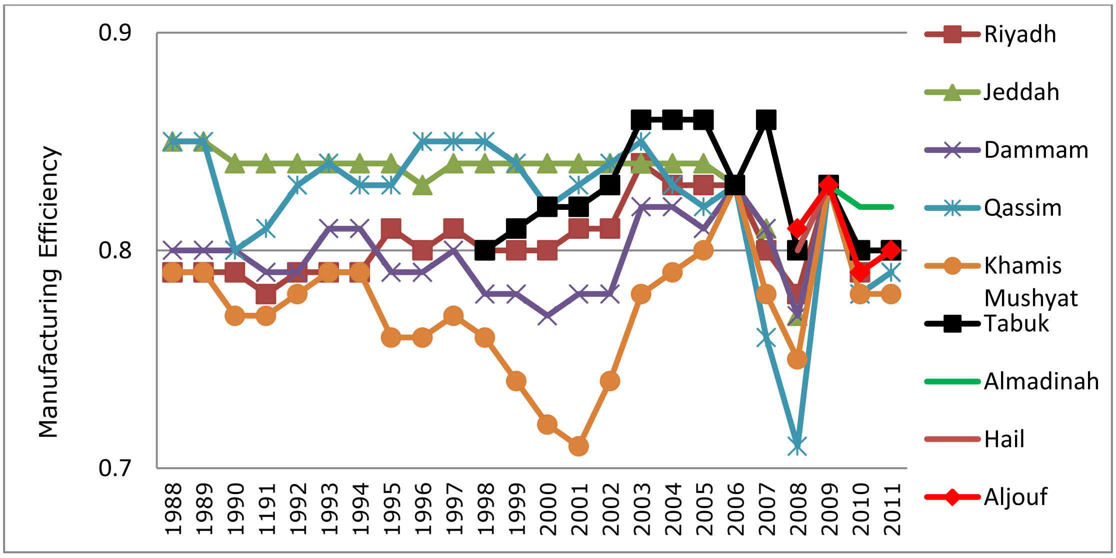

Figure 1.4: Manufacturing yield for GSFMO mills (1988-2011)

1.4.1.4. Average salaries and wage costs per worker in each branch (1990-2011)

There are two types of the workers in the organisation; namely permanent salaried workers and temporary waged workers. Figure 1.5 shows the average salaries and wage costs per worker in each branch during the period 1990 to 2011. This average ranges from a minimum of 37,650 riyals (Almadinah) to a maximum of 68,890 riyals (Riyadh branch). Based on these data, it can be clearly shown that the Riyadh branch has the highest average salaries and wage costs per worker compared to the Almadinah counterpart, which has the lowest average salaries and wage costs.

By calculating a maximum and a minimum of the average salaries and wage costs per worker in the various branches, the Jeddah branch was found to be the lowest amongst all branches (18,600 riyals per worker). On the other hand, the Khamis branch was the highest (109,800 riyals per worker). Also, all branches witnessed a relative stability in the average salaries and wage costs per worker, with the standard deviation ranging between a minimum of 11.78 in the Almadinah branch and a maximum of 20.34 for the Qassim branch (Appendix 4).

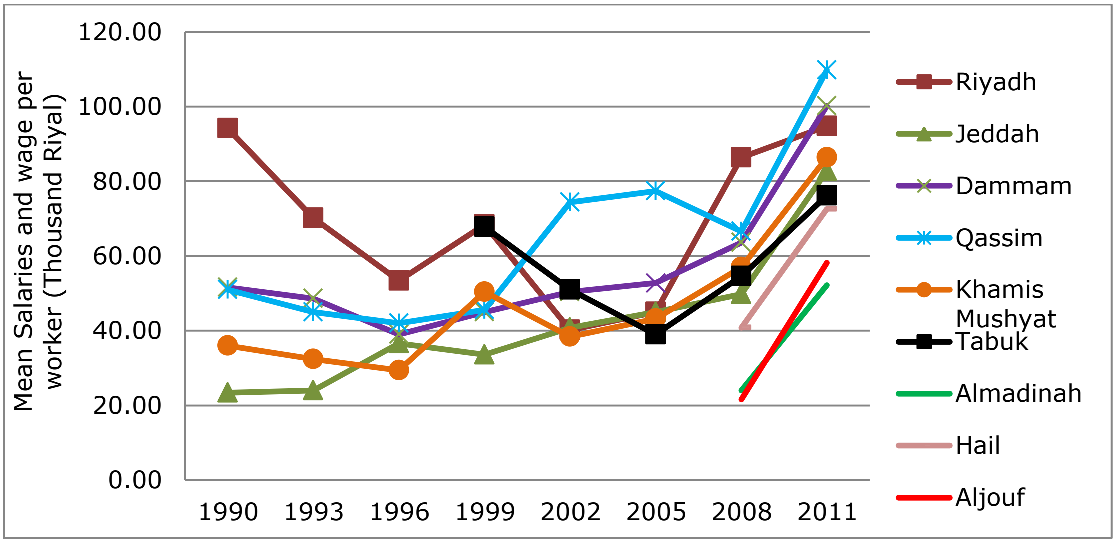

Figure 1.5: average salaries and wage costs per worker in each branch (1990-2011)

1.4.1.5. Average salaries and wage costs per tonne of flour in the GSFMO branches (1990-2011)

When variations in the average salaries and wage costs per tonne of flour for the GSFMO branches during the study period were analysed, as revealed in Figure 1.6, there is a clear disparity in the average salaries and wage costs per tonne of flour in all branches. The average cost of salaries and wages ranged from a minimum of 31.23 riyals per tonne in the Khamis Mushayt branch to a maximum of 247.20 riyals per tonne in the Aljouf branch (Appendix 5). It is therefore evident that the Khamis Mushayt branch achieved the lowest average salaries and wage costs per tonne of flour, as opposed to the Aljouf branch which incurred the highest value.

Examining the maximum and a minimum average salaries and wage costs per tonne of flour for the different branches of the GSFMO, the Aljouf branch was shown to be the highest branch in this aspect (766.80 riyals per tonne), which is considered as an outlier in the data; thus, it was removed from the Figure 1.6, while the Jeddah branch was shown to be the lowest (16.20 riyals per tonne). There is also instability in the average salaries and wage costs per tonne of flour for the GSFMO branches, with the standard deviation varying between a minimum of 7.75 in the Riyadh branch and as high as 346.46 in the Aljouf branch.

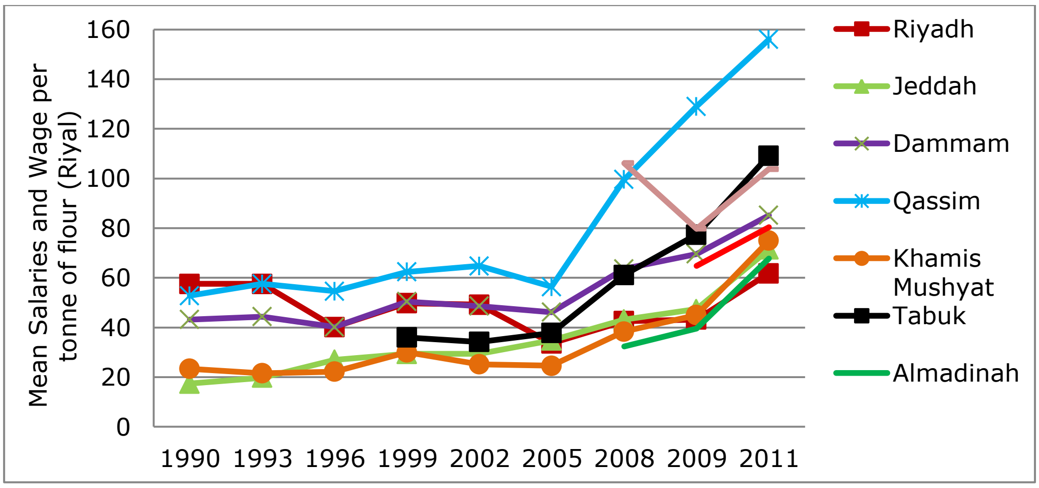

Figure 1.6: Average salaries and wage costs per tonne of flour in GSFMO branches (1990-2011)

1.4.1.6. Average operating costs per tonne of flour in GSFMO branches (1990-2011)

As concluded from the data shown in Figure 1.7, there seems to be a variation in the average operating costs per tonne of flour in the GSFMO branches (1990-2011). The average operating costs ranged from a minimum of 7.03 riyals per tonne in the Khamis Mushayt branch to a maximum of 50.67 riyals per tonne in the Aljouf branch (Appendix 6). Accordingly, it can be clearly shown that the Khamis Mushayt branch has the lowest average operating costs per tonne of flour compared to the Aljouf branch, which has the highest operating costs.

When calculating a minimum and a maximum of the average operating costs per tonne of flour in GSFMO branches, the Khamis Mushayt branch had the lowest operating costs (3.18 riyals per tonne), as opposed to the Aljouf branch with the highest operating costs (145.44 riyals per tonne). Because Aljouf branch was an outlier in the data in 2008, it was removed from Figure 1.7. The Almadinah branch displayed the most stable costs among all branches in terms of operating costs due to a decreased standard deviation of 1.98 compared to Aljouf branch, which was marked by instability; hence the high standard deviation of 63.21.

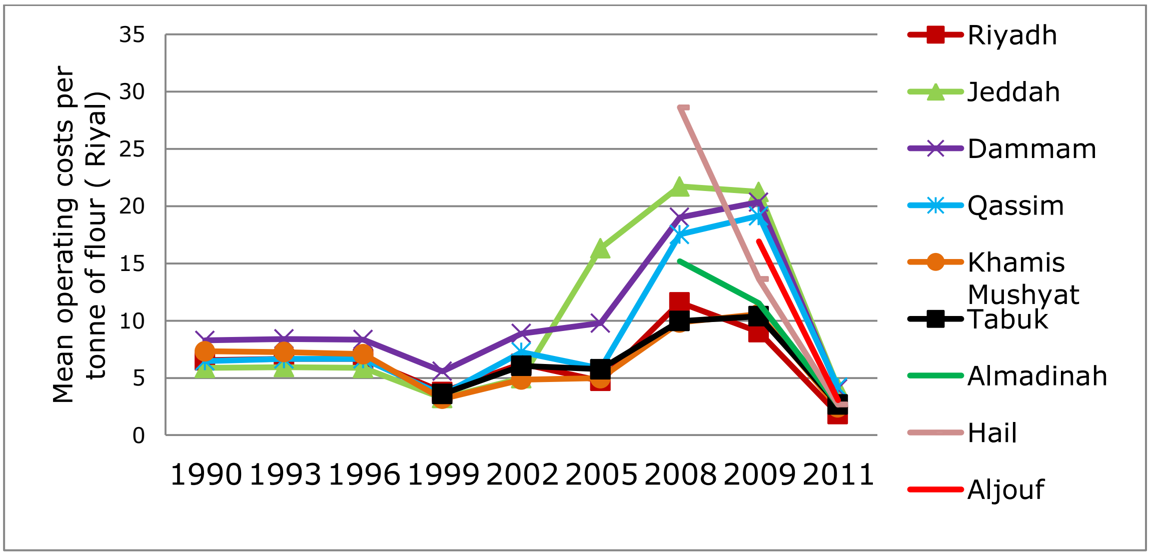

Figure 1.7: Average operating costs per tonne of flour in GSFMO branches (1990-2011)

1.4.1.7. Average maintenance and hygiene contracts costs per tonne of flour in the GSFMO branches (1990-2011)

The estimation of the average maintenance and hygiene contracts costs per tonne of flour in the GSFMO branches for the study period showed that the Tabuk branch has the lowest average maintenance and hygiene contracts costs, with an average of 34.74 riyals per tonne. In contrast, the Dammam branch has the highest average maintenance and hygiene contracts costs, with a mean of 65.96 riyals per tonne (Figure 1.8).

Examining minimum and maximum maintenance and hygiene contracts costs per tonne of flour, the Tabuk branch was found to be the lowest amongst all branches (18.48 riyals per tonne). The Dammam branch exceeded that of the Tabuk branch with a rate of 86.84% (140.46 riyals per tonne). By contrast the Riyadh branch, witnessed a relative stability in the mean maintenance and hygiene contracts costs, due to the decline of the standard deviation to 8.59, while the Dammam branch was characterised by lack of stability compared to the rest of the branches because of the high standard deviation of 21.84 (Appendix 7).

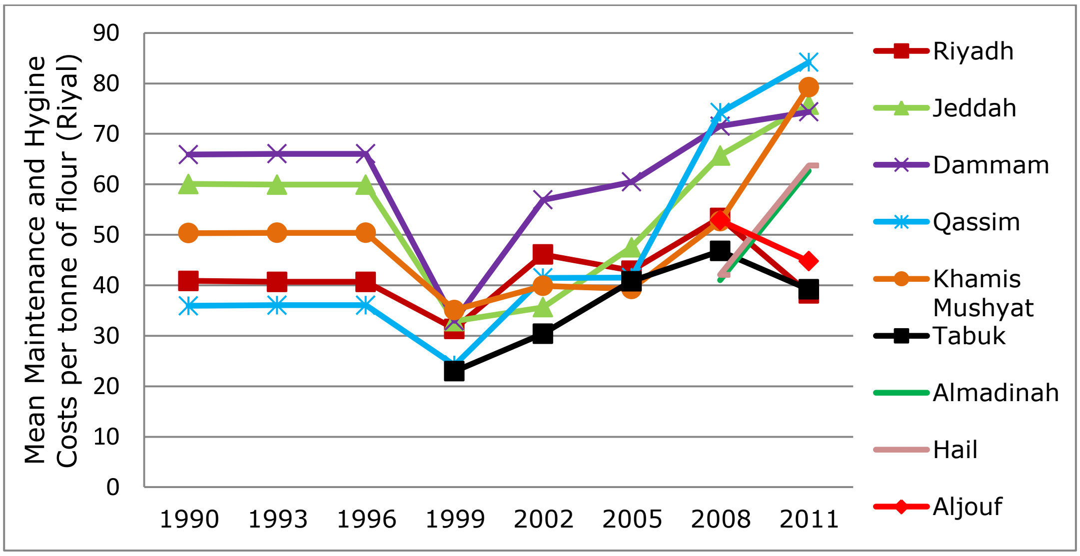

Figure 1.8: Average maintenance and hygiene contracts costs per tonne of flour in the GSFMO branches (1990-2011)

1.4.1.8. Storage capacity of wheat silos the GSFMO

The amount of wheat used in the milling industry tripled from 1.06 million tonnes in 1988 to 3.04 million tonnes in 2011, while the storage capacity of the GSFMO increased from 1.78 million tonnes in 1988 to 2.52 million tonnes during the period from 2008 to 2011 (Table 1.5). It is also evident that the proportion of the storage capacity of the silos to the amount of wheat used is declining over time, with a decrease from 167.8% in 1988 to 82.7% in 2011. The continuous decline in the silos storage capacity related to the amount of wheat used during the period between 1988 and 2011 led to a need to transfer wheat from branches which had an excess of stored wheat to those with low capacity storage, which adds to the GSFMO transport costs and leads to an increased mean cost of flour production, as well as disrupting the smooth operation in some mills because of the imbalance between the storage capacity of the silos and the amount of wheat used in those branches. This in turn will affect the technical and economic efficiency of the mills operating within these branches.

Table 1.5: Ratio of storage capacity of wheat silos to use of the GSFMO silos

Year	Amount of wheat used (thousand tonne)	Storage capacity of silos (thousand tonne)	% of storage capacity of silos for amount of wheat used
1988	1060.5	1780	167.8
1989	1235.7	2380	192.6
1990	1339.8	2380	177.6
1991	1215.3	2380	195.8
1992	1340.5	2380	177.5
1993	1434.8	2380	165.9
1994	1520.2	2380	156.6
1995	1539.9	2380	154.6
1996	1678.2	2380	141.8
1997	1697.4	2380	140.2
1998	1725.3	2380	137.9
1999	1795.8	2380	132.5
2000	1856.6	2380	128.2
2001	1975.5	2380	120.5
2002	2163.8	2380	110.0
2003	2283.8	2380	104.2
2004	2372.4	2380	100.3
2005	2461.1	2380	96.7
2006	2311.1	2380	103.0
2007	2534.9	2441	96.3
2008	2667.4	2520	94.5
2009	2892.4	2520	87.1
2010	2888.1	2520	87.3
2011	3045.8	2520	82.7

Source: Collected and calculated using: GSFMO, Annual reports (1988-2011).

1.5. Aim and Objectives of the Study

The study aims to estimate efficiency and productivity growth of the flour mills and explain variation in this efficiency and productivity growth. The importance of this study arises from the fact that the GSFMO has been incurring financial losses over the past few decades. In this case, there are several ways to analyse productivity. For example, one could look at the individual inputs such labour, wheat and machinery productivity. However, it is important to study the technology that is embedded across the joint use of labour, machines and wheat. One approach to examining this aspect is to consider efficiency analysis. Therefore, the aim of this study is to draw an efficiency analysis to explore the extent of efficiency and productivity variation across branches of the GSFMO, and to explain the causes for that variation. Accordingly, the study's objectives are:

1) To study the production activities of the GSFMO (1988-2011).
2) To measure the TE, AE and CE of the GSFMO's branches, using Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) and to explain variation in efficiency levels.
3) To estimate productivity growth using DEA (2008-2011) and SFA (1988-2011).
4) To estimate variables affecting the GSFMO's branches' efficiency. These variables include age of branch managers, experience, education level, temperature, number of mills in each branch, infrastructure and machine conditions.
5) To determine the amount of resources that can be used to lower the production cost and to achieve 100% TE.
6) To determine the best method that can be used to achieve the study objectives.

7) To provide recommendations and policies to improve the financial situation and operation of the flour mills.

By achieving these objectives, we aim to make recommendations related to the extent to which labour, wheat and machinery can be changed to optimise efficiency, either jointly by reducing all of these inputs, or by reducing some of them. In addition, by employing the empirical findings, it is hoped that some policy implications can be drawn in relation to the management of flour mills, and how the GSFMO can use the existing stock of infrastructure and machinery to improve productivity. Building on these recommendations, there may be necessary changes with inputs mix; the investment in different mills; or the future investment in the mills, given the potential differences between older and newer mills, which may inform the GSFMO how to improve efficiency and productivity.

1.6. Summary

Analysing the current situation of flour mills in the GSFMO, a number of issues have been identified, including the monopoly of the organisation of the milling industry in the KSA and the wide variation in performance demonstrated by the input-output efficiency measures calculated above.

For a number of years during the study period, the silos' storage capacity of wheat has remained constant, whilst the amount of wheat used has increased. Hence, the proportion of storage capacity of the silos has steadily decreased relative to the amount of wheat used. Given the lack of a balance between storage capacity of the silos and the amount of wheat used in the milling industry for all the branches, the increased movement of wheat between the branches of the GSFMO may lead to extra transportation costs for the organisation and a rise in the costs associated with producing flour.

It has also been observed that a clear discrepancy exists in the human and machine productivity between all branches, in addition to the constant upward trend in the costs of flour production, particularly from salaries and wages, operating costs, and maintenance costs. Naturally, this increase in production cost could mean reduced cost efficiency of the GSFMO's mills. Regarding financial reports, despite the governmental annual financial support, the GSFMO still incurs significant losses each year. This may then require a re-evaluation of the capital assets of the organisation and the operation of the resources used in the milling industry in an economical manner in order to improve TE, AE and CE. In recent years, the Saudi Arabian government has pursued a policy of economic reform and structural change, including the privatisation policy of the GSFMO, allowing the private sector access into the milling industry in 2003. In light of the losses incurred by the organisation and the absence of economic and financial indicators regarding the activities of these mills, the private sector has not ventured into the industry, and consequently the GSFMO is still under the management and control of the state.

Therefore, this study aims to investigate a number of issues, including the estimation of the TE, CE and AE of the flour mills of the organisation (1988-2011), using DEA and SFA approaches. In addition, it is equally crucial to explain variation in efficiency levels between the mills, while carrying out further analysis to estimate variables which may have an impact on efficiency levels, such as branch managers' experience, age, education level, machine condition, number of mills in each branch, temperature and infrastructure condition.

Another aim of the study is to estimate productivity growth over a period of four years (2008-2011), using the DEA approach, and for the whole study period (1988-2011), using the SFA approach. The study is based on both primary data, including interviews with branch managers and secondary data, which involved use of reports on costs, inputs, outputs and revenue issued by the GSFMO (1988-2011) to cover the nine milling branches. Moreover, this study aims to: identify the problems that the milling industry is faced with in Saudi Arabia; determine the reasons for the losses incurred by the GSFMO; determine the resources that could be used to lower the production costs; identify the best method to achieve the study objectives; and finally offer recommendations for the organisation to improve efficiency and productivity growth.

As the GSFMO monopolises the milling industry in Saudi Arabia and due to the absence of other companies responsible for the milling industry, the organisation is not subject to competition as is the case with private companies. In the case of the latter sector, firms are in a perfectly competitive market and market drivers incentivise firms to be highly efficient in order to compete in the market and survive. However, being a state monopoly, the GSFMO is in a protected environment where it is not subject to competition and therefore may not be expected to have the same levels of efficiency and be as profit-making focused as private firms.

One of the studies shedding light on the importance of privatisation is that of Van De Walle (1989) who examined this issue in developing countries and confirmed that privatisation has been driven by large lack of satisfaction with the performance of public companies and the necessity to cut government expenses and financial support. However, Van De Walle concluded that unless technical difficulties and political factors are addressed, there might not be significant gains in efficiency. Also, Meibodi (1998) estimated the efficiency of the electricity supply industry in Iran. Given that electricity is a state monopoly in Iran, TE can be adversely affected. Therefore, Meibodi suggested the privatisation of the electricity industry as one major factor in increasing TE and the establishment of an independent regulatory system to replace the direct involvement of the government in the sector. Alabi and Mafimisebi (2004) also studied how to increase private participation in agriculture through privatisation. Their findings confirmed that efficiency can be reduced by state ownership and monopoly.

Moreover, Amungwa (2009) appraised the privatisation of agricultural extension services in Cameroon. Based on the results, the author concluded that one of the benefits of privatising agricultural extension services is that it did result not only in larger participation with private companies and non-governmental organisations, but also in wider collaboration between them in providing extension services for farmers, which is likely to increase the efficiency and continuity of the information systems accessible to farmers.

In addition, Makuyana and Odhiambo (2014) who examined the dynamics of public and private investment in Malawi found that there were a number of private sector growth constraints as opposed to the large investment in the public sector. One of the recommendations of Makuyana and Odhiambo's study is for the government to address the potential constraints facing the private sector and to limit the domination of the public sector and convert its investments towards the economic activities of the private sector. Also, as shown in a number of studies, such as Ferrantino and Ferrier (1995), Bekele and Belay (2007), and See and Coelli (2012), public firms have previously been found to be less efficient than private ones. The overall aims of this study include determining how a firm could perform in a protected environment with no private companies to compete with. In other words, how can an underperforming monopoly (GSFMO) behave in order to enhance the performance of its constituent mills?

This could be achieved by two main routes; first by improving performance relative to where they observe or aspire to be, which may exceed current performance level. This would equate to the organisation moving the frontier outwards to get more output from the same amount of inputs or reduce the amount of inputs to get the same outputs. Second, they can improve by learning from the characteristics of management practices of the high performing branches in the most efficient year, to be used as 'benchmarks' of behaviour or actions for other less efficient branches. This means that one branch might perform better than it has previously been doing before because it has better infrastructure, better machine conditions and better management. Therefore, while a monopoly organisation does not compete with other firms, efficiency analysis is relevant because it can improve individual branch performance relative to its ability in terms of efficiency, including learning from good practices in other branches, or moving its frontier outwards.

Thus, there need to be a number of recommendations to improve the GSFMO's performance in terms of changing labour, wheat and machinery in order to optimise efficiency, either jointly by reducing all of these inputs, or by reducing some of them. Furthermore, by utilising the empirical results, it is expected that policy implications can be achieved in terms of the management of flour mills, and how the GSFMO can employ the available stock of infrastructure and machinery to enhance productivity.

In the next chapter, the theoretical framework of the study will be established, including an explanation of theoretical concepts such as efficiency and productivity growth.

2. EFFICIENCY AND PRODUCTIVITY: THEORIES AND MEASUREMENT CHAPTER

The concept of efficiency and economic production provides the basis for understanding the variation between the various firms. This chapter explains the theories underlying production theory, production functions, concepts of efficiency, different types of efficiency measurements and productivity growth. In addition, this chapter will describe two approaches; namely the non-parametric statistics (Data Envelopment Analysis (DEA)) and the parametric statistics (Stochastic Frontier Analysis (SFA)). It will also describe the difference between input-orientated and output-orientated assumptions. A comparison between the SFA and DEA approaches are outlined to identify the advantages and disadvantages of each approach providing a framework for efficiency measurements. Also, this chapter provides a mathematical formulation of DEA, SFA and TFPG.

2.1. Production Theory

A production, or transformation, function represents a set of physical technological processes that transforms a set of inputs into a set of outputs (Fuss and McFadden, 1978). This transformation process takes place in an entity that has control over processes and choices in converting its resources into outcomes (Thanassoulis, 2001). Traditionally, a firm can be referred to as an example of such entity (Bogetoft and Otto, 2011).

The production transformation process can be presented in a mathematical function as a production function. As an example of this, in the economy where there are N inputs, such as machines, raw materials and workers that produce a single output, the production function can be represented in the following (Coelli, *et al*., 2005):

$q = f(x)$

Where q denotes outputs and x denotes multiple inputs or $x = (x_1, x_2, x_3,..., x_N)$. The function of x in the above formula can take different types of forms according to the assumption on the production process, as described in the following section.

2.1.1. Returns to Scale (RTS)

RTS concepts refers to the relationship between input levels used in the production process and the output levels as the outcome of this process (Rawson, 2001). This is an important concept in output maximisation or input minimisation. In general, RTS can be classified as the following (*ibid*):

- Constant Returns to Scale (CRS)

CRS refers to the condition where there is a linear relationship between inputs and outputs in which an increase in inputs will produce the same proportional increase in outputs.

- Variable Returns to Scale (VRS)

VRS refers to the condition where an increase in inputs produces a proportionately different increase in output. In the case where an increase in inputs produces a proportionately greater prorata increase in outputs, this is referred to as Increasing Returns to Scale (IRS). On the other hand, where an increase in inputs produces a proportionately lower prorata increase in outputs, this is referred to as Decreasing Returns to Scale (DRS) (Rouse and Putterrill, 2005). IRS, CRS and DRS can be seen in Figure 2.1. In this figure, the two units 1 and 2 which are lying on the frontier represent CRS. On the lower left of the frontier, the lines start vertically from the horizontal axis going through units 5 and 6 to link up with the CRS segment of the frontier. Similarly, on the top right of the frontier, it can be seen that the VRS part of the frontier leaves from CRS frontier going through units 3 and 4 on the top right handside. The left side of the VRS frontier can be called IRS and the right side can be referred to as DRS.

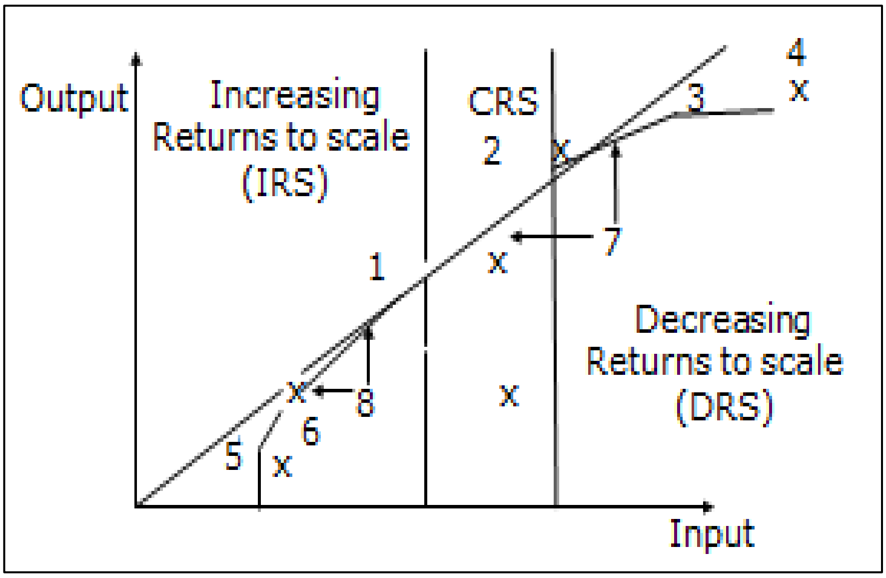

Figure 2.1: IRS, CRS and DRS Frontier Regions
Source: Rouse and Putterrill (2005)

CRS assumption is valid only in the condition of firms that operate at an optimal production scale (Coelli, *et al.*, 2005). In reality, different internal and external conditions facing the firms in their daily operation would cause them not to be operating at optimal scale. In this case, the VRS assumption is more appropriate to be applied (*ibid*).

2.1.2. Production Functions

The objective of a production function is to represent the relationship between inputs and outputs in a mathematical format (Chambers, 1988). Ideal production functions have to conform to the law of diminishing marginal productivity; be non-decreasing in *x*; and most importantly, they can be applied in practice (Coelli, *et al.,* 2005).

Among different production functions that have been proposed, two functions are widely used in studies related to production processes, which are Cobb-Douglas and Transcendental Logarithmic (Translog) production functions. The Cobb-Douglas production function was developed by Charles W. Cobb and Paul H. Douglas in 1928 and since then, it has remained the most widely used theoretical function in production economics (Felipe and Adams, 2005). It conforms to the basic properties of production theories, such as non-decreasing in *x* and concavity, although on the other hand, it has disadvantages where it imposes fixed and global returns to scale, and assumes that one input can be freely replaceable with other inputs without changing their marginal product (Castiglione, 2012). Although widely used, the Cobb-Douglas production function is also argued to be too restrictive due to its properties of global returns to scale and constant elasticity of substitution (Afriat, 1972).

The Transcendental logarithmic (Translog) function, developed by Christensen *et al.* (1973), is a generalisation of Cobb-Douglas. It removes the above constraints whilst also providing more flexibility by providing squares and interaction variables. It conforms to the law of diminishing marginal productivity and enables varying returns to scale to be accomodated (Caves *et al.,* 1980; Odhiambo *et al.,* 2004).

Complete mathematical formulation of both Cobb-Douglas and Translog production function are presented in the Chapter 4. The following section explains the theoretical concept of different efficiency measures.

2.2. Efficiency Concept

2.2.1. Introduction

The concept of efficiency in production refers to the degree to which the actual use of inputs in producing a given quantity of outputs meets the optimum use of inputs in this process (Bhagavath, 2009). The observed difference between the actual and optimal use of inputs is due to inefficiency (Coelli *et al.,* 2005). This concept is important to measuring the performance of an organisational unit.

Farrell (1957) proposed an analytical approach to the measurement of overall efficiency of a complex transformation process with multiple inputs and multiple outputs. He stretched the traditional concept of productivity into productive efficiency (Cooper *et al.,* 2004).

In his work, Farrell proposed an analysis of efficiency which was based on the earlier work of Koopmans (1951) and Debreu (1951). Koopmans had introduced the concept of "Pareto criterion" in the final goods (outputs) where an increase in an output can be obtained up to the point that a further increase in this output will reduce other outputs. Farrell then extended this Pareto-Koopmans criterion to inputs, in addition to outputs, and used performance of other units to assess each unit in regard to their usage of inputs and outputs, creating a "Farrell measure of efficiency" which is a measure of relative efficiency. This "Farrell measure of efficiency" is actually a measure of technical efficiency, which suggests the removal of unused resources from production without reducing outputs level (Coopers *et al.,* 2004).

Meeusen and van den Broeck (1977), Aigner *et al.* (1977), and Battese and Corra (1977) built upon Farrell's approach by developing the SFA method. Following this, Charnes *et al.* (1978) introduced the DEA method. Because of the significance of efficiency measurement for a wide range of services and products in both developing and developed countries, numerous studies have been conducted, not only to measure efficiency, but also to develop and extend SFA algorithms (Kumbhakar and Lovell, 2000) and DEA algorithms (Cooper *et al.*, 2004). As a result of the practical use of these techniques for the estimation of efficiency, many research studies in several fields emerged. These studies which have used SFA and DEA approaches are explored in detail in the literature review chapter.

2.2.2. Efficiency Types

Efficiency can be defined into different types; namely, technical, allocative, and economic efficiency. These different efficiency types are described in the Figure 2.2.

In Farrell (1957) the relationship of TE and AE can be shown in Figure 2.2:

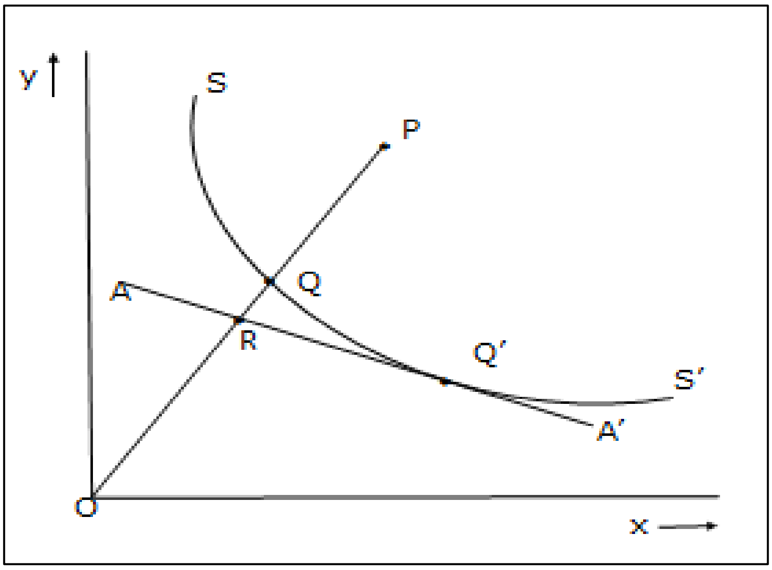

Figure 2.2: Technical and Allocative Efficiency
Source: Farrell (1957)

In the graph above, SS' curve represents an isoquant: the mixture of inputs x and y that produce the given quantity of outputs for a firm that is perfectly efficient. Farrell (1957) showed that point Q represents the same inputs mixture used by perfectly efficient company Q with company P that produce the same output. The difference in inputs quantity used between company P and perfectly efficient company Q reveal the TE level of company P, which is calculated as the ratio OQ/OP.

AA' line represents isocost: the combination of inputs x and y that have the same cost of production. Therefore in order to produce the quantity of outputs as those produced by company Q and P, it is Q' not Q that offers the mix of inputs x and y that produces outputs at the minimum cost of production. Consequently, the ratio of OR/OQ shows the ratio of optimal cost of producing output to the actual cost needed to produce outputs, or the AE of company Q. Note that AE can only be calculated for company Q that has already reached 100% TE. Economic Efficiency (EE) is defined as the ability of a firm to provide the maximum output at minimum cost for a certain level of technology. According to Bhat *et al.* (2001), EE estimates the production of an optimal output value using a particular value of inputs; or equally, utilising the minimum value of inputs for the production of a particular value of output. In the Figure 2.2, EE is shown at the ratio of OR/OP.

Summarising, TE relates to how the physical quantities of output are related, while the measurement of EE pertains to how the output's value and the input's value are linked to each other.

Coelli *et al.* (1998) refers to EE as the end result of technical and allocative efficiency. As such, the EE of any firm is determined by the extent it is technically and allocatively efficient (Ishengoma, 2005). Farrell (1957) and Thanassoulis (2001) stated that EE as the multiplication of technical and allocative efficiency levels.

2.3. Measurement of Efficiency

Traditional measurement of efficiency is the ratio analysis whereby two major contemporary models used for efficiency measurement are nonparametric and parametric approaches. The former refers to mathematical programming models such as DEA and the latter pertain to the stochastic frontier and econometric studies. These two methods will be described in the following sections.

2.3.1. Non-Parametric Statistics: DEA

Developed by Charnes *et al.* (1978), DEA is a nonparametric frontier approach (Charnes *et al.,* 1994; Zhu, 2003), which is often utilised in management science and economics (Begum *et al.*, 2009) and is widely used to estimate resource use efficiency and to rank production units based on how they perform (Banaeian *et al.*, 2011). DEA extends the efficiency concept from Farrell (1957) into conditions with multiple inputs and multiple outputs using linear programming-based algorithms. In DEA, units to be assessed for their efficiency are referred to as decision-making units (DMUs); thus extending the use of DEA to measure efficiency and productivity not only limited to traditional production scenarios, but also to any activity transforming inputs into outputs (Thanassoulis, 2001).

As it is based on linear programming algorithms, DEA is a data-oriented method as opposed to regression-based methods such as SFA, COLS and MOLS in the sense that it seeks to create a piece-wise frontier on top of all the data, rather than aiming for central tendency as in frontier approaches using regression analysis (Cook and Zhu, 2005). This piece-wise linear frontier results in the envelopment of observed input and output data (Coelli *et al.*, 2002), therefore the terms "data envelopment" is used. Due to its absence of the need for key statistical assumptions, such as normal distribution and constant variances, its application is more generic and flexible and has been used to measure efficiency in the profit-oriented business contexts or non-profit institutions such as hospitals, police, poverty programmes, schools, business firms and cities (*ibid*). Since it requires few assumptions, DEA is also able to be implemented in the condition where the relationship nature of inputs and outputs are unknown (Cooper *et al.,* 2004).

Since Charnes *et al.* (1978), there have been many published articles that apply DEA methodology in various scenarios, or enhancing the DEA algorithms or models, so that it can be implemented in different conditions. Seiford's (1997) bibliography of DEA-related articles from 1978-1996 details the wide-ranging growth in the sector. Seiford collated over 800 published articles and dissertations in relation to DEA. Tavares (2002) listed as many as 3203 DEA references, 2152 authors and 1242 keywords between 1978 and 2001. This interest in DEA as a method of efficiency estimation shows the potential of this approach and its wide applicability.

After Charnes *et al.* (1978), who developed a basic DEA model comprising an input orientation and assuming constant returns to scale (CRS), subsequent studies have examined alternative sets of assumptions, as in Banker *et al.* (1984) who introduced a variable returns to scale (VRS) model. It is also possible to measure an output-orientated DEA model. Both input and output orientations will be explained below.

2.3.1.1. Input-orientated DEA Model

In relation to the input-based TE concept from Farrell (1957), Charnes, *et al.* (1978) developed input-orientated DEA model to calculate and to improve TE of DMU by proportional reduction in the use of inputs whilst keeping the outputs constant. The choice of orientation in DEA is not a crucial matter as in econometric-based methodology, with many analysts tending to choose input-orientated models as input costs are usually the largest parts of DMU expenses (Coelli, *et al.,* 2005), however the choice of orientation can be different in contrasting industries. The graphical illustration of this model can be seen in the Figure 2.3.

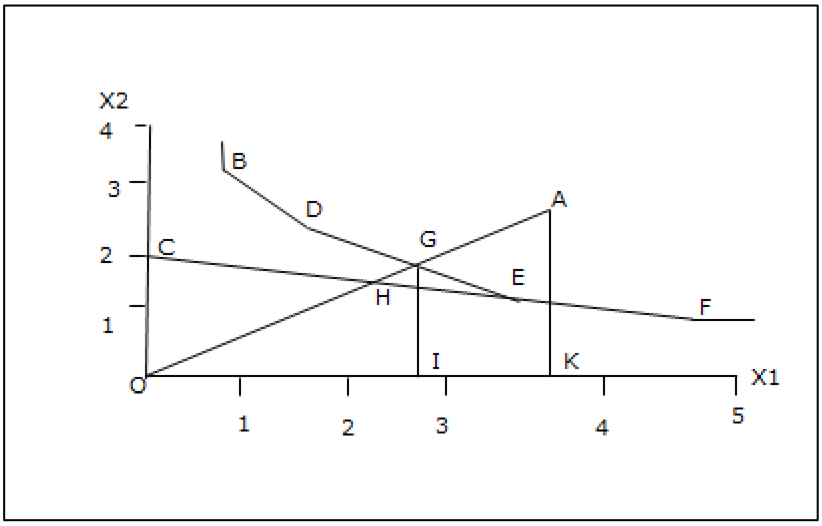

Figure 2.3: Graphical Illustration of Input-orientated DEA Model
Source: Thanassoulis, 2001

Figure 2.3 depicts the illustration of two inputs, X1 and X2, and one output condition. BDGEF is a piece-wise input frontier that represents the maximum reduction of input combination that can be achieved whilst keeping the output constant, which is constructed from connecting DMUs B, D, G, E and F which represents best performing DMUs as benchmarks to other DMUs in the data. Input levels along radial line OA represent condition with the same input-output mixture with DMU A, where moving from A toward O will be reducing input levels whilst keeping the input-output proportion constant. In this case, point G depicts a condition with the lowest input levels from DMU A whilst retaining the same input-output proportion. Consequently, DMU at point G will be the performance benchmark for DMU at point A. TE of DMU A is computed relative to DMU G, or OG/OA. TE of DMU A can be increased if it moved toward condition at DMU G.

2.3.1.2. Output-orientated DEA Model

Another way to measure efficiency of DMU is by computing an output-orientated DEA model, which strives to improve TE by increasing output proportionally whilst keeping the input constant (Charnes, *et al.,* 1978). Under CRS condition, input-orientated and output-orientated will have the same value whilst in VRS condition the values will be different (Coelli, *et al.,* 2005). Graphical illustration of output-orientation is presented at Figure 2.4.

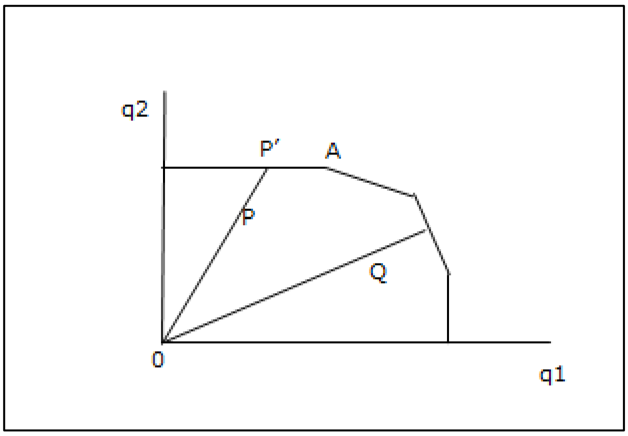

Figure 2.4: Graphical Illustration of Output-orientated Model
Source: Coelli *et al* (2005)

Figure 2.4 represent conditions of two outputs, $q1$ and $q2$, and one input. P'A represents piece-wise frontier constructed from DMU that have maximum combination of outputs $q1$ and $q2$ whilst keeping input constant; it is the benchmark for all DMUs in the data. For DMU at point P, movement along OP' toward P' will increase the output levels proportionally while keeping its input constant. Therefore DMU at P' is the benchmark for DMU at P and TE of DMU at P is OP/OP'.

The DEA models utilised in this study are input and output-orientation specification under Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) models. These models are described in the following sections.

2.3.1.3. Charnes, Cooper and Rhodes (CCR) Model

Charnes *et al.* (1978) introduced this model which is used to estimate the overall TE of decision making units (DMUs) with multiple inputs and multiple outputs under the assumption of Constant Return to Scale (CRS). An efficiency score is attributed for every DMU that is achieved as a maximum of weighted outputs to weighted inputs ratio. The efficiency ratio has to be less than or equal to one for individual DMU. With the use of linear programming, the multiple-output and multiple-input for every DMU can be linearly aggregated to a single virtual output and a single virtual input. This virtual output to virtual input ratio provides a measure of efficiency for a given DMU, with weights to be determined. Hence, efficiency is a function of the weights of the virtual input-output combination.

The mathematical approach to this model is given as follows:

$$\max\ h_0 = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{1}$$

Subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1;\ \text{j=1,2,…,n},$$

$$u_r, v_i \geq 0; r = 1,2, \dots, s; i = 1,2 \dots, m$$

From the equation (1), it can be explained that h_0 is the measure of efficiency of producer being assessed, x_{ij} and y_{rj} are the *ith* input of *jth* DMU and *rth* output of *jth* DMU respectively. Thus, (x_{i0} , y_{i0}) are the input-output of the assessed producer. On the other hand, u_r and v_i are the weights of output and input computed from the linear programming, which have a value between 0 and 1.

However, in a ratio formula such as above, the solutions can be infinite. Due to this, Charnes *et al.* (1978) then proposed the transformation of the above ratio model into an equivalent linear programming model as follows:

$$\max z_0 = \sum_{r=1}^{s} \mu_r \, y_{r0}$$

(2)

Subject to:

$$\sum_{r=1}^{s} \mu_r \, y_{rj} - \sum_{i=1}^{m} v_i \, x_{ij} \leq 0, j = 1,2, \ldots n$$

$$\sum_{i=1}^{m} v_i \, x_{i0} = 1$$

$$\mu_r, v_i \geq 0; r = 1,2, \ldots, s; i = 1,2, \ldots, m$$

In solving the linear programming equation (2), the duality of linear programming will be utilised as in the following (Cook and Zhu, 2005):

$$\theta^* = \ Min \ \theta$$

(3)

Subject to:

$$\sum_{j=1}^{n} \lambda_j \, y_{rj} \geq y_{r0}, \qquad r = 1,2, \ldots, s$$

$$\sum_{j=1}^{n} \lambda_j \, x_{ij} \leq \theta x_{i0}, \qquad i = 1,2, \ldots, m$$

$$\lambda_j \geq 0, \quad j = 1,2, \ldots, n$$

Equation (3) is regarded as the envelopment form of DEA since it will seek optimal solutions for some DMUs which are located on the frontier to be the benchmark in assessing other DMUs. Optimal solutions (θ, λ) for each of the DMUs are calculated in equation (3). θ is the efficiency score for the particular DMU_0, which is a radial measure of technical efficiency. As an efficiency score, the value of θ is secured to be less than or equal to one by the constraints set above, and it is relative to other DMUs. The most technically efficient DMUs will have θ = 1 whereby relatively inefficient DMUs will have θ = 0. The optimal value of λ for a specific DMU, i.e. λ=1, signifies that this particular DMU point is located on the constructed production frontier, which will become the benchmark for other DMUs with the same input mix. The CCR model constructs a feasible production frontier which is closed and convex; hence called envelopment under the constant returns to scale assumption (Färe *et al*., 1994).

Equation (3) yields a piece-wise linear production frontier whereby some sections run parallel to the axes. In this case, an efficiency measurement which involves the proportional shift of inputs or outputs may cause a condition whereby, for an efficient point in the sections of production frontier parallel to the axes, it is possible to still reduce inputs without altering outputs or increase output without altering inputs. These input savings or output expansions are referred to as input or output slacks (Cook and Zhu, 2005). Among other authors, Cooper *et al.* (2004) and Cook and Zhu (2005) presented the following two-stage linear programming algorithm to accommodate this slack in the DEA computation:

$$Min\ \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \qquad (4)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io} \qquad i = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \qquad r = 1,2, \dots, m;$$

$$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$$

In the equation (4), S_i^- and S_r^+ denote slack variables for inputs and outputs respectively. There is also an infinitely very small positive number, ε, which allows the minimisation over θ to anticipate the optimisation involving slack variables mentioned before. Therefore, the equation is computed over a two-stage process; firstly, minimisation of inputs over θ via the optimal θ^* in equation (3); then, optimisation of the slack variables enables the movement into efficient production frontier.

The DEA model from equation (4) is referred to as input-orientated DEA model since it attempts to maximise the proportional reduction in inputs whilst holding the current outputs constant. Conversely, a model can be presented that attempts to maximise the increase in outputs whilst holding the current inputs constant as output-orientated model (Thanassoulis, 2001; Cook and Zhu, 2005; Coelli *et al.*, 2005).
The Output-orientated CCR model with slack variables can be presented as follows (Cook and Zhu, 2005):

$$Max\ \phi + \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \qquad (5)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \qquad i = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi y_{ro} \qquad r = 1,2, \dots, m;$$

$$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$$

As in equation (4), in equation (5) S_i^- and S_r^+ denote slack variables for inputs and outputs respectively. As before, there is also an infinitely very small positive number, ε, which allows the maximisation of over ϕ before the optimisation involving slack variables in the two-stage process as mentioned before in equation (4).

2.3.1.4. Banker, Charnes and Cooper (BCC) Model

Banker *et al.* (1984) developed the DEA model further by dropping the CRS assumption in the CCR model above with a more realistic assumption of Variable Returns to Scale (VRS). As can be noticed, the CRS assumption is only valid in a condition where all DMUs operate at optimal scale. However, there are many constraining conditions in the real world that would not make this ideal condition happen, for example constraints from political, demographic and economic situations. In this situation, using the CCR model to measure the TE will not be accurate due to the existence of scale inefficiencies. In the VRS assumption used in BCC model, it attempts to compute most productive scale size for each DMU and also identifies its TE all at the same time. Under the VRS assumption, there are different points on the production frontier which shows increasing, constant or diminishing returns to scale for different DMUs in observation (Ray, 2004).

In denoting VRS assumption in their model, Banker *et al.* (1984) added a convexity constraint for λ_j , which is $\sum_{j=1}^{n} \lambda_j = 1$. This additional constraint guarantees that a DMU would only be compared to similar-sized DMUs; hence comparing a DMU with a smaller number of combinations. Therefore, TE scores provided by the BCC model are greater than or equal to those in the CCR model (Thanassoulis, 2001).

The input-orientated BCC model can be presented formally as follows (Cook and Zhu, 2005):

$$Min\, \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \tag{6}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io} \qquad i = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \qquad r = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \qquad j = 1,2,\dots,n$$

Similar to equation (4), in equation (6) S_i^- and S_r^+ denote slack variables for inputs and outputs respectively. ε is an infinitely very small positive number which allows the minimisation over θ to anticipate the optimisation involving slack variables mentioned before. The only difference is that there is an additional convexity constraint, $\sum_{j=1}^{n} \lambda_j = 1$, which ensures that a DMU would only be compared to similar-sized DMUs as mentioned previously.

The TE scores assessed under VRS condition are referred to as pure technical efficiency as they are computed by eliminating the problem of scale efficiency in the analysis (Thanassoulis, 2001).

On the other hand, the output-orientated BCC model, which calculates pure technical output efficiency, can be presented as follows (Cook and Zhu, 2005):

$$Max\, \phi + \varepsilon \left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \right) \tag{7}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \qquad i = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = \phi y_{ro} \qquad r = 1,2,\dots,m;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$

Similar to equation (5), in equation (7) S_i^- and S_r^+ denote slack variables for inputs and outputs respectively. ε is an infinitely very small positive number which allows the maximisation over ϕ before the optimisation involving slack variables in two-stage process mentioned before. The only difference is that there is an additional convexity constraint, $\sum_{j=1}^{n} \lambda_j = 1$, which ensures that a DMU would only be compared to the similar-sized DMUs as mentioned previously.

2.3.1.5. DEA Model for Economic Efficiency (EE) and Allocative Efficiency (AE)

With the availability of price data, the above CCR and BCC models can be extended to measure the economic (cost) efficiency. Coelli *et. al.* (2005) and Thanassoulis (2001) stated that one of the objectives of extending these models is to find a point where cost can be minimised.

In the case of input-orientated CCR model under CRS condition, the first step to compute EE is by solving the following linear programming:

$$\underset{x_i}{\text{Min}} \sum_{j=1}^{m} w_{ij_0}\, x_{i0}^* \tag{8}$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j\, x_{ij} - x_{i0}^* \leq 0, \qquad i = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j\, y_{rj} - y_{ro} \geq 0, \qquad r = 1,2, \dots, m;$$

$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$

In equation (8) above, x_{i0}^{*} is the optimal solution denoting cost minimising input quantities given the input prices w_{ij_0} and output level y_{ro}. This equation (8) would then be compared to the actual cost at which particular DMU_{j0} delivers its output, which is denoted as $w_{ij}x_{ij}$, to compute the EE as follows:

$$EE = \frac{w_{ij}x_{ij}^{*}}{w_{ij}x_{ij}} \qquad (9)$$

For the case of input-orientated BCC model with VRS assumption, as in equation (8), the cost minimising input quantities would be computed with the same equation but with added constraint of $\sum_{j=1}^{n} \lambda_j = 1$ so that it can be written as follows:

$$\underset{x_i}{\text{Min}} \sum_{j=1}^{m} w_{ij_0}\, x_{i0}^{*} \qquad (10)$$

Subject to:

$$\sum_{j=1}^{n} \lambda_j\, x_{ij} - x_{i0}^{*} \leq 0, \qquad i = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j\, y_{rj} - y_{ro} \geq 0, \qquad r = 1,2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$$

Cost-minimising quantities x_{i0}^{*} computed from equation (10) would then be compared as a percentage of the actual cost faced by particular DMU_{j0} to calculate the EE as in equation (9).

AE for both CRS and VRS condition could be calculated as follows (Coelli *et. al.,* 2005; Thanassoulis, 2001):

$$AE = \frac{\text{EE}}{\text{TE}} \qquad (11)$$

Where AE is Allocative Efficiency, EE is Economic Efficiency calculated from equation (9). TE is the Technical Efficiency under CRS condition as calculated in equation (4) or Technical Efficiency under VRS condition as calculated in equation (6).

2.3.2. Parametric Method: SFA

A modern method to measure efficiency is by utilising parametric methods (Coelli *et al.*, 2005). The parametric method is an econometric-based method that conforms to basic statistical assumptions, such as normal distribution and constant variances in data (Murillo-Zamorano and Vega-Cervera, 2001). There are two main groups in the efficiency measurement using parametric method, namely deterministic and stochastic (Anouze, 2010).

Efficiency measurements under deterministic approaches include Corrected Ordinary Least Squares (COLS) from Winsten (1957) and Modified Ordinary Least Squares (MOLS) from Afriat (1972) and Richmond (1974). Deterministic approaches in parametric methods construct a production frontier as a benchmark for performance based on regression analysis; where no consideration is taken for measurement errors and other statistical errors, all deviations from the frontier is attributed to technical inefficiency (Coelli, *et al.,* 2005; Murillo-Zamorano and Vega-Cervera, 2001).

The main efficiency measurement method under stochastic approach is SFA, which is based on works by Aigner, *et al.* (1977) and Meeusen and Van den Broeck (1977). The SFA is concerned with parametric empirical estimation of an efficiency frontier by taking into account any measurement errors and other sources of statistical noise that may arise in the estimation of the stochastic element. This results in a frontier known as the stochastic production frontier (Coelli *et al.,* 2005).

The basic concept of SFA is that deviation from the frontier is not all due to flaws in a firm's operation, in the form of technical inefficiency, but also due to statistical noise

(Aigner *et al.,* 1977; Meeusen and Van den Broeck, 1977; Murillo-Zamorano and Vega-Cervera, 2001). It is assumed that the additional random error is independent and has normal distribution with zero mean and constant variance (Anouze, 2010). This random error can have positive or negative value so that the stochastic frontier will have variation around a deterministic frontier, given the value of the random error (Coelli, *et al.,* 2005).

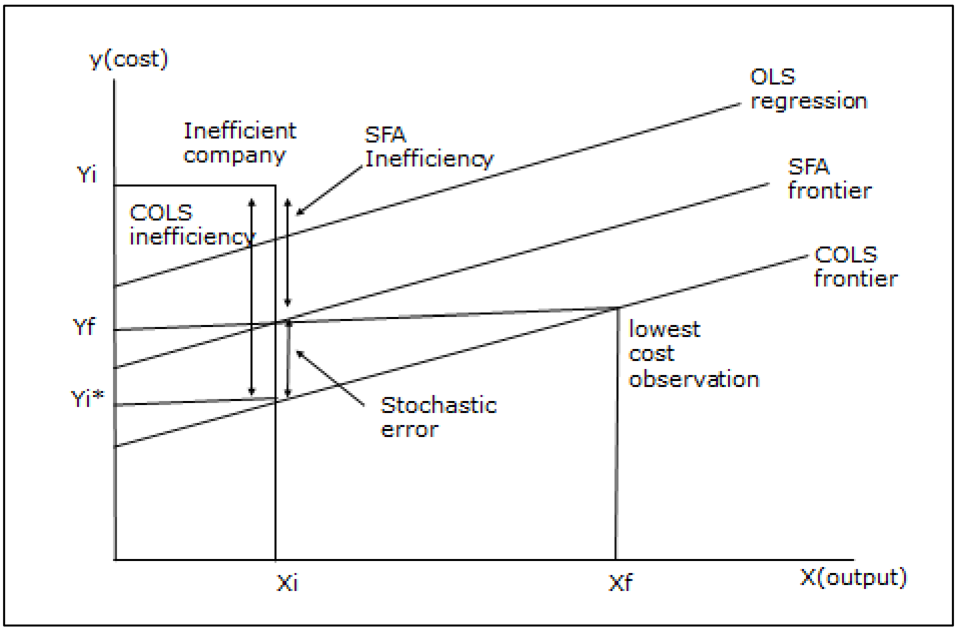

Figure 2.5: Comparison of SFA and COLS frontier with OLS Regression Analysis
Source: Giraleas, 2011

Figure 2.5 shows different inefficiency calculations from COLS and SFA frontier approaches under a cost minimisation approach. An inefficient firm is located at vector (Xi,Yi). The COLS frontier represents a frontier with the lowest cost observation. As can be observed from the graph, the difference between lowest cost observation point located at vector (Xi, Yi*) and point (Xf,Yf) is all attributed to inefficiency under COLS. While from SFA frontier analysis, the difference between point at (Xi,Yi*) and its projection on SFA frontier (Xi,Yf) is due to stochastic error, therefore the SFA inefficiency is calculated from SFA frontier (Xi,Yf) to (Xi,Yi).

On the other hand, the technical inefficiency variable in SFA is also assumed to be independent and identically distributed under exponential or half-normal distribution. The stochastic frontier production function is specified as follows:

$$y_{it} = f(x_{it}\,;\beta) + \varepsilon_{it} \qquad i = 1,\ldots, N, \tag{12}$$

Where y_{it} is the output level, f(.) refers to an appropriate functional form, x_{it} is the actual input vector, β denotes the parameter vector, which needs to be estimated and ε_i is the disturbance term, which could be decomposed into two components as follows.

$$\varepsilon_{it} = v_{it} - u_{it} \qquad i = 1, \ldots, N. \tag{13}$$

Where the first component in the error term, v_{it}, is the symmetric error that accounts for statistical noise, where $v_{it}\, i.i.d{\sim}N(0, \sigma_v^2)$ that is assumed to be independently and identically distributed random errors, which have normal distributions with mean zero and unknown variance σ_v^2, and where u_i represents non-negative random variable associated with technical inefficiency. The random variable is assumed to have half-distribution or exponential distribution. The observed output, y_{it} , is bounded by the stochastic quantity , = $f(x_{it}\,;\beta)$+ v_{it} where v_{it} takes into account random variation of production outside the control of the individual unit. Therefore the basic SFA model for the production function can be written by combining equation (12) and (13) as follows:

$$y_{it} = f(x_{it}\,;\beta) + v_{it} - u_{it} \tag{14}$$

The technical efficiency of the i-th unit is specified as follows:

$$TE_{it} = \frac{y_{it}}{f(x_{it}\,;\beta) + v_{it}} = \frac{\exp(y_{it})}{\exp[f(x_{it}\,;\beta) + v_{it}]} = \exp(-u_{it}) \tag{15}$$

There are many functional forms to estimate the physical relationship between input and output such as Cobb-Douglas and Translog. These functional forms will be elaborated on in more detail in Chapter 4.

2.3.3. DEA and SFA Comparison

Over the years, many authors have compared the efficiency results from calculation using DEA and SFA approaches. Studies such as Banker *et al.* (1993), and Hjalmarsson *et al.* (1996) have implemented both methods to compare the results. Since each method has its own advantages and disadvantages, there is no definite answer of which method is more robust; the choice between DEA and SFA as methodology for assessing performance has been argued to be mainly influenced by personal assessment of its advantages and disadvantages (Giuffrida and Gravelle, 1997).

Given its nature as a non-parametric approach, DEA has clear advantages in the sense that it does not need prior specification of functional form and distribution (Hjalmarsson, *et al.,* 1996; Bauer, *et al.,* 1998; Coelli, *et al.,* 2005) and also no specific assumption on technology except about convexity of the frontier (Hjalmarsson, *et al.,* 1996; Bauer, *et al.,* 1998). DEA has also proven to be applied in the scenario where relationships between output and input are complex and often unknown, if other methods, such as regression-based SFA, are used (Cooper *et al.,* 2004; Ebnerasoul, *et al.,* 2009). As opposed to regression-based method such as SFA, DEA can readily be used to compute efficiency in the condition of multiple inputs and multiple outputs (Ebnerasoul *et al.,* 2009) whilst complex procedure have to be made in regression-based method, such as SFA, to create a single aggregate dependent variable (Thanassoulis, 1993). As DEA measures each DMU against its own benchmark(s) that have similar characteristics, sources of inefficiency are able to be assessed and quantified and target performance can be set (Thanassoulis, 2001; Ebnerasoul, *et al.,* 2009). DEA is also able to separate scale efficiency and pure technical efficiency (Javed, *et al.,* 2011).

On the other hand, in DEA all deviation from frontier is attributed to inefficiency where SFA offers richer specification in which it recognised that deviation from frontier is due to both inefficiency and stochastic variable, representing statistical and measurement errors (Hjalmarsson, *et al.,* 1996; Murillo-Zamorano and Vega-Cervera, 2001; Coelli *et al.,* 2005; Bogetoft and Otto, 2011). SFA also made possible standard statistical tests and the use of confidence intervals (Hjalmarsson *et al.,* 1996). However, the best way to separate errors from inefficiency is also a challenge to SFA since neither of these variables can be directly monitored (Bauer *et al.,* 1998). The latter authors also commented on the difficulty in deciding which distribution is more suitable for the inefficiencies for SFA, whether half-normal or exponential distribution.

In their comment on DEA, Bauer *et al.* (*ibid*) stated that there is a potential problem of self-identifiers and near-self-identifiers in DEA, where in the case of multiple inputs and outputs, matching a DMU to other DMUs with many dimensions may result in a DMU to be measured as highly efficient (or even fully efficient) due to one of its variables, where there is no other DMUs in the data that can match this particular DMU in this variables. Therefore, this DMU will be considered fully efficient due solely to this variable. Thanassoulis (2001) and other authors noted this problem as the loss of discriminatory power.

In summary, DEA and SFA each has its own advantages and disadvantages so the choice of implementation depends on the data and individual perceptions and consideration of these advantages and disadvantages (Reinhard *et al.,* 2000).

2.3.4. Issues in efficiency estimation

As highlighted above, the DEA and SFA methods of estimating efficiency have been intensively used in the literature. Moreover, the previous section has highlighted the fact that none of these approaches has proven to be more preferred to the other; however, the choice between the two is arbitrarily determined. However, it is important to notice that, apart from these standard methods, there are two more approaches that have been reported in the relevant literature, which refer to the bootstrapping and semi-parametric approaches.

In statistics, bootstrapping, which was first introduced by Efron (1979), is a way of obtaining a more representative sample from the underlying unobservable population. This method is based on the concept and practice of repeatedly drawing subsamples out of the given sample with the replacement of this random sample. With respect to measuring efficiency, bootstrapping was introduced by the seminal work of Simar and Wilson (1998) with the aim of making a statistical inference about the obtained estimates of efficiency by constructing the confidence intervals on the DEA efficiencies, given that the bootstrap bias is an approximation of the DEA bias. However, such a strong assumption has been criticised in the literature as it is rarely satisfied in applied work (Tziogkidis, 2012). In addition, bootstrapping is a computationally intense method of analysis (Xue and Harker, 1999).

On the other hand, the semi-parametric approach, proposed by Fan, Li and Weersink (1996), combines both stochastic and non-parametric approaches. Thus, it allows for statistical noise in the data and does not require the specification of a functional form for production technologies. This approach is highly recommended in cases where the production units have different technologies; and hence, it is difficult to model their production technologies adequately (Gorton and Dvidova, 2004; Henningsen and Kumbhakar, 2009). Despite the flexibility offered by the semi-parametric approach, it has not been heavily adopted in applied research. According to Henningsen and Kumbhakar (2009), the lack of studies employing the semi-parametric approach to estimate efficiency is largely due to the non-availability of software.

In this study, although these potential methods of measuring efficiency; i.e., bootstrapping and semi-parametric, seem to be quite promising, it has been decided to rely mainly on the standard methods of measuring efficiency; i.e., DEA and SFA. This choice of methods is justified by a number of reasons, most of which are related to the context in which this work is applied. First, given that the bootstrapping approach assumes equality between the DEA and bootstrapping biases, empirical research has found that to meet such an unrealistic assumption the sample size has to be sufficiently large. Given the constraint of the small sample within this study, it was not plausible to apply the bootstrapping approach. Second, the semi-parametric approach is more helpful in cases where the production units use different technologies, which is not the case in this study, where the technologies used by the various units do not differ substantially. Third, given the intensive computational nature of both methods; i.e., bootstrapping and semi-parametric, it was deemed appropriate to use the conventional methods of measuring efficiency. For these reasons, it is believed that both DEA and SFA methods are expected to provide a robust way of estimating efficiency, and thus will be used in this study.

2.4. Total factor productivity growth (TFPG)

In traditional contexts, productivity in a condition where there is only a single input and a single output is referred to as the ratio of its output to its input (Thanassoulis, 2001). In a more realistic condition where there are multiple inputs and multiple outputs working together in a transformation process, productivity is regarded as "the ratio of an index of its output levels to an index of its input levels"; consequently the change of this ratio from one period to another is regarded as the productivity growth of the particular DMU or firm (*ibid*).

Further, Thanassoulis (2001) and Coelli *et al.* (2005) stated that in early literatures, productivity growth was attributed only to a change in technology by economists. However, later research had come to agreement that a change in productivity can happen due to the combination of the change in technology and also change in efficiency. The first notion, change in technology, represents the overall improvement or decline in an industry's efficient boundary due to the change in general technology used by firms or DMUs in that particular industry in the transformation or production process. This change is also referred to as boundary shifts (Thanassoulis, 2001). The second notion, the change in efficiency, reveals the change in performance of an individual firm or DMU in its transformation or production process relative to the industry's efficient frontier.

From the above definition of productivity growth, it can be seen that the productivity of a firm or DMU can change because of three factors: first, if there is an improvement in overall technology in the industry, even if the firm's efficiency itself does not change, it will experience productivity growth. Secondly, if the overall technology in the industry stays constant but the firm's efficiency improves then it will also experience productivity growth. The third scenario can happen when both overall technology change and also a firm's efficiency improve, then the productivity growth will be a sum of these changes. Complete mathematical formulation of TFPG using DEA and SFA are presented below.

2.4.1. TFPG using DEA

Fare *et al.* (1994) developed a Malmquist index (MI) approach to measure productivity growth of DMU using DEA methodology. The Malmquist index separated the Total Factor Productivity Growth (TFPG) into two components, which are boundary shifts and efficiency catch-up. As mentioned previously, boundary shifts account for the change in the overall industry and efficiency catch-up component computes the change in the firm's own efficiency. The efficiency catch-up component can be further separated into scale efficiency change and pure technical efficiency catch-up (Thanassoulis, 2001). Scale efficiency change tracks whether the firm or DMU has moved closer to its most productive scale size. Pure technical efficiency catch-up component measures the change in a firm's TE relative to the boundary related to VRS technology.

In the DEA analysis, TFPG is calculated by MI (Thanassoulis, 2001; Coelli *et al.*, 2005). MI is constructed by radial measurement of DMU distance in period $t+1$ and period t relative to the production frontier at period $t+1$ and period t. In this notion, MI allows that productivity change may have been caused by a mixture of efficiency change at the firm level and technological change at the industry level (Thanassoulis, 2001). Moreover, Thanassoulis stated that in DEA, since MI is calculated relative to the CRS frontier, "the input-orientated and output-orientated Malmquist index are equal" (2001:182).

The formula of MI can be presented as follows (*ibid*, 2001):

$$MI_{j0} = \frac{C\_EF_{T_{t+1}}^{D_{t+1}}}{C\_EF_{T_t}^{D_t}} \times \left[\frac{C\_EF_{T_t}^{D_{t+1}}}{C\_EF_{T_{t+1}}^{D_{t+1}}} \times \frac{C\_EF_{T_t}^{D_t}}{C\_EF_{T_{t+1}}^{D_t}}\right]^{\frac{1}{2}} \qquad (16)$$

In the first part of the equation (16), $C\_EF_{T_{t+1}}^{D_{t+1}}$ is the CRS TE of DMU$_{j0}$ at period *t+1* calculated against the CRS boundary at period *t+1*, $C\_EF_{T_t}^{D_t}$ is the CRS technical efficiency of DMU$_{j0}$ at period *t* calculated against CRS boundary at period *t*. The ratio of $C\_EF_{T_{t+1}}^{D_{t+1}}$ / $C\_EF_{T_t}^{D_t}$ in the first part is referred to as Catch-up component or Efficiency Catch-up (EC). EC relates the closeness of DMU$_{j0}$ on period *t+1* to its condition in period *t*.

In the second part of equation (16), $C\_EF_{T_t}^{D_{t+1}}$ is the CRS TE of DMU$_{j0}$ at period t+1 calculated against the CRS boundary at period t; whereas, $C\_EF_{T_{t+1}}^{D_t}$ is the CRS TE of DMU$_{j0}$ at period *t* as calculated against the CRS boundary at period *t+1*. The calculation on the second part of equation (12), which is $\left[\frac{C\_EF_{T_t}^{D_{t+1}}}{C\_EF_{T_{t+1}}^{D_{t+1}}} \times \frac{C\_EF_{T_t}^{D_t}}{C\_EF_{T_{t+1}}^{D_t}}\right]^{\frac{1}{2}}$, is referred to as Boundary Shift component or Technical Change (TC). TC calculates geometric means of the distance caused by movement of the boundary between period t and period t+1 at two locations: $\frac{C\_EF_{T_t}^{D_{t+1}}}{C\_EF_{T_{t+1}}^{D_{t+1}}}$ computed the distances of these two boundaries at the output mix of DMU$_{j0}$ in period *t+1*, whereby $\frac{C\_EF_{T_t}^{D_t}}{C\_EF_{T_{t+1}}^{D_t}}$ computed the distances of these two boundaries at the output mix of DMU$_{j0}$ in period *t*.

2.4.2. TFPG using SFA

To estimate TFPG using SFA, it is possible to use the production frontier with a single output, which can be decomposed into three components of productivity change; namely, returns to scale, technical change, and change in technical efficiency (Kumbhakar and Lovell, 2000 and Vencappa *et al.,* 2008).

In the analytical framework, the authors started with a deterministic production frontier, which is written as follows:

$$y = f(x, t; \beta)\ \exp\{-u\} \tag{17}$$

Where y is the scalar output of a producer, $f(x,t;\beta)$ is the deterministic kernel of a stochastic production frontier for which the technology parameter vector *β,* which need to be estimated, $x = (x_1,\ x_2, \ldots\ x_n)\ \geq 0$ is an input vector*, t* is a time trend to represent technical change, which can be neutral or non-neutral, and $u \geq 0$ is output-oriented technical inefficiency. Technical is not limited to be neutral with regards to inputs; neutrality needs that $f(x,t;\beta) = A\ (t)^{\cdot}\ g\ (x;\beta)$.

A main measure of the ratio of technical change is specified by:

$$T\Delta = -\frac{\partial \text{In}\ f(x,t;\beta)}{\partial t^{\cdot}} \tag{18}$$

The technical change ratio above can be positive, negative or zero, which would result in shifting the production function up, down or leave it unchanged. A primal measure of the rate of change in technical efficiency is given by

$$TE\Delta = -\frac{\partial u}{\partial t^{\cdot}} \tag{19}$$

The technical inefficiency decreases, stays unchanged or increases through time. $TE\Delta$ can be explained as the ratio at which a producer moves toward or away from the frontier, which itself may be shifting through time.

In the scalar output case a conventional Divisia index of productivity change is defined as the difference between the rate of change of output and the rate of change of an input quantity index, and so

$$TFP = \dot{y} - \dot{X}$$

$$= \dot{y} - \sum_n S_n x_n, \qquad (20)$$

Where a dot over a variable indicates its rate of change [e.g., $\dot{y} = \left(\frac{1}{y}\right)\left(\frac{dy}{dt}\right) = d\ln y/dt$], $S_n = \frac{w_n x_n}{E}$ is the observed expenditure share of input $x_n, E = \sum_n w_n x_n$ represents total expenditure and $w = (w_1, \ldots, w_n) > 0$ is an input price vector.

Totally differentiating equation (17) and inserting the resulting expression for $\dot{y}$ into the equation (20) yields:

$$TFP = T\Delta + \sum_n(\varepsilon_n - S_n)\, x_n + TE\Delta$$

$$= T\Delta + (\varepsilon - 1). \sum_n \left(\frac{\varepsilon_n}{\varepsilon}\right) x_n + TE\Delta + \sum_n [\left(\frac{\varepsilon_n}{\varepsilon}\right) - S_n] x_n, \qquad (21)$$

Where $\varepsilon_n = \varepsilon_n(x, t; \beta) = \frac{x_n f_n}{f(x,t;\beta)}, n = 1, \ldots, N,$ represent elasticities of output with respect to each of the inputs. The scale elasticity $\varepsilon = \varepsilon_n(x, t; \beta) = \sum_n \varepsilon_n\,(x, t, \beta)$, which represents a measure of returns to scale characterising the production frontier. This takes a value of less than, equal to, or greater than 1, corresponding to decreasing, constant and increasing returns to scale.

Four components explain the TFPG. These are technical change, scale efficiency change, technical efficiency change and allocative inefficiency change. The effects of production technology and technical efficiency on the TFPG depend on their changes over time. However, if any of these components do not change over time, this implies zero contribution to the TFPG. Moreover, the TFPG impact of scale economies is dependent on the underlying assumptions; whether the production function experiences constant or variable returns to scale. In particular, assuming CRS indicates that inputs changes are not related to productivity change. On the other hand, if VRS is assumed, then changes in inputs will contribute to productivity, and this contribution will be dependent on the output elasticity. If the output elasticity is greater than one, then increasing inputs would lead to an increase in the TFPG. If, however, the output elasticity is less than one, then increasing inputs would lead to a decrease in the TFPG.

Therefore, the interpretation of the first three components in equation (21) is quite straightforward, as shown above, and can be estimated fairly easily. However, the interpretation of the fourth term in equation (21), which represents the allocative inefficiency, is less straightforward. It captures the deviations of inputs' normalised output elasticities from their expenditure shares, or of input prices from the value of their marginal products. The availability of inputs and output prices is a precondition of computing the allocative inefficiency. When prices are not available, this component is dropped out, and hence equation (21) can be written as follows:

$$TFP = T\Delta + (\varepsilon - 1).\sum_n (\varepsilon_n / \varepsilon) x_n + TE\Delta \qquad (22)$$

The advantage that equation (22) offers is the reliance solely on quantity information, and hence does not require information on prices. Thus, the change in TFPG can be attributed to three components; technical change, scale efficiency and technical efficiency change. In practice, one or two of these components can have a trivial impact on TFPG, and thus is allowed to be zero. For example, if the data show that technical efficiency is time invariant, the third term in equation (22) is discarded. In the case that technical efficiency is constant over time and CRS prevail, the TFPG is solely attributed to technical change (Kumbhakar and Lovell, 2000 and Vencappa *et al.,* 2008).

2.5. Summary

This chapter has covered the underlying theory of efficiency and its measurement, from production theory, production functions, concepts of efficiency, different types of efficiency measurements and productivity growth, to provide a comprehensive background of the analysis in this study. Efficiency measurement methodology used in this study will be the modern non-parametric approach of DEA and also the modern parametric approach of SFA to provide a comprehensive picture and comparison of the technical efficiency from these two methodologies.

DEA and SFA methods have their own advantages and disadvantages. As a non-parametric method, the prime benefit of DEA is that DEA is data centred, so that prior assumptions regarding the technology, functional forms and distribution are not required. Moreover, it is capable of calculating efficiency where multiple inputs-multiple outputs are used and benchmarking performance of a firm to the best-practice firms on the frontier with the same characteristics.

On the other hand, DEA does not calculate the possibility of an occurrence of statistical or measurement error. In this regard, SFA has shown its advantages, where it can separate technical inefficiency from measurement error. Therefore, SFA is also widely used in efficiency measurement studies since it can give more accurate calculation on TE. However, SFA requires a prior assumption on the distribution of inefficiency variable and the technology of its frontier. SFA also benchmarks a firm performance to an average measure, not actual performance of any benchmark firms. Given these advantages and disadvantages of SFA and DEA, this study will apply both these methodologies so a robust result can be achieved by a comparison of results from these two methods.

Despite the potential benefits of using bootstrapping and semi-parametric methods in efficiency measurement, this study is only focused on the standard methods of measuring efficiency; i.e., DEA and SFA. The selection of these methods is justified by a number of reasons, which are related to the context in which this work is undertaken. For example, since the bootstrapping approach assumes equality between the DEA and bootstrapping biases, empirical research has found that to meet such an unrealistic assumption the sample size has to be sufficiently large. Due to the constraint of the small sample within this study, it was not plausible to apply the bootstrapping approach. In addition, the semi-parametric approach is more useful in cases where the production units use various technologies, which is not the case in this study, where the technologies used by the various units do not differ substantially. Moreover, given the intensive computational nature of both methods; i.e., bootstrapping and semi-parametric, it was deemed appropriate to use the conventional methods of measuring efficiency. Accordingly, it is believed that both DEA and SFA methods are expected to provide a robust way of estimating efficiency, and thus will be used in this study. In this chapter, a mathematical formulation of the various methods was also provided.

Chapter 3 focuses on the literature review, assessing different studies that have been performed using DEA and SFA in measuring performance, and the different issues that may arise in these methods. It will also assess studies using these two methods in different sectors that can be used as reference material for this study.

3. LITERATURE REVIEW CHAPTER

3.1. Introduction

Performance measurement is one way to evaluate how an organisation has worked toward achieving its vision and missions. It is intended ultimately to secure control of an organisation, by assessing its actual achievement against targets set by shareholders and making organisational change if it misses its target (Thanassoulis, 2001). For this purpose, managers pursue ways to increase their organisation's productivity. One of these is by controlling and measuring an organisation's efficiency (Ebnerasoul, 2009).

The concept of efficiency has been widely used in organisational performance measurement; it has also become an important notion in measuring productivity growth (Thanassoulis, 2001). This concept is particularly important in emerging countries, where resources are thought to be less fully exploited (Ali and Chaudhry, 1990). In the agricultural sector, several factors influence productivity and production output as well as management practices, such as "farm management, resource use, population pressure, fragile ecosystem, poverty, land tenure, inadequate knowledge of appropriate technologies and technical know-how, inadequate price incentives, socio-cultural factors and farmers' perceptions and attitudes which are inherently unpredictable" (Oyewo, 2011, p. 211).

Due to the importance of the agricultural sector, especially for developing countries suffering from scarcity of resources, it has become paramount to measure the efficiency of industries in this sector in order to improve performance.

The current chapter gives an overview the literature in an attempt to measure efficiency in different settings. In particular, many conceptual and measurement issues arise when studying efficiency, such as the assumptions related to the underlying production function relating the proportional change in inputs to the proportional change in output. Moreover, although there is number of techniques to measure efficiency, including the widely used modern approaches of DEA and SFA, each of these approaches builds on a set of assumptions that is required for the measurement process. Therefore, this review of literature intends to group existing studies based on the context that they were conducted in. The main focus here will be on the economic performance of the countries where these studies were carried out. For this purpose, the literature is divided into two distinct subsections according to where these studies were implemented; developed and developing countries. This is aimed at reflecting on the experience of different social and institutional contexts. For example, it is well known that data availability and credibility are more problematic in developing countries. Another motivation behind this distinction is to draw on countries' experiences in order to introduce a generic guideline for which technique may be more appropriate in what context.

3.2. Efficiency Measurement Studies in Developed Countries

Several studies have investigated efficiency in various parts of the world, both in developing and developed countries, by using DEA, SFA or a combination of both DEA and SFA. In developed countries, some of these studies are presented in Table 3.1, which provides an overview by methodology, country, sector, aim, data and period of study.

Table 3.1: Efficiency Measurement Studies in Developed Countries

Authors	Methodology	Country	Sector	Study Aim	Data	Time Period
Schaffnit *et al* (1997)	DEA	Canada	Banking	TE of Bank Personnel	291 Canadian bank branches	1993
Luo *et al* (2011)	DEA and SFA	China	Banking	TE of Chinese Commercial Banks	14 listed commercial banks	1999 - 2008
Avkiran (2001)	DEA	Australia	Education	TE and SE of Australian Universities	36 universities	1995
Johnes *et al* (2012)	DEA	UK	Education	TE of England Higher Educations	600 education providers	2001-02 and 2002-2003
Kontodimopoulos *et al* (2007)	DEA	Greece	Healthcare	TE and SE of 2 largest Healthcare Providers	194 healthcare units	2004
Tsekouras *et al* (2010)	DEA	Greece	Healthcare	TE of ICUs in public healthcare	39 ICU of Greek hospitals	2004
Zhang *et al* (2012)	DEA	China	Transportation	TE of Airport Airside Activities	37 airport airsides	2009
Cullinane *et al* (2006)	DEA and SFA	Global (mostly developed countries)	Transportation	TE of Container Port Industry	30 global container ports	2001
Castiglione (2012)	SFA	Italy	Manufacturing	TE & ICT investment in Italian manufacturing firms	4497 manufacturing firms (1995-7), 4680 firms (1998 - 2000), 3452 firms (2001-03) and 514 firms (all periods)	1995 - 2003
Tingley *et al* (2005)	DEA and SFA	UK	Fisheries	Factors affecting TE of fisheries in English Channel	68 fishing boat sample	1993 - 2000
Wilson *et al* (1998)	SFA	UK	Agriculture	TE of UK maincrop potato production	140 maincrop potato producers	1992
Wilson *et al* (2001)	SFA	UK	Agriculture	TE of wheat farms in Eastern England	74 wheat farms	1993 - 1997
Iraizoz *et al* (2003)	DEA and SFA	Spain	Agriculture	TE of horticultural production in Spain's Navarra	46 horticultural farms	1994
Odeck (2007)	DEA and SFA	Norway	Agriculture	TE & Productivity Growth of Norwegian grain producers	19 specialised grain farm producers	1987 - 1997
Barnes (2008)	SFA	UK (Scotland)	Agriculture	TE of 4 major sectors of Scottish agriculture	Scottish Farm Account Survey	1989 - 2004
Guzman *et al* (2009)	DEA	Italian and Spain	Agriculture	TE Comparison of Italian & Spain fruit and vegetable sector	81 Italian & 106 Spanish Firms	2001-2005

In the following section, a summary of studies in developed countries (Table 3.1) will be outlined followed by a detailed analysis of each study separately.

From studies conducted in developed countries, it can be seen that seven authors used only DEA in their studies (Schaffnit *et al.*, 1997; Avkiran, 2001; Johnes *et al.*, 2012; Kontodimopoulos *et al.*, 2007; Tsekouras *et al.*, 2010; Zhang *et al.*, 2012; and Guzman *et al.*, 2009), four studies used only SFA (Castaglione, 2012; Wilson *et al.*, 1998; Wilson *et al.*, 2001; and Barnes, 2008), and five studies adopted both DEA and SFA in their methodology (Luo *et al.*, 2011; Cullinane *et al.*, 2006; Tingley *et al.*, 2005; Iraizoz *et al.*, 2003; and Odeck, 2007). While DEA has been found to be widely used in education, healthcare, and banking sectors, where the relationship between inputs and outputs are not apparent, SFA has been widely used in agricultural, fisheries and other manufacturing sectors. However, this does not mean that either methodology is used exclusively in a particular sector. It can be shown in Table 3.1 that studies using SFA require larger data sets while studies using DEA can be performed with less than 100 observations. This is due to the regression methodology in SFA that requires a larger number of data observation to create better fits of the regression line. As an example, a study by Castaglione (2012) using SFA involved 4497 manufacturing firms (1995-97), 4680 firms (1998-2000), 3452 firms (2001-03), and 514 firms (all periods) in its analysis. A SFA study with a modest dataset is Wilson *et al.* (2001) which involved 74 wheat farms. Conversely, a study using DEA from Avkiran (2001) on TE and SE of Australian universities included only 36 Australian universities while Zhang *et al.* (2012) used 37 airport airsides in their DEA study on airport airside TE. Nevertheless, some studies using both DEA and SFA listed in Table 3.1 are found to have less than 100 observations in the sample, as in Luo *et al.* (2011) with 14 listed Chinese commercial banks, Culinane *et al.* (2006) with 30 global container ports and Odeck (2007) with 19 specialised grain farm producers.

Most of the studies using SFA utilise panel data in their sample, such as Wilson *et al.* (2001), Barnes (2008), and Castaglione (2005). While some studies using DEA utilise panel data, as in Johnes *et al.* (2012) and Guzman *et al.* (2009), DEA can also be used in studies that utilise only cross-sectional data as in Schaffnit *et al.* (1997) and Kontodimopoulos *et al.* (2007). All studies using SFA in Table 3.1 utilise second stage regression approaches to identify factors that influence TE, while not all DEA studies listed use second stage regression or other post DEA analysis techniques. It is argued here that the use of second stage regression or other post DEA analysis will enhance the findings from DEA studies. The studies which follow this approach are analysed in detail in the following section.

Schaffnit *et al.*'s (1997) analysis of efficiency in the Canadian banking sector, focused in particular on the performance level of bank personnel. Drawing upon 291 branch observations for only one year (1993) and using DEA methodology the most efficient branches were found to make more profits and provide better services, while high density neighbourhoods were shown to have a positive effect on banking performance. However, the authors did not take into consideration new branches and five extremely large branches which had different activities and size structures to the ones used for the purpose of this study.

In China, Luo *et al.* (2011) used both DEA and SFA to analyse the efficiency of 14 Chinese commercial banks between 1999 and 2008, and analyse the impact of the global credit crunch on the Chinese financial banks. Luo *et al.* observed that within DEA estimation the decision making units (DMUs) that are most efficient within the sample have the highest efficiency classification of one, and when there will be several simultaneous ratings of one, no cross-section or periodic comparisons are feasible. Therefore, Luo *et al.* used the DEA Super-Efficiency Model to overcome this problem. The Super-Efficiency DEA model provides the same efficiency score for those DMUs that are inefficient as produced by standard DEA techniques, while it generates scores greater than one for efficient DMUs. Another advantage of using super-efficiency is to identify outliers (Banker and Chang, 2005). However, there are a limited numbers of studies which apply the super-efficiency approach (Du *et al.,* 2012; Amirteimoori and Kordrostami, 2012).

In the educational sector, Avkiran (2001) examined relative technical and scale efficiency of Australian universities using DEA. Similar to Schaffnit *et al.* (1997), data was taken for only one year (1995) but for a smaller sample size (36), using publications by the Department of Employment, Education, Training and Youth Affairs (DEETYA), and Selected Higher Education Statistics series and a report by Andrews *et al.* (1998). All 36 universities were covered for the time of the study; however the single year analysis is argued here to have limited the study's findings. Results show that this sector was performing well on technical and scale efficiency; however, there seemed to be slack in terms of fee-paying enrolments, which Avkiran recommends as an area for improvement. The issue of data quality is important and Avkiran note the unreliable nature of the data drawn from publications used by universities, with a number of mistakes revealed by the independent audits in terms of classification and counting of publications. Moreover, this study could have produced more robust results had it used second stage regression approaches to identify the possible factors affecting the efficiency of these universities. Other education studies include Johnes *et al.* (2012), who analysed TE of the further education sector in England, using DEA approaches on a sample of 600 further education providers in England for the period 2001-2002 and 2002-2003. Their main findings showed a mean TE ranging from 78% to 86%, with results from the second stage regression noting that the composition of student and teacher, as well as regional features, impact on efficiency in each subject.

In the healthcare sector, Kontodimopoulos *et al.* (2007) used DEA in comparing technical and scale efficiency of the two largest primary health care providers in Greece: National Health System (NHS) and the Social Security Foundation (IKA). Utilising data on 194 units (103 NHS and 91 IKA) with three inputs; medical personnel, nursing/paramedical staff, and administrative/other employees and two outputs, including the aggregate number of scheduled/emergency (s/e) patient visits and imaging/laboratory (i/l) diagnostic tests the data were limited to only one year. In terms of technical and scale efficiency, IKA outperformed NHS with 84.9% vs. 70.1% and 89.7% vs. 85.9% for s/e and i/l respectively. On the other hand, there were scale inefficiencies that are associated with smaller primary care centres, while larger care centres seemed to suffer most from technical inefficiencies.

Tsekouras *et al.* (2010) found similar results using DEA in regard to the effect of scale inefficiencies from analysis of productive efficiency of 39 intensive care units (ICUs) of the Greek public healthcare system. Their results indicate that while TE improved significantly with the introduction of medical equipment and technology, scale efficiency remained the same. Similarly, the structure of the medical staff, proximity to pools of knowledge and asymmetric information were found to be crucial factors for the enhancement of the ICUs productive efficiency; the study also found that location of healthcare services is an important variable affecting scale efficiency.

Both Kontodimopoulos *et al.* and Tsekouras *et al.'s* studies, raise questions on whether the effort to increase TE in health care is politically suitable. Kontodimopoulos *et al.* (2007) suggested from their DEA model that improving TE in inefficient units, which were mostly located in rural areas, can be achieved by reducing inputs (physicians, nurses and administrative staffs) in a country where healthcare services in rural areas are still not adequate. On the other hand, Tsekouras *et al.* (2010) suggested from their DEA model that increasing scale efficiency (by increasing size of the unit) is more suitable than increasing TE to satisfy the demand for healthcare in Greece. These two finding demonstrate the need to understand and interpret results from efficiency studies appropriately. Again, one possible limitation of both studies is the data period of one year, and that basing recommendations on results from a single years' analysis may be open to question.

In the transportation sector, Zhang *et al.* (2012) estimated TE of 37 Chinese airport airside activities from 2009 data using DEA. The data were taken from the Statistical Data on Civil Aviation of China and Aeronautical Information Publication of China. Output variables used include the number of aircraft movements while inputs involve take off distance available (TODA) and landing distance available (LDA). Zhang *et al.* found that there are significant differences in efficiency levels between Chinese airport airsides, in particular showing that the larger airsides tend to perform better than smaller airsides. However, this study also draws upon as single years' data set.

Cullinane *et al.*'s (2006) analysis provided extensive information by estimating TE of 57 global container ports using both DEA and SFA approaches. While SFA approaches tend to draw upon larger data sets, data was drawn from a single year (2001) from information supplied by trade publications. In spite of the reliability of information and data sources, the authors depended on these secondary data only. Cullinane *et al.* argue that input-orientated DEA models are deeply linked to operational and managerial matters, while the output-orientated approach is associated with planning and wider economic strategies. Hence, they utilised both input- and output-orientated approaches for comparison purposes. In terms of the SFA model, TE was estimated using the log-linear Cobb-Douglas, and results showed that DEA efficiency under the specification of constant return to scale (CRS) gives the lowest efficiency score. Moreover, the estimated mean TE from SFA was larger than those achieved from the DEA analyses under variable returns to scale (VRS). In this study, scale of operation, greater private sector participation and transhipment have been shown to be associated with high levels of TE. Cullinane *et al.*'s (2006) study arguably provides more robust comparative results than the study from Zhang *et al.* (2012) in the transportation sector since it presented efficiency results from both methods.

In the manufacturing sector, Castiglione (2012) analysed the TE and information communication technology (ICT) investment of Italian manufacturing firms, drawing upon large sample sizes and using SFA. Both translog and Cobb-Douglass functions were estimated based upon data over an eight year period (1995-2003); investment in ICT positively impacted on firms' TE, with group, size and geographical position also positively related to efficiency. Conversely, older firms were found to be more efficient than newer ones. In contrast to the study noted above, this study used data from 4497 firms for the period 1995-97, 4680 firms for 1998-2000, 3452 firms for 2001-03, and 514 firms for all periods observed (1995-2003). While representing large sample sizes the findings may have been more solid if an identical panel data set was used for the whole period. Moreover, another possibility would have been to separate the data into small-size, medium-size, and large-size companies in order to provide analysis within comparable groups given the large sample size data set available.

Tingley *et al.* (2005) studied factors affecting TE in fisheries in the English Channel using SFA and DEA approaches, drawing upon two primary data sets; namely the log books and a survey for a seven year period (1993-2000). Broad consistency was found between the two models in terms of the factors influencing TE. As also found by Cullinane *et al.* (2006), TE estimates from the SFA were shown as consistently greater than DEA estimates.

From efficiency assessment studies in the agricultural sector, Wilson *et al.* (1998) estimated TE in the UK's potato production using SFA from 140 observations of maincrop producers in a single year (1992). Minimum estimated TE was 33.22%, while the maximum was 97.29%, with an average of 89.5%. Wilson *et al.* ascribed differences in efficiency levels to managerial decisions and farm characteristics identifying positive correlation of TE with irrigation of potato crops and storage of potatoes after harvest. On the other hand, years of experience, the overall farm size and chitting of seed potatoes each have a negative relationship on TE. Wilson *et al.*'s study demonstrated the importance of management in explaining efficiency variation in a developed countries' agriculture. Building upon this, Wilson *et al.* (2001) utilised SFA in an analysis of TE of wheat farmers, focusing on management, as it is not observable compared to other variables such as labour, costs and land. They contributed a novel procedure to quantity marginal effects of the variables included within the inefficiency models. With their aim of explaining the effects of management on the technical performance; specifically they accounted for personal variables such as experience and further education as well as decision making objectives factors like profit maximisation and maintaining the environment.

Wilson *et al.* (2001) drew upon two data sources; secondary production data from 1993-1997, in 1997. Technical efficiencies were found to range from 49.51% to 98.01% maximum, with average of 87.01%. Farmers who sought to maintain the environment, maximise their profits and consult more information sources were more efficient than those who did not. In addition, managers with more experience and better education were also found to be more efficient. Years of experience seemed to have a positive effect on TE. Lastly, it was found that TE is positively correlated with size of the farm. An important aspect of the paper was drawing upon panel data plus managerial data from a single year. In this, Wilson *et al.* argued that the managerial data represented managerial inputs that applied to the five years of production data. However, while this assumption may not be valid, it provides an indication of how previous research has combined secondary and primary data in efficiency studies.

Iraizoz *et al.* (2003) estimated the TE of 46 horticultural producers in Spain's Navarra region using data from 1994. Both tomato and asparagus production were analysed separately in this study. The authors used DEA and SFA; using the Cobb-Douglas functional form for the latter method. Results from this showed that there is relative inefficiency in the production of tomato and asparagus, which means that there should be a potential rise in output or reduction in input for both products (20% for tomato and 10% for asparagus). Results also indicated that there is no conclusive evidence related to farm size influence to efficiency as identified in Wilson *et al.* (2001). However, lack of depth in the data available was noted as a stumbling block in terms of attributing efficiency variations to a single reason. In addition to this, one critique is the modest sample size for a single year and the results will be stronger if the study had used data from more than one year, as there may be external factors, such as the weather affecting production efficiency. The latter may influence the efficiency in that particular year, especially since SFA is used because the regression-based method will produce better results if time series data are used.

Odeck (2007) estimated TE and productivity growth by comparing DEA and SFA assessment of Norwegian grain producers, focusing on both productivity growth and TE, which have previously either been studied separately or not covered in detail within the context of Norwegian grain producers. Data on 19 specialised grain farm producers over 11 years (1987-1997) was drawn from management accounts in agriculture and forestry gathered by the Norwegian Agricultural Economics Research Institute (NAERI). Crop yield was used as an output measure, while total labour inputs, capital cost, agricultural area, seeds and fertilizers' cost were used as inputs. The study used cross sectional data for each year; however, due to the limited number of observations, Odeck undertook analysis using pool data over the 11-year period to achieve a total of 209 observations.

As in Iraizoz *et al.* (2003), Odeck's (2007) results showed consistency between the DEA and SFA models, with results indicating that there is potential for improved efficiency but that there has been a productivity improvement in the sector in the region of 30-38% across the 11 years' of observations. Technical change was observed to play a significant role in productivity growth.

The lack of TE studies in the developed countries not only applied at the national level as argued by Wilson *et al.* (2001), but was also evident more specifically in the local level. Barnes (2008) showed that Scotland, lacked any studies estimating TE. The author investigated four major Scottish agricultural sectors, including cereals, dairy, sheep, and beef by utilising Scottish data and the SFA methodology used in paper by Hadley (2006), which focused on England and Wales, in order to compare the findings between different areas of the UK. The study used sixteen years of data from 1989 to 2004. The data were taken from the Scottish Farm Account Survey (SFAS) to cover the four agricultural sectors as defined by the Scottish Executive Environment and Rural Affairs Department (SEERAD). The FAS data also contained useful information that can be adopted for explanatory variables to evaluate inefficiency.

Barnes found that the translog functional form of the SFA was preferred to other functional forms, such as the Cobb-Douglas and used procedures adopted by Wilson *et al.* (2001) in calculating marginal effects of variables within the inefficiency model. Barnes argued that the Scottish data are more constricted regarding the sample size and motives of TE than English and Welsh data as used in Hadley (2006). There were similar major findings between Hadley (2006) and Barnes (2008), in which comparable average TE scores around 70%-75% for cereal and 78%-82% for sheep farms were found. Moreover, both studies similarly found feed cost as the most important factor affecting TE of sheep, dairy and beef. Conversely, both studies have different returns to scale and most important factors affecting production of cereal.

Barnes further found negative significant effects of 'least favourable area' (LFA) and 'environmentally sensitive area' (ESA) to efficiency, while positive significant effect of land ownership on efficiency was found for all sectors except for beef production. This conforms with Hadley's study which notes the importance of owning land in achieving efficiency compared to tenanted land. Equally, debt was shown to have a significance only in the dairy sector, with a higher debt ratio being correlated with greater efficiency. Findings from Barnes' (2008) study also showed that total agricultural area has a small effect on efficiency with mixed signs as in Hadley (2006), albeit that in Barnes' study this effect was demonstrated by a positive sign for cereal farms, similar to Wilson *et al.* (2001). Barnes panel data estimation identified that time had a significantly negative effect for all farm types, where on average TE of all farms was found to be lagging behind the frontier. Finally, key variables affecting efficiency such as age and education were not used in Barnes' study since these variables have only been introduced into the Scottish data collection process only recently, and hence, were not available to the author.

Guzman *et al.* (2009) compared Italian and Spanish fruit and vegetable firms by estimating the TE using DEA. Drawing on secondary data from a period of five years (2001-2005) on the Bureau van Dijk for (81) Italian agricultural cooperatives (IAC) and for 106 Spanish Sistema de Análisis de Balances Ibéricos (SABI) Guzman *et al.* found a higher ability of Italian cooperatives to optimise input use and maximise outputs relative to the Spanish cooperatives. However, the high value of the Spanish cooperatives is shown in their ability to exploit scale economies, achieving an average TE of 97%. Also, the efficiency of Italian firms increased from 83% in 2001 to 88% in 2003. On the other hand, Spanish firms exhibited decreasing efficiency from 91% in 2001 to 86% in 2003. In addition, the average score of TE under VRS was very similar for both data sets of cooperatives for the entire period of study. However, one critique of this study is that it does not measure the influence of country effect on the efficiency results as part of a second stage analysis, since Spanish and Italian firms may face a different environment which may affect their efficiency; therefore, they arguably cannot be directly compared from the different frontiers.

The above overviews of efficiency studies in developed countries has highlighted the breadth of sectors for which efficiency studies have been undertaken, and also the data constraints and opportunities faced by different researchers. While SFA approaches typically require large data sets, some authors (Wilson *et al.*, 2001; Iraizoz *et al.*, 2003; Tingley *et al.*, 2005; Cullinane *et al*., 2006; Odeck, 2007; and Luo *et al.*, 2011) have utilised this approach with modest number of observations. The review has also identified some studies which have compared SFA and DEA (Iraizoz *et al.*, 2003; Tingley *et al.*, 2005; Cullinane *et al*., 2006; Odeck, 2007; and Luo *et al.*, 2011) and moreover explored how the use of primary data collection can be combined with secondary data when estimating and explaining variation in TE (Wilson *et al.*, 2001; Cullinane *et al.*, 2006 and Castiglione, 2012).

3.3. Efficiency Measurement Studies in Developing Countries

In developing countries, issues of data availability, data quality and sectoral coverage may highlight issues not observed from developed country studies. Some of the efficiency measurement studies that utilise DEA, SFA and both DEA and SFA methods in a developing country context are presented in Table 3.2 and 3.3.

Table 3.2: Efficiency Measurement Studies in Developing Countries

Author	Methodology	Country	Sector	Study Aim	Data	Time Period
Bhagavath (2009)	DEA	India	Transportation	TE of State Road Transport Undertakings (STUs)	44 State Road Transport Undertakings	2000-2001
Alkhathlan and Abdul Malik (2010)	DEA	Saudi Arabia	Banking	TE of Saudi commercial banks	10 commercial banks	2003-2008
Assaf *et al* (2010)	DEA	Saudi Arabia	Banking	TE of Saudi Banks	9 banks	1999-2007
Kehinde and Awoyemi (2009)	SFA	Nigeria	Forestry	Improving EE of sawnwood in Ondo and Osun states	170 sawnwood producers	2003
Kehinde *et al* (2010)	SFA	Nigeria	Forestry	TE of sawnwood in Ondo and Osun states	170 sawnwood producers	2003
Radam *et al* (2010)	SFA	Malaysia	Forestry	TE of Malaysian wooden furniture industry	511 furniture manufacturing industries	2005
Ferrantino and Ferrier (1995)	SFA	India	Agriculture	TE of vacuum-pan sugar factories	239 Indian Sugar Companies	1980-1985
Alrwis and Francis (2003)	DEA	Saudi Arabia	Agriculture	TE, AE, & EE of Broiler Farms	40 broiler farms in Central Region of Saudi Arabia	1993
Krasachat (2003)	DEA	Thailand	Agriculture	TE of Thai rice farms	74 rice farmer households	1999
Bekele and Belay (2007)	SFA	Ethiopia	Agriculture	TE of grain mill producer	42 grain mill product manufacturing firms	1999-2000
Begum *et al* (2009)	DEA	Bangladesh	Agriculture	EE of Poultry Farms	100 farmers	2007
Mulwa *et al* (2009)	DEA and SFA	Kenya	Agriculture	Impact of liberalization on efficiency and productivity of sugar industry	Case study on Mumias Sugar Company	1980-2000
Dlamini *et al* (2010)	SFA	Swaziland	Agriculture	TE of small-scale sugarcane farmers	40 sugarcane scheme and 35 individual surgarcane farmers	2006-2007

Table 3.3: Efficiency Measurement Studies in Developing Countries

Author	Methodology	Country	Sector	Study Aim	Data	Time Period
Kaur *et al* (2010)	SFA	India	Agriculture	TE of wheat production	564 wheat farmers	2005-2006
Narala and Zala (2010)	SFA	India	Agriculture	TE of Irrigated Rice Farms	240 cultivators in Gujarat	2007-2008
Khai and Yabe (2011)	SFA	Vietnam	Agriculture	TE of rice production	4216 rice farmers	2005-2006
Oyewo (2011)	SFA	Nigeria	Agriculture	TE of maize farmers in state of Oyo	120 maize farmers	2008
Abatania *et al* (2012)	DEA	Ghana	Agriculture	TE of farm households in the Northern region	189 farms	2005-2006
Adhikari and Bjorndal (2012)	DEA and SFA	Nepal	Agriculture	TE of household farm	2585 household farms	2003
Mousavi-Avval *et al* (2012)	DEA	Iran	Agriculture	TE and SE of Barberry farmers	144 barberry producers	2008-2009
Elhendy and Alkahtani (2013)	DEA	Saudi Arabia	Agriculture	TE of conventional and organic date farms	A total of 220 farms (126 conventional and 94 organic farms)	
Amaechi *et al.* (2014)	SFA	Nigeria	Agriculture	TE of the oil palm produce mills industry	30 mills	2005
Kibirige (2014)	SFA	Uganda	Agriculture	TE among small holder maize farmers	The total farm size was 170 maize farmers	

In regard to efficiency studies in developing countries (Tables 3.2 and 3.3), eight studies were performed using DEA methodology exclusively (Bhagavath, 2009; AlKhathlan and Abdul Malik, 2010; Assaf *et al*., 2010; Alrwis and Francis, 2003; Krasachat, 2003; Begum *et al.*, 2009; Abatania *et al.*, 2012 and Mousavi-Avval *et al*., 2012), ten studies used SFA methodology exclusively (Kehinde and Awoyemi, 2009; Kehinde *et al.*, 2010; Radam *et al.*, 2010; Ferrantino and Ferrier, 1995; Bekele and Belay, 2007; Dlamini *et al.*, 2010; Kaur *et al.*, 2010; Narala and Zala, 2010; Khai and Yabe, 2011 and Oyewo, 2011), and two studies adopted both DEA and SFA methodologies (Mulwa *et al*., 2009 and Adhikari and Bjorndal, 2012). Within Table 3.2 and 3.3 most of the studies in agriculture and forestry sectors utilise SFA as their methodology, while efficiency studies in banking sectors mostly use DEA. Examples of SFA studies in the agriculture sector include Khai and Yabe (2011), Ferrantino and Ferrier (1995), and Radam *et al.* (2010), whereas Abatania *et al.* (2012) an Mousavi-Avval *et al.* (2012) are examples pertaining to DEA studies in the agricultural sector.

Most of SFA studies listed in Table 3.2 and 3.3 used a large dataset sample: more than 100 units of data, as in the case of Narala and Zala (2010) and Kaur *et al.* (2010). Conversely, DEA studies listed in Table 3.2 and 3.3 typically used a small sample size, including Assaf *et al.* (2010), AlKhathlan and Abdul Malik (2010) and Bhagavath (2009). Studies using both DEA and SFA methods used large sample data sets, as in Adhikari and Bjorndal (2012). Furthermore, most of the studies using SFA, DEA, and both DEA and SFA were performed on panel data.

Bhagavath (2009) estimated TE of 44 State Road Transport Undertakings (SRTUs) in India using DEA methodology, drawing upon (2000-2001) data from the Association of State Road Transport Undertakings and from Central Road Transport. Three input variables were observed - fleet size, average kilometre travelled per bus per day, and cost per bus per day, and one output variable; revenue per bus per day.

Bhagavath estimated average TE of 89.4% under VRS and 83.4% under CRS. From the 44 SRTUs, only eight were found to be scale-efficient or operating at their most productive scale size. On the other hand, SRTUs which operated as firms have relatively higher TE. This study used only two years of data and so it was not possible to measure productivity growth. Moreover, the lack of data on explanatory factors meant that second stage regression was not computed to see which factors affect efficiency in this sector.

In the forestry sector, Kehinde and Awoyemi (2009) utilised SFA to analyse economic efficiency (EE) of 170 sawnwood producers in 2003 in Ondo and Osun states in the southern part of Nigeria. Using the Cobb Douglass production function to estimate technical, allocative and economic efficiencies, and a regression method to estimate the determinants of the observed inefficiencies. Mean TE, AE and EE of sawnwood in Ondo was respectively calculated as 68%, 81% and 54%, and 79%, 83%, and 67% for Osun.

In another Nigerian study using the same data set, Kehinde *et al.* (2010) analysed factors that affect TE of sawnwood producers in Ondo and Osun states in Nigeria finding that medium-scale sawmillers are more efficient (89.22%) than small-scale sawmillers (86.93%). Small-scale producers were observed to be operating at decreasing return to scale; however, medium-scale sawmillers were operating at increasing return to scale. Level of education, capacity utilisation, and years of sawmilling operation were found to have a significant positive relationship with TE, whilst manager's age has a negative insignificant relationship with TE.

From the agricultural processing sector, Ferrantino and Ferrier (1995) estimated the TE of 239 vacuum-pan sugar factories in India over a five year period (1980-85). Drawing upon the Cooperative Sugar Directory and Yearbook 1985-1986 and the Indian Sugar Yearbook 1986-87, input variables included the milling capacity of the roller machines, the boiling capacity of the plant, the power generating capacity of the plant, and the agricultural sucrose into the sugar recovery process. Findings from a translog production function SFA approach showed that there was not considerable inefficiency in the sector, however smaller firms and firms with access to sweeter sugar cane, proved more efficient than others. In addition, publicly owned firms were less efficient than other firms, as noted in Chapter 1 and of direct relevance to this thesis. However, the authors did not collect any primary data to consolidate their research findings, nor include labour as an input variable, which was sacrificed to provide a larger sample to provide more feasible and robust inter-year comparisons. In contrast, Radam *et al.* (2010), who estimated TE of the Malaysian wooden furniture industry, used labour as an input in their study, and found that many firms operated below 100% efficiency level, and that labour intensive firms were found to be inefficient.

Following Ferrantino and Ferrier (1995), Dlamini *et al.* (2010) estimated TE on small-scale sugarcane farmers of the Vuvulane scheme and Big bend individual farmers in Swaziland, finding that efficiency variations were clearly noted in both groups.

Regarding the Vuvulane, efficiency varied between 37.5% and 99.9%, with a mean of 73.6%; for Big bend farmers, efficiency ranged from 71% to 94.4% with a mean of 86%. Dlamini *et al.* observed an over-use of land by the sugarcane farmers at Vuvulane; increased farm size, education and older age of the sugarcane farmers led to decreased technical inefficiency. This finding on positive relationship of farm size to TE contrasted the result of Ferrantino and Ferrier (1995) above, where smaller firms were found to be more efficient in vacuum-pan sugar factories.

In Africa, Mulwa *et al.* (2009) also studied efficiency and productivity of the Kenyan sugar industry, which was liberalized in 1992 to encourage the private sector to play an active role. The study aims to analyse efficiency levels before and after the liberalisation process and used secondary data collection for a period of 20 years spanning from 1980 to 2000 by means of Kenya Sugar Authority (KSA) yearbooks of statistics and Mumias Sugar Company (MSC) annual records, including the amount of crushed cane, processed sugar, chemicals, power, labour, capital level, and cost of inputs. Because of its dependence on secondary data only; i.e. annual records, this study could not provide extra insights into the industry or other factors explaining variation in the TE of the sugar sector. Empirically Mulwa *et al.* found that there were no major differences between DEA and SFA as both prove useful for data analysis.

Also in the agricultural sector, Krasachat (2003) used DEA to study TE of Thai rice farms drawing upon interview data from 1999 and based on a random selection of 74 rice farm households in three districts of the northeastern region of Thailand. In this study, one output and five inputs were used, identifying wide variations of efficiencies between farms, where the average technical inefficiency could be decreased by 29% by applying the best practices of efficient rice farms. However, findings were not conclusive for farm size and irrigation in terms of having an impact on scale inefficiency of rice farms, and there is evidence that the provincial differences in the data seem to have influenced scale inefficiency of rice farms. However, this paper also suffers from data limitations as it only uses one year of cross-sectional data

(1999), which may be the cause for all variables in the second stage regression to be insignificant. Had this study been expanded using data for more than one year, the results on the second stage analysis may have proven to be more robust. However, the study found that pure technical inefficiency, not scale inefficiency, is the major problem for overall inefficiency.

The efficiency of rice products was also studied by Narala and Zala (2010) who analysed TE of 240 rice farms in Central Gujarat together with the evaluation of socio-economic factors relating to variation in TE using SFA methodology. The authors found that all rice farms had major inefficiencies in their production processes with 86% of observed inefficiency ascribed to the farmers' inability to take decisions and 14% related to factors out of their control. In addition, the stochastic frontier estimates showed that the inputs of fertilisers and irrigation were highly significant and positively correlated with TE.

Large differences in the level of TE at farm-level were observed, ranging from 71.39% to 99.82% with the average level standing at 72.78% for all farms. Medium farm-size groups were found to be the most efficient with 99.82% due to the fact that farmers had agriculture as their main job. The most important factors affecting TE included operational area, experience, educational background, and distance of field from canal irrigation area, while the number of working members in the family was shown to have a negative relationship with TE.

Using SFA, Khai and Yabe (2011) focused on analysing TE of rice production in Vietnam using data from the 2006 Vietnam Household Living Standard Survey (VHLSS), which included an 85 page questionnaire modified for the Vietnamese case. More than 4,000 farmers were interviewed and the total data accepted included almost 3,800 from the original 9,189. The SFA method, applying the Cobb-Douglas production function, was used, followed by a second step where the Tobit function sought to determine factors that can have an impact on Vietnamese rice farmers' TE. TE ranged from 16.5% to 98.5%, with a mean TE of 81.6%. Intensive labour was found to be the most important positive factor affecting efficiency, followed by irrigation, improving farmers' experience and education. However, this finding contrast with the results of Radam *et al.* (2010) in the forestry sector mentioned earlier, which found that labour-intensive firms tend to be more inefficient.

Within these studies on rice production While Narala & Zala (2010) used seven inputs, with seeds and irrigation as the two extra variables, socio-economic factors were not taken into consideration in the aforementioned studies by Krasachat (2003), and Khai and Yabe (2011). While using DEA to estimate TE, Krasachat (2003) also included fewer variables, including fertilisers, labour, capital, land, and 'other inputs'.

Using DEA, Begum *et al.* (2009) estimated TE, AE and EE of 100 poultry farms in Bangladesh in 2007 randomly selected from Kaliakoir and Sripur Thanas under the Gazipur region because it is a highly concentrated area for poultry farms. Secondary data was obtained from the FAOSTAT website and Bangladesh Bureau of Statistics (BBS).

Begum *et al.*'s study, found that there is a considerable technical, allocative and economic inefficiency in poultry production in Bangladesh, with 88%, 70%, 62% respectively under CRS, and 89%, 73%, and 66% respectively under VRS. By using Tobit Analysis, Begum *et al.* found that farmer's educational background, experience, training, farm size, and poultry farm size have a significant and positive influence on TE, AE, and EE.

Kaur *et al.* (2010) estimated TE of 564 wheat producers in a number of regions in the Punjab state of Pakistan over 2005-2006. Data collection was based on the three-stage random sampling method obtaining 58 households in semi-hilly regions (region I), 318 in central areas (region II), and 188 in south-western regions (region III). Results indicated a mean TE of 87% in Punjab as a whole with mean regional variation of 86% to 94% TE. The authors found that TE has a positive correlation with age, education and experience of farmers, as well as percentage of area under the crop. The finding on farmer education confirms the result of Begum *et al.* (2009) cited earlier.

In Nigeria Oyewo (2011) estimated the TE of 120 maize producers in the Nigerian state of Oyo using SFA methodology. In terms of the study sample, the author utilised cross-sectional data based on a three-stage stratified random sampling method. The first stage divided the Ogbomoso zone into five local government areas (LGAs); then, the authors selected their small scale maize farmers from four of these five areas in the second stage. The last stage involved choosing 30 farmers from each of the four LGAs, bringing the total to 120. In this study, primary data was gained with the interview schedule provided for the maize farmers. To analyse the data collected from the field, the stochastic frontier production specifying a Cobb-Douglas form was used to estimate the TE in the operation of farmers in the area under study.

Mean TE was estimated at 96.1%, whereas the return to scale (RTS) was 58.7% in the study area, demonstrating a positive and significant link between the size of the farm, seed and output; a positive effect of farm size on TE is in line with finding from Dlamini *et al.* (2010), Narala and Zala (2010) and Begum *et al.* (2009) in the agricultural sector.

In Uganda, Kibirige (2014) estimated TE among 170 small holder maize farmers in the Masindi District of Uganda using data collected from a structured questionnaire. Estimation of TE was conducted using SFA under the Cobb-Douglas production function, with the author using OLS to estimate the variables which affect TE second stage analysis. TE ranged between a minimum of 4% and a maximum of 92%, with mean TE of 58% and group membership, household size, education levels, occupation and seed planted were shown to have a positive relationship with TE. However, selling at the farm gate had a significant negative relationship with TE. Previous authors (Coelli *et al*., 2002; Tingley et al., 2005) have noted that the use of the Tobit regression analysis is more suitable than OLS when explaining efficiency results, and hence Kibirige could have compared results from a Tobit analysis with results from the OLS analysis.

In a study by Abatania *et al.* (2012), TE of farm households in the Northern region of Ghana was examined using DEA, drawing upon data from the Ghana Living Standards Survey (GLSS) (2005-2006) on 189 farms. Input variables included land, labour, and variable input cost; while outputs comprised maize, millet, sorghum, beans, groundnuts, and rice. Using the DEA model as a first stage to estimate TE, the findings under VRS showed that the majority of farms are technically inefficient, which was also the case for scale efficiency; the estimated mean technical and scale efficiencies were approximately 77% and 94% respectively.

A second stage using ordinary least squares (OLS) regression was used to determine the factors affecting TE. These were found to include hired labour and geographical location of farms, as well as gender and age of household, which significantly affect TE of Ghanaian crop production. It was found that older farmers were more technically efficient than younger farmers, while female farmers were shown as more technically efficient than male farmers. However, it is argued here that the study could have produced more robust results if it had calculated productivity growth using Malmquist Index as identified by several authors as an appropriate approach and decomposed the productivity into the effect of technological change on farming and TE change, so that more complete information could be collected.

Adhikari and Bjorndal (2012) analysed TE of Nepalese agriculture. Using data from 2585 households from the Nepal Living Standards Survey (NLSS) in 2003 from Central Bureau of Statistics (CBS) Nepal, the findings show that under both SFA and DEA models, there has been a high degree of technical inefficiency affecting agriculture in Nepal. Adhikari and Bjorndal found that land ownership and level of education of household head have a significant positive effect on TE. Values of land, age of household head, and government extension programme also have a positive relationship with TE, although not statistically significant. Uniquely, the farther the farm was from the road, the higher its TE, which may be due to better irrigation systems further from residential areas. The positive relationship of education with TE confirms the results in other studies in developing countries, such as Kehinde *et al.* (2010), Begum *et al.* (2009) and Kaur *et al.* (2010).

In Iran, Mousavi-Avval *et al.* (2012) analysed the technical and scale efficiencies of 144 farmers and identified the wasteful uses of energy in various farm sizes of barberry production by using the DEA method. Significantly this study takes into account the environmental impacts and energy concerns of agricultural activities. Thus, it aims to improve efficiency in energy use to reduce environmental footprints. Data was collected from primary interviews during the production year 2008-2009. Total energy input and yield level of small farms were found to be greater than those of large farms. Small farms also used their energy resources more efficiently. In terms of areas of improvement, diesel fuel, electricity and biocides were identified by the authors as potential areas. For enhanced energy use efficiency and reduced environmental impacts of barberry production, the authors also suggested improving energy use efficiency of water pumping systems, timing, amount and reliability of water application, usage of the conservation tillage and integrated pest management techniques.

Within Saudi Arabia which is the geographic focus of this thesis, there has been a shortage of efficiency studies with a limited number of academic research studies carried out to analyse the TE of some major industries such as the banking and agricultural sectors. In the agricultural sector, Alrwis and Francis (2003) studied broiler farms in Saudi Arabia by estimating their technical, allocative and economic efficiencies, in addition to determining the difference between the mean TE for large and small farms. Primary data was collected from 40 out of 154 broiler farms in the central region of Saudi Arabia, categorising farms into two groups in respect to their output capacity.

Findings revealed that TE under the assumption of CRS is 72.9%, and 81% under the assumption of VRS. Allocative and economic efficiencies were estimated to be 77.9% and 56.4% respectively under CRS and 81.9% and 66.4% for VRS. With regards to small farms, the mean TE stood at 82.1% and 87.2% for CRS and VRS respectively. On the other hand, under CRS, the mean of allocative and economic efficiencies reached 71% and 58.5% respectively, while it reached 74.5% and 65.3% under VRS. Similarly, findings proved that the mean TE for large farms under CRS reached 81.6%, while under VRS, it reached 89.9%. The mean AE and EE stood at 84.5% and 68.3% respectively. TE, AE and EE estimates are greater for large farms than small farms under the VRS. However, it is argued here that these mean differences of TE, AE and EE between large farms and small farms could have been analysed further in a second stage analysis to observe their statistical significance before a conclusion that large farms have higher efficiency than small farms can be drawn. The differences between average mean efficiency of large farms and small farms are very small and there may be sample size differences between large and small farms sample size in dataset, which need to be fully explored before firm recommendation are made.

AlKhathlan and Abdul Malik (2010) estimated TE of ten out of twelve Saudi commercial banks between 2003 and 2008 using DEA and found that mean TE under CRS varied between 82% and 87%, while under VRS, it ranged from 88% to 95%. Results show that in general Saudi commercial banks are relatively efficient in managing their financial resources. However, as noted for Alrwis and Francis (2003) one critique to this study is that the result could be improved by performing a second stage analysis of, for example, productivity growth using a malmquist index to estimate whether there has been a change in pure TE in the 2003-2008 period apart from changes in scale efficiency and banking technology.

In contrast to the above paper, Assaf *et al.* (2010) estimated TE of Saudi banks using a two-stage DEA approach: the first stage was undertaken with a DEA-VRS model to calculate efficiency scores, while the second stage was undertaken with a bootstrapped truncated regression model to identify factors that affect TE. Using data from nine banks over the period of 1999-2007, they found that average efficiency scores of these banks decreased slowly over the 1999-2003 period, then increasing constantly until it reached 90.21% in 2007. From their second stage analysis asset, liquidity ratio, and net profit margin have a significant positive relationship with TE, while dividend payout ratio and foreign ownership have a significant negative relationship with TE. This shows that banks that distribute more dividends to their shareholders have lower efficiency, while foreign ownership does not necessarily mean higher efficiency for Saudi banks. This study provides a robust analysis for the Saudi Arabian context since it utilises data comprehensively by performing TE analysis, followed by determining the factors that may influence this TE change over the period in observation.

Elhendy and Alkahtani (2013) studied the resource use efficiency of 126 conventional and 94 organic date farms in Saudi Arabia using DEA approaches. TE ranged between 8% and 54% and CE ranged between 15% and 20%. In addition, AE was lower than TE, which can lead to overutilisation of inputs and therefore low productivity and low outputs. Also, the majority of respondents operated very far from the efficiency frontier, while the decision making units were not all operating at the optimal scale. The authors did not note the duration of the study, but the results imply the study results to just one year. As noted for other studies, it is recommended to use more than one year in order to achieve robust results, and additionally to identify the influence of managers and management variables, such as age, education and years of experience on efficiency.

In spite of the wide ranging studies conducted with various agricultural and industrial products such as wheat, rice, maize, sugar, banking, medical care and universities, there seems to be a paucity of studies relating to grain mill products. One study worthy of note is Bekele and Belay (2007), who estimated the TE of grain mill products in Ethiopia. The industrial sectors in Ethiopia appear to be plagued with technical, scale, and allocative inefficiencies (Tybout, 1990). Since Ethiopia is a poor country with scarce resources and as the manufacturing sector is said to contribute lowest globally to the gross domestic product (GDP), Bekele and Belay (2007) stated in their study that it has become paramount for efficiency to be maintained with existing technology.

Data was for the 1999-2000 production year and drew mainly from a survey conducted by the Central Statistical Authority (CSA) covering up to 90% of the grain mill products manufacturing firms (GMPMF), which accounted for 42 firms. The highest number of participating firms were private (80%; 36 firms) with fewer publicly owned enterprises (20%; nine firms). In addition, a questionnaire was adopted and distributed among managers and officers in the above selected firms to capture further information.

TE ranged between 18.9% and 95% with mean TE level at 75.6%. Form of ownership, firm size, availability of books of accounts, and number of products and by products produced by the firm were shown as significant factors in deciding the firm's TE levels; while there was a positive impact of size and availability of books of account on TE, a higher number of products and by-products produced were shown to negatively affect TE levels. Similar to Ferrantino and Ferrier (1995), these results show that publicly owned firms were found to be generally less efficient than privately owned ones.

Arguably, the limitations of this study include the single year production period for the analysis. Moreover, Bekele and Belay's inclusion of both public and private sectors may arguably lead to a confusion of the results because while they have included both private and public sectors for comparison, they have not particularly expanded their analysis to account for the major differences or drivers as to why these results related to different efficiencies.

Amaechi *et al.* (2014) estimated TE using a translog stochastic frontier production function model in the oil palm produce for 30 mills industry in Nigeria for one year (2005). In addition, the author used the Tobit regression to estimate the effect of variables, such as age, education and process experience of oil millers. TE ranged between 37.48% and 93.46%, with such variations ascribed to differences in millers' management practices and improper utilisation of the available resources. Regarding the effects of management variables, while education, processing experience, membership of cooperative society, credit, capital, throughput, petroleum energy and water have a significant positive relationship with TE, age, household size and interest on loans have a significant negative relationship with TE. It is argued here that using a one year timeframe with a small sample size is not sufficient in order to achieve an adequate number of observations since the SFA model depends on as many observations as possible to account for TE, in contrast to DEA approaches which can draw upon smaller numbers of observations.

The above overview of studies in developing countries has highlighted issues of data availability and quality that have often led authors to consider only single year time frames or not to include an explanation of the factors influencing variation in efficiency, such as Alrwis and Francis (2003); Krasachat (2003); Bekele and Belay (2007); Begum *et al.* (2009); Kehinde and Awoyemi (2009); Kehinde *et al.* (2010); Radam *et al.* (2010); Dlamini *et al.* (2010); Kaur *et al.* (2010); Narala and Zala, 2010; Khai and Yabe, 2011 and Oyewo, 2011 ; Abatania *et al.* (2012); Mousavi-Avval *et al*. (2012); and Adhikari and Bjorndal (2012). Moreover, studies have been identified which draw upon a combination of secondary and primary data on the potential effect that explain variation in efficiency such as Begum *et al.* (2009), and Bekele and Belay (2007). Comparing results from developed and developing countries has demonstrated the wider range of TE estimates in developing countries, albeit that often these studies did not seek to explain this variation. Within Saudi Arabia, there has been only a limited number of efficiency studies. Moreover, the above literature has shown the potential low level of efficiency in public ownership operations which is of direct interest to this current study.

3.4. Summary

Measuring efficiency in developing countries suffering from scarcity of resources has become paramount extremely essential to improve performance. The current chapter gives an overview of the literature by grouping existing studies based on the context that they were conducted in. In addition, this chapter focused on the economic performance of the countries where these studies were carried out.

Accordingly, the literature was divided into two distinct subsections according to where these studies were implemented; developed and developing countries, which was aimed at reflecting on the experience of different social and institutional settings on the one hand. For instance, it has been well-documented that data availability and credibility are more problematic in developing countries. On the other hand, another motivation behind this distinction is has been to reflect on countries' experiences in order to determine which technique may be more appropriate in what context.

Based on the above literature in both developed and developing countries, it can be seen that while some studies used the DEA and SFA model individually, a combination of both to estimate TE can be used to provide efficiency comparison and arguably provide more robust findings than can be achieved from analysis based on only one form of efficiency study. Some studies covered one period year only (Schaffnit *et al.*, 1997; Wilson *et al.*, 1998; Avkiran, 2001; Iraizoz *et al.*, 2003; Kaur *et al.*, 2010; Abatania *et al.*, 2012; Mousavi-Avval *et al.*, 2012; and Zhang *et al.*, 2012), while others covered longer periods, including Ferrantino and Ferrier (1995); Wilson *et al.* (2001); Tingley *et al.* (2005); Odeck (2007); Guzman *et al.* (2009); Mulwa *et al.* (2009); Luo *et al.* (2011) and Johnes *et al.* (2012).

Studies which extend their analysis using second stage analysis after efficiency measurement have provided more robust and comprehensive analyses of their topics. Some of the studies that uses second stage analysis in the developing countries such as Assaf *et al.* (2010), Kehinde and Awoyemi (2009), and Abatania *et al.* (2012).

While some authors adopted primary data collection methods (Alrwis & Francis, 2003; Oyewo, 2011; and Mousavi-Avval *et al.*, 2012), others used secondary data in their analyses of TE, such as Ferrantino and Ferrier (1995); Guzman *et al.* (2009); Tsekouras *et al.* (2010) and Zhang *et al.* (2012). On the other hand, both primary and secondary research techniques were used by a number of authors in their data collection, for example, Wilson *et al.* (2001), Begum *et al.* (2009), and Bekele and Belay (2007). The latter used a structured questionnaire and a survey made by the Central Statistical Authority (CSA) and was found to be the only study conducted on grain mill products in Ethiopia.

In this current study, a combination of DEA and SFA methodologies will be used to provide comprehensive efficiency comparison, which will be followed by second stage regression analysis to explain variation in efficiency. Even though the researcher's study is addressing the same sector as Bekele and Belay (2007) above; i.e. grain mill products, it is not actually focused on comparing private and public firms differences. On the other hand, it aims to estimate the efficiency and productivity growth of the government-owned flour mills producer, namely GSFMO, in Saudi Arabia using both models (SFA and DEA) as opposed to the adoption of SFA approach only in Bekele and Belay's study. As such, it will be the first study in Saudi Arabia dealing with the milling industry and providing a robust estimation approach that also seeks to explain productivity growth and variation in efficiency levels.

4. RESEARCH METHODOLOGY AND DATA SOURCES CHAPTER

4.1. Introduction

According to Vogt (1993), research methodology can be defined as the science of planning measures in the conduct of research studies in order to achieve the most convincing results. Using the widely known terms, 'method' and 'methodology' can be sometimes confusing. As stated by Collis and Hussey (2003), the method is so strongly interlinked with the assumptions and the beliefs of the concept that it pervades the whole research design.

Data collection is valued as an important step in this research. This chapter is concerned with data collection and how it is analysed. This will be followed by a statistical description of inputs and output variables. The main reason for data collection is to identify, describe and explore inputs and output variables determining the production of flour in the branches of the GSFMO. Also, the chapter is concerned with identifying a method to estimate efficiency and productivity growth in GSFMO. The researcher used two methods of analysis; Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). The DEA analysis was used to measure TE, CE and AE under CRS and VRS input and output orientated. Moreover, an efficiency measure with the SFA method was used in this study and is based on the Cobb-Douglas and Transcendental Logarithmic (Translog) production functions. Both methods were used to estimate productivity growth for the GSFMO. Finally, the methods used in this chapter have a mathematical formulation which as explored in Chapter 2.

4.2. Data collection

4.2.1. Secondary Data

Adopting a positivist approach, this study used secondary data published by the GSFMO during 1988-2011, specifically the annual reports. The study is also based on the lists of budgets and profit and loss analysis of the 22 mills which are distributed over nine branches; namely, Riyadh, Qassim, Hail, Jeddah, Tabuk, Aljouf, Dammam, Almadinah and Khamis Mushayt, as shown in Figure 1.1. Even though the GSFMO operates 11 branches, only nine branches were considered in this study because two of these branches do not have mills, but only silos to store wheat used for the milling industry. Moreover, unbalanced data was only available because three of the nine branches were only established in 2008 (Almadinah, Hail, and Aljouf) with the Tabuk branch established in 1998.

Based on the annual reports, data was obtained pertaining to the number of mills, storage capacity of silos (in tonnes), amount of wheat used (in tonnes), amount of flour produced (in tonnes), number of machine operating hours (in hours), and number of man hours (in hours). Ideally, the researcher sought to achieve the data for each mill (22 mills); however, this was not possible because the data does not pertain to each mill separately, but is included in the annual reports for each branch independently. In addition, no other governmental or non-governmental body has access to the data, except the GSFMO, which is a monopoly in the Saudi Arabia.

Branch level revenues, expenses and losses data were obtained from the annual reports produced by the internal control administration, specialised in the organisation's financial statement analyses between 1990 and 2011 because these data were not accessible from 1988, as opposed to output and inputs variables which were available from 1988 to 2011. Considering the aforementioned nine branches and the 24 year period, the pooled data used in this sample provided 146 observations, which is consistent with Odeck (2007).

In this study, the inputs and output variables are described in terms of one output, the amount of flour for each branch in tonnes per year, regardless of the flour type. Flour refers to a fine, powdery foodstuff that can be produced from the grinding and sifting of wheat.

Wheat, machine hours, and man hours are the three largest inputs involved in the flour production process in this study. First, wheat (measured in tonnes each year for each branch) is considered a major cost in the flour production process as it is purchased locally and imported from abroad; however, the organisation is under state control, and thus the government provides it an annual budget as a form of support. The largest proportion of this financial support is used by the GSMFO to buy wheat from local and foreign suppliers, in return for selling flour at affordable and governmentally fixed prices for the population.

The second input is the number of machine hours per year for each branch, without taking into account certain factors, including work breaks, sudden machine breakdowns and maintenance as such data is unobtainable. The third input is man hours (administrative and machine operators) and involves the number of man hours per year for each branch. The contribution of each of these workers toward the production of flour is considered similar regardless of whether they hold managerial, administrative or machine-operating positions. However, this study uses the total number of man hours in the mills for each branch while eliminating the total man hours in the General Department of the GSFMO since these general Department man hours are not directly associated with the milling process of any individual branch. In addition, price of flour (per tonne), price of wheat (per tonne), cost of man hours (per hour) and cost of machine hours (per hour) are also used in this study as fully detailed and displayed within appendices 8-11 inclusive.

4.2.2. Primary Data

In order to complete the data collection and to confirm the results of the analysis using DEA and SFA approaches, interviews have been undertaken with managers of the above nine branches. The interviews took place with the participation of a total 13 managers, including four managers in the headquarters (Riyadh) and nine managers from the various branches. Four of the meetings involved a face-to-face interview with the General Manager of the GSFMO's headquarters. The rest of the managers were interviewed by phone because of the long distance to cover travelling from one branch to another.

Interviews with the branches managers have been conducted using a questionnaire to provide the opportunity to collect a wide array of information concerning activities in the different branches of the company. The questionnaire was carefully designed to affirm validity and accuracy when it is measured. By carefully designing the questionnaire, the data quality and the response from participants will be maintained, and bias will be reduced. Also, the quality of the response rate will be positively influenced (Williams, 2003).

The questionnaire was divided into five sections (A, B, C, D and E), with each section consisting of a group of questions related to each other. Section A captured some general information about the respondents, such as name, title (open question), educational level (open question), age (years) and the length of time in their current job (closed question: years).

Section B examined training and skills acquisition. It captured data on whether managers have received training in the milling industry (closed question: yes/no) followed by the type of courses they have attended since their recruitment, if they indeed attended any courses (open question). To highlight managers' skills, a question was also posed about whether participants have taken training after they have become managers (yes/no closed question). They were also asked about the number of courses they have taken and achieved if their answer was positive (open question). This is followed by another question on any specific type of training courses to allow the managers to clarify whether they have successfully passed the courses or not (open question). Data was also captured about the location of the courses attended with three choices of answers; inside the Kingdom, outside the Kingdom or both (closed question). This section also covers the source of information managers have gained about the milling industry (closed questions: internal experts, attracting external consultants or both) and how they interact with other branch managers, as well as the organisation's headquarters whether by visit, email, phone or all of these methods. Further questions asked about headquarter visits to GSFMO's branches in terms of whether this occurred once a week, once a month, once a year or never were included. This question led to another open question about which branch interacts most with the headquarters. Closed questions about whether the interaction between different branches to gain experience through the exchange of skills with other managers are also included. An open question allowed managers to provide reasons behind the interactions.

Section C addresses questions concerned with the milling process. Closed questions (yes/no) in this section explore issues or opportunities in the milling industry as a result of resorting to imported wheat to substitute locally produced wheat. In another closed question, managers were also asked about the difference in terms of manufacturing yield between using locally produced wheat and imported wheat. The questionnaire asked about whether the number of employees was sufficient in the branch (es) (closed question: yes/no), while further details asked respondents to specify approximately the number of workers required to fill the shortage gap in each branch. A further question captured information about whether the branch has more workforce than required and how many were needed to be laid off. The frequency of maintenance and improvement to mills were also captured via the questionnaire (closed question: monthly, every six months, or annually), together with a question about the type of machinery used in their branch (closed question, options of: mostly new, mix machine, or mostly old). The final closed question in this section was about managers' perceptions of facilities, such as roads and services in the branches and whether they were excellent, average or poor.

Section D was concerned with the profits gained and losses incurred in the mills. The first question was about profit and loss in the mills (closed question, options of: make profits or incur losses). If the organisation incurs losses, managers were asked in an open question about what they believe to be the reasons behind these losses. Another open question asked them about their suggestions to help reduce losses.

The final part (Section E) captured information about problems faced by the milling industry. Managers were asked via an open question about their point of view regarding the major problems faced by the milling industry in the branches. A further open question related to how these issues could be resolved. The interview questionnaire is attached in the appendices section (Appendix 12).

4.3. Descriptive statistics of inputs and output variables determining the production of flour in the branches of the GSFMO

The quantity of produced flour in the GSFMO's branches is determined by a variety of factors, which include the amount of wheat used in the milling industry, the actual number of machine hours in the mills and the number of man hours. Data have been collected in relation to each of the amount of flour produced, the amount of wheat used in the milling industry, the number of hours for the actual operation of the mills and number of man hours for each branch every year during the period of the study (1988-2011).

From the data contained in Table 4.1, it can be stated that the amount of flour produced for the Riyadh branch ranged from a minimum of 227,527 tonnes and a maximum of 573,501.2 tonnes, with a mean of 367,855.5 tonnes.

The amount of flour produced for the Jeddah branch varied between 426,722 tonnes and 562,179.7 tonnes. The difference between the minimum and maximum amount of flour produced was 135,457 tonnes, representing 28.37% of the mean amount of flour produced in Jeddah branch. By contrast the difference between the minimum and maximum amount of flour for Riyadh branch was 345,974 tonnes, representing

94.05% of the mean amount of flour produced in this branch. This indicates that Jeddah branch produced a similar amount of flour each year, in contrast to the other branches.

According to the data in Tables 4.1, the amount of flour produced for the Dammam branch varied between 182,433 tonnes and 287,348 tonnes, with a mean of 237,761 tonnes. Flour production in the Qassim branch ranged from a minimum of 147,534 tonnes to a maximum of 226,957 tonnes. The amount of flour for the Khamis Mushayt branch varied between 198,271 tonnes and 407,366 tonnes. In Tabuk, the amount of flour produced varied between 84,299 tonnes and 168,182 tonnes, with a mean of 139,270 tonnes. For the Almadinah branch flour production ranged from 118,546 tonnes to 156,921 tonnes; for the Hail branch production varied between 71,314 tonnes and 146,013 tonnes, while in Hail the difference in flour production was approximately 50% of mean production, Aljouf showed a much wider variation in all variables except for man hours. For instance, the amount of flour produced ranged from 4,538 tonnes to 143,345 tonnes.

The standard deviation of the quantity of flour produced ranged from 18,391 in the Almadinah branch to 129,451. Also, the amount of wheat used in the milling industry ranged from a minimum of 5,580 tonnes in the Aljouf branch to a maximum of 726,022 tonnes in the Riyadh branch. This indicates that Riyadh branch used the largest amount of wheat to produce the highest amount of flour compared to the other branches. In terms of the number of man hours in all branches, the lowest was 119,040 hours in the Tabuk branch and the highest was 917,760 hours in the Jeddah branch, while machine hours ranged from a minimum of 223 hours in the Aljouf branch to 43,358 hours in the Jeddah branch.

Regarding the number of man hours, the Jeddah branch has the highest number of man hours (917,760 hours) compared to the other branches. The data also shows that although the Jeddah branch produces less flour (562,180 tonnes) than Riyadh (573,501 tonnes), it incurs more man hours (917,760 hours) and machine hours

(43,358 hours) than its counterpart in Riyadh with 823,680 man hours and 33,999 machine hours. The data also shows that the Khamis branch produces more flour (407,366 tonnes) than the Dammam branch (287,348 tonnes) by approximately 30% despite the fact that Dammam has more machine hours (23,769 hours) than Khamis (23,053 hours). The most striking difference related to the number of machine hours in the Aljouf branch, which ranged from 223 hours to 7,049 hours, with a mean totalling 4,617 hours (Table 4.1).

Table 4.1: Descriptive statistics of inputs and output variables in all branches

Variables	Branch	Unit	Mean	Maximum	Minimum	Std. Dev.
Amount of Flour	Riyadh	Tonne	367,855.50	573,501.20	227,527.00	129,451.10
	Jeddah	Tonne	477,547.00	562,180.00	426,722.00	34,490.20
	Dammam	Tonne	237,761.00	287,348.00	182,433.00	29,902.00
	Qassim	Tonne	180,548.00	226,957.00	147,534.00	20,767.89
	Khamis Mushyat	Tonne	308,182.10	407,366.00	198,271.00	68,071.88
	Tabuk	Tonne	139,270.00	168,182.00	84,299.00	25,241.60
	AlMadinah	Tonne	145,998.40	156,921.20	118,545.70	18,390.73
	Hail	Tonne	121,003.60	146,012.80	71,314.20	33,967.98
	Aljouf	Tonne	93,689.55	143,345.10	4,537.90	61,369.22
Amount of Wheat	Riyadh	Tonne	454,515.80	726,021.80	281,566.00	160,730.10
	Jeddah	Tonne	577,132.00	690,414.00	508,482.00	47,972.87
	Dammam	Tonne	297,870.00	362,453.00	232,666.00	33,902.00
	Qassim	Tonne	220,628.00	277,154.00	177,040.80	25,899.65
	Khamis Mushyat	Tonne	399,600.40	510,243.00	251,385.00	83,134.70
	Tabuk	Tonne	167,488.00	201,818.40	105,404.00	26,821.20
	AlMadinah	Tonne	177,166.50	190,423.90	145,541.30	21,177.94
	Hail	Tonne	150,167.60	183,640.60	88,679.20	42,933.57
	Aljouf	Tonne	116,106.30	179,245.70	5,579.90	76,662.03
Man hours	Riyadh	Hour	510,480.00	823,680.00	247,680.00	191,881.70
	Jeddah	Hour	726,080.00	917,760.00	566,400.00	91,569.70
	Dammam	Hour	430,000.00	639,360.00	243,840.00	93,332.51
	Qassim	Hour	416,880.00	591,360.00	257,280.00	93,575.76
	Khamis Mushyat	Hour	396,400.00	668,160.00	211,200.00	124,864.80
	Tabuk	Hour	258,925.70	359,040.00	119,040.00	88,319.54
	AlMadinah	Hour	360,960.00	393,600.00	309,120.00	40,819.76
	Hail	Hour	383,520.00	399,360.00	353,280.00	20,937.39
	Aljouf	Hour	360,480.00	382,080.00	312,960.00	32,408.59
Machine hours	Riyadh	Hour	25,739.61	33,999.50	19,598.00	5,215.95
	Jeddah	Hour	37,849.00	43,357.70	33,582.00	2,290.36
	Dammam	Hour	20,882.60	23,769.00	14,493.10	2,506.50
	Qassim	Hour	13,662.00	15,795.00	10,674.00	1,477.23
	Khamis Mushyat	Hour	18,805.97	23,053.00	12,888.00	3,208.85
	Tabuk	Hour	7,047.80	8,352.00	4,476.00	1,177.21
	AlMadinah	Hour	6,462.62	7,553.00	3,721.00	1,832.26
	Hail	Hour	5,984.40	7,242.00	3,369.70	1,778.00
	Aljouf	Hour	4,617.37	7,049.00	223.00	3,023.53

Source: Collected and calculated using: GSFMO, Annual report (1988-2011)

4.4. Method of Analysis

Efficiency measures with the DEA method used in the present study is both CRS and VRS input- and output-orientated models. On the other hand, efficiency measures with SFA method used in the current study is based on Cobb-Douglas and Transcendental Logarithmic (Translog) production functions. Efficiency scores obtained from all methods and specifications will then be compared. DEA analysis is computed by PIM-DEA software version 3.1 and SFA analysis is performed using STATA/SE software version 12.0.

4.4.1. Data Envelopment Analysis (DEA)

Data Envelopment Analysis (DEA) is a non-parametric method in assessing efficiency that requires no assumption on the data distribution (Charnes *et al*., 1978). DEA orientations that are used in this study are both input and output orientation models to provide options for GSFMO to increase its efficiency. DEA is applied as a comparison with the efficiency results calculated from the SFA method since DEA does not need *a priori* assumption regarding the production function as is required in SFA (Cook and Zhu, 2005). The DEA models utilised in this study are input and output-orientation specification under CRS and VRS models when estimating TE as a first stage. The second stage regression involves estimating the effect variables, such as experience, age of branch managers, education level, temperature, number of mills in each branch, infrastructure and machine conditions on the GSFMO's efficiency using Tobit regression. However, when estimating CE and AE, DEA is used under input-orientated assumption since the government has fixed the price of flour to make it affordable for the population. These models are described in Chapter 2.

4.4.2. Stochastic Frontier Analysis (SFA)

Proposed by Aigner *et al.* (1977) and Meeusen and van den Broeck (1977) stochastic frontier analysis is concerned with parametric empirical estimation of efficiency frontier by taking into account any measurement errors and other sources of statistical noises that may arise in the estimation of the stochastic element. This results in a frontier known as the stochastic production frontier (Coelli *et al.,* 2005). More specifically, it can be computed using this method where any deviations from the frontier may not only be caused by inefficiency but also due to the noise in the data (Bogetoft and Otto, 2011).

With regard to the above benefit, SFA is used in this study since it can separate the inefficiency, which in turn will reflect TE, from the statistical noise; whereas in DEA all deviations from efficient frontier is regarded as caused by inefficiency. Building on the SFA theoretical framework introduced in chapter 2, this subsection discusses the functional form adopted in this study. There are many functional forms to estimate the physical relationships between input and output data. The Cobb-Douglas functional form offers simplicity and is popular in empirical work (Miller, 2008); thus, it is used in this study. The model is written as follows:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{3} \beta_1 \, ln \, x_{it} + \beta_2 \, ln \, x_{it} + \beta_3 \, ln \, x_{it} \; + v_{it} - u_{it} \qquad (23)$$

Where Y_{it} (amount of flour) is the output of branch i at time t, X_{it} (amount of wheat, machine hours and man hours) is the used inputs of branch i at time t, i equals 1, 2,...N, β is an unknown parameter vector to be estimated, v_{it} is the familiar disturbance term representing statistical error and u_{it} is a non-negative random variable representing technical inefficiency.

Another popular functional form is the transcendental logarithmic (Translog) production function which is widely used because it is more general and flexible than the Cobb-Douglas since it allows more varying returns to scale (Odhiambo *et al.,* 2004). Given this, Translog function is also used in this study as a comparison to the Cobb-Douglas function.

The Translog functional form for the stochastic frontier production function can be specified as follows:

$$\ln Y_{it} = \beta_0 + \sum_{k=1}^{3} \beta_k \ln X_{kit} + \frac{1}{2} \sum_{k=1}^{3} \sum_{j=1}^{3} \beta_{kj} \ln X_{kit} X_{jit} + v_{it} - u_{it} \quad (24)$$

Where $\ln$ denotes natural logarithms, Yit represents amount of flour for the i-th branch in the t-th year. Xit represents inputs variables which $X1$ is amount of wheat per tonne each year, $X2$ is machines hours per hour each year, $X3$ is man hours per hour each year, t the linear time trend (1988=1,…, 2011=24) and β are parameters to be estimated.

4.4.3. Total factor productivity growth (TFPG)

In this study, TFPG is calculated using DEA and SFA as explained in chapter 2. For the DEA technique, the MI was employed for the period of four years, since MI requires the data calculated to be balanced. Balanced data used in this study is only available for four years from 2008 to 2011 because three out of the nine branches were only established in 2008. Furthermore, due to the small sample size restrictions under DEA, this study considered the SFA technique for 24 years (1988-2011) in order to estimate the TFPG.

4.5. Summary

This chapter examined the data collection adopted in the study; namely secondary and primary data. Secondary data pertains to the data collected from the annual reports published by the GSFMO from 1998 to 2011. As for primary data, it was centred on interviews with branch managers of the GSFMO. With respect to secondary data in this study, three inputs and one output were used. The inputs included amount of wheat used in tonnes, man hours (hours), and machine hours (hours) for each branch per year, while the output variable was the amount of flour for each branch in tonnes per year. Also used are the price of flour, price of wheat, cost of man hours, and cost of machine hours to estimate CE and AE in the organisation. Next, a statistical description of inputs and output variables was undertaken to determine the production of flour in the branches of the GSFMO.

It should be noted that the Jeddah branch produced a similar amount of flour each year, in contrast to the other branches. In terms of the number of man hours in all branches, the highest was also identified in Jeddah branch, while Tabuk had the lowest. In addition, regarding machine hours, the Jeddah branch ranked highest, with Aljouf lowest. On the other hand, Riyadh branch used the largest amount of wheat to produce the highest amount of flour compared to the other branches.

To estimate efficiency and productivity growth of GSFMO, two methods of analysis will be used; namely DEA and SFA. As shown in this chapter, the DEA approach is used to measure TE, CE and AE under CRS and VRS input and output orientated. Also in this chapter, the SFA method, which is based on Cobb-Douglas and Translog production functions, was used to estimate TE for which the mathematical formulation of these production functions is provided in this chapter. Both DEA and SFA were used to estimate productivity growth for the GSFMO.

The methods discussed in this chapter will be used to estimate TE, CE, AE and productivity growth. The findings achieved through these methods will be analysed in the following chapter which pertains to results.

5. RESULTS CHAPTER

5.1. Introduction

This chapter presents the TE as a first stage; then, it outlines the second stage regression and productivity growth results for all branches of the GSFMO in six sections. Section one illustrates the TE results using DEA and contains two sub-sections covering the mean TE results for all branches and TE scores under CRS and VRS-input and output orientated assumptions for each branch separately during the study period (1988-2011). Section two is concerned with TE results attained using the Pooled SFA model under Cobb-Douglas and Translog Production Functions. This model uses both exponential distribution and half-normal distribution estimation assumptions.

The chapter presents the second stage regression results for all branches in section three, for the years between 2008 and 2011, to estimate the effect of efficiency explanatory variables on TE level such as branch manager's age, experience, temperature in branch locations, number of mills in each branch, machine and infrastructure condition. The next section discusses the mean CE and AE results under CRS and VRS input-orientated assumption for all branches, as well as the CE and AE results under CRS and VRS input-orientated assumption.

Section five explores the productivity growth results for all branches using DEA. It presents the mean TFPG, TC and EC for the period between 2008 and 2011. Additionally, it shows the TFPG, TC, and EC for all branches in three periods, which span from 2008 to 2009; 2009 to 2010; and 2010 to 2011. Finally, the chapter concludes by discussing the productivity growth results for all branches using SFA during the study period (1988-2011).

5.2. Technical Efficiency (TE) Results using DEA

5.2.1. Mean TE for all branches (1988-2011)

Prior to the presentation of new TE results for the branches, it is important to comment on the interpretations of TE results at the outset from efficiency estimation techniques. Within TE literature results are presented given an assumption that inputs can be linearly increased or decreased either as a bundle of inputs to reduce technical inefficiency or individual inputs in order to improve efficiency. However, in reality, the use of inputs are often considered jointly, and therefore, we need to bear in mind that when we commenting upon the potential improvements to efficiency from the results generated, these are effectively partial results as we need to consider results as a whole when it comes to providing recommendations. However, the estimation technique does provide us with results as presented below. We will come back to considering the recommendations flowing from these results in a later chapter.

As a first stage, TE under CRS and VRS input and output-orientated was estimated. A review of the data contained in Table 5.1 shows that under CRS, both input- and output-orientated findings are equal in all branches (Thanassoulis, 2001). Under CRS, mean TE ranged between a minimum of 91.72% in the Khamis Mushayt branch and a maximum of 97.63% in the Almadinah branch. The Almadinah branch can increase output by 2.37% without having to increase inputs or reduce the inputs by the same rate (2.37%) to produce the current output level achieved. By contrast, the Khamis Mushayt branch, which is ranked last, has a mean TE of 91.72%, indicating greater scope for output expansion or inputs reduction.

Under input-orientated variable return to scale (VRS), mean TE for the various branches of the GSFMO ranged from 93.16% in the Dammam branch to 98.77% for the Jeddah branch. In addition, under output-orientated VRS, mean TE for the various branches of the GSFMO ranged from 93.21% in the Dammam branch up to 98.79% for the Jeddah branch.

Table 5.1 shows that TE under input-orientated VRS is estimated to be lower than TE under output-orientated VRS, with the exception of the Aljouf branch. Similarly, the Tabuk branch has an equal TE estimate under both input- and output-orientated VRS. Thus in general, it can also be seen that TE under VRS is estimated to be greater than TE estimated under CRS. Finally, mean TE in all branches did not fall below 91% as shown in Figure 5.1.

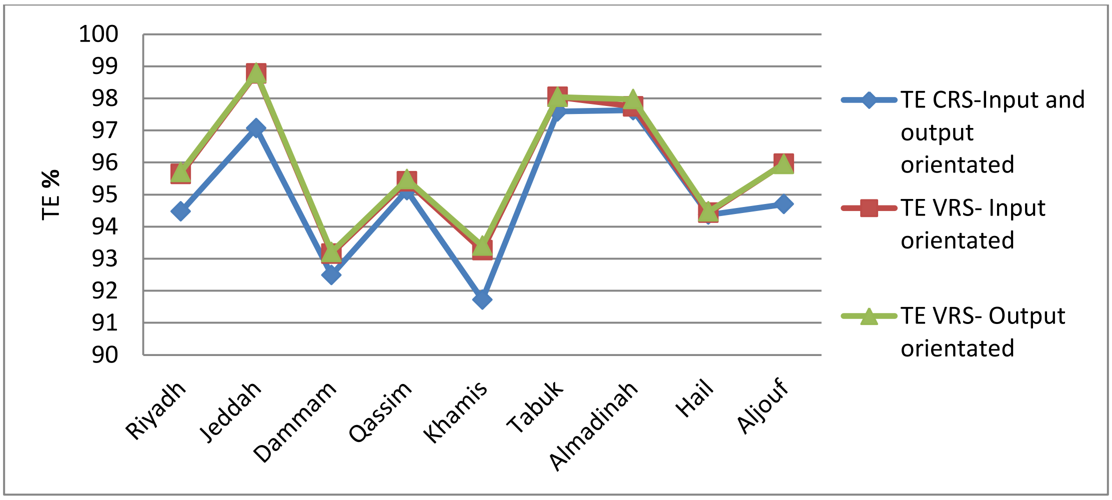

Figure 5.1: Mean TE of all branches under CRS and VRS (1988-2011)

Table 5.1: Mean TE for all branches (1988-2011)

DMUs	Technical Efficiency(TE) CRS-Input and output orientated	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Riyadh	94.47	95.64	95.7
Jeddah	97.07	98.77	98.79
Dammam	92.49	93.16	93.21
Qassim	95.13	95.41	95.48
Khamis	91.72	93.26	93.4
Tabuk	97.59	98.04	98.04
Almadinah	97.63	97.75	97.97
Hail	94.37	94.43	94.47
Aljouf	94.7	95.96	95.95

5.2.2. TE under CRS and VRS-input and output orientated for all branches

While the above results provided the mean TE for all branches, this does not show the full range of TE estimates for all years and branches. TE for all branches in every year was estimated to find the lowest and highest TE scores. Focusing on TE under CRS in the Riyadh branch (Figure 5.2 and Appendix 13), TE is estimated to have varied between a minimum of 91.44% in 1991 to 100% in both 2004 and 2005. However, there was generally an improvement in the TE of the Riyadh branch under CRS over time, which has increased from 92.95% in 1988 to 100% in 2004 and 2005; this was then followed by a decrease to 94.01% later in 2011. Under VRS-input orientated, TE in the Riyadh branch ranged from 91.56% in 1991 to 100% in 2004, 2005, 2009, 2010, and 2011. Above all, there has been an improvement in the TE in the Riyadh branch under input-orientated VRS, increasing from 93.38% during 1988 to 100% during 2004, 2005, 2009, 2010 and 2011; these latter years contrast with the results presented for TE estimated under CRS. TE for Riyadh under VRS-output orientated assumption ranged between a 91.7% in 1991 to a 100% during the years 2004, 2005, 2009 and 2011. There are variations in TE results across years; however, the results indicate both efficiency change occurring over time, but that uncertainty in the production process exists as shown by the large reductions in efficiency estimates in some years, such as 2006, 2007, and 2008. Whilst we are observing variations in efficiency, we are also observing uncertainty in what the estimates are likely to be from year to year. There is also variation and uncertainty from the results, as demonstrated, and the results will be explored further via finding from the second stage regression analysis. These findings will then inform appropriate recommendations that can be made given the variation and uncertainty in results.

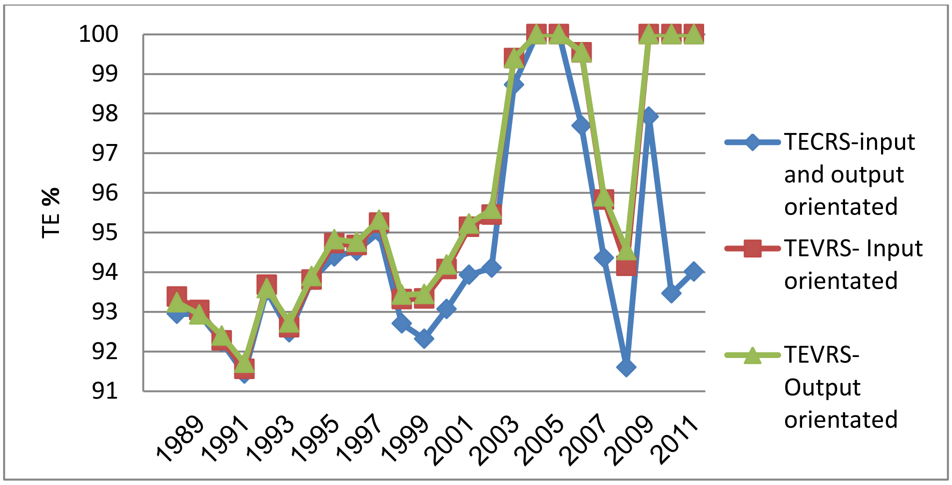

Figure 5.2: TE of the Riyadh branch under CRS and VRS (1988-2011)

TE estimated under CRS in the Jeddah branch has shown almost identical results to Riyadh, with estimations ranging between 90.26% in 2008 and 99.07% in 2003 (Figure 5.3 and Appendix 14); TE estimate of the Jeddah branch under CRS declined considerably to 92.14% in 2011. The study of TE in the Jeddah branch shows a clear variation under input-orientated VRS with a minimum of 91.83% in 2008 to 100% during the years 1989, 2003, and 2007. As a result, the TE in the Jeddah branch declined under input-orientated VRS from 99.88% in 1988 to 94.74% in 2011, unlike the Riyadh branch where there was an increase in some years. Contrary to the estimation of TE in the Jeddah branch under output-orientated VRS, TE varied between a minimum of 91.98% in 2008 and maximum of 100% during the years 1989, 2003, and 2007 (Figure 5.3 and Appendix 14). The results in Jeddah also demonstrate uncertainty in the years 2006, 2007, and 2008.

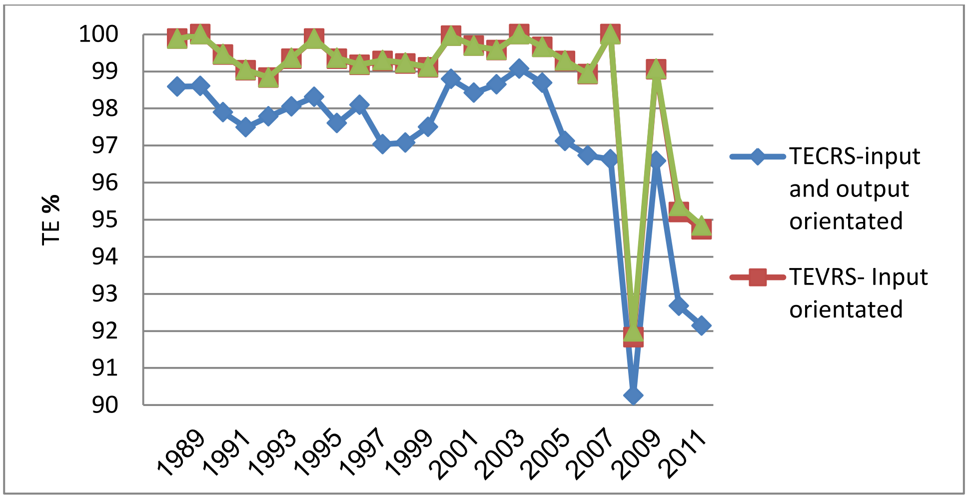

Figure 5.3: TE of the Jeddah branch under CRS and VRS (1988-2011)

Compared to other branches operating over the long term (24 years), Dammam, Qassim, and Khamis have shown substantial inefficiency. For example, under CRS, TE in the Dammam branch ranged between a low of 89.42% in 2008 and a maximum of 96.6% in 2006 (Figure 5.4 and Appendix 15); the Dammam branch's TE under CRS has witnessed a decrease from 93.9% in 1988 to 91.73% in 2011. An examination of the data displayed in Appendix 15 regarding TE under VRS-input orientated in the Dammam branch clearly reveals that TE under VRS was at its lowest with 90.15% in 2008, while it achieved a maximum TE with 97.41% in 2009. On the whole, TE under input-orientated VRS in the Dammam branch did witness a fluctuating trend during the period of study. Examining TE in the Dammam branch (Figure 5.4 and Appendix 15), it reached its lowest in 2008 with 90.3% and the highest point in 2006 with 97.64%. The results in Dammam also reflect the uncertainty and variation seen in Riyadh.

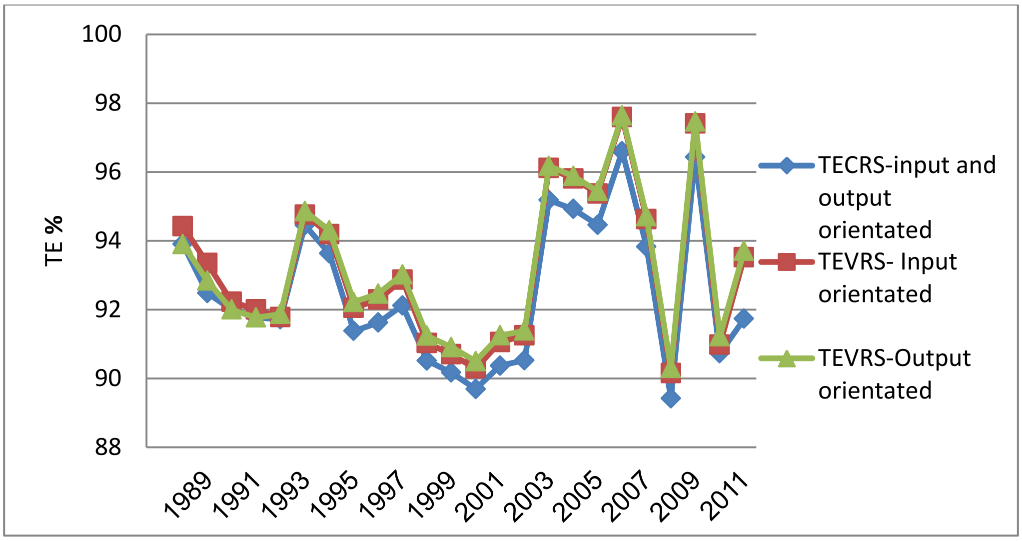

Figure 5.4: TE of the Dammam branch under CRS and VRS (1988-2011)

The case of the Qassim branch is also important in this context being another long term operating branch, with TE ranging from 82.66% in 2008 to 98.72% in 1998 (Figure 5.5 and Appendix 16). Overall, TE under CRS in the Qassim branch has witnessed a noticeable decline from 97.91% in 1988 to 90.87% in 2011. Regarding the lowest branches in terms of TE under VRS-input orientated, the Qassim branch had a minimum of 82.66% in 2008, which was similar to TE under CRS, to a high of 99.66% in 1988 (Figure 5.5 and Appendix 16). This means that TE in the Qassim branch under input-orientated VRS experienced a decline from 99.66% in 1988 to 91.03% in 2011. On the other hand, TE under output-orientated in the Qassim branch was comparatively lower, varying between 83.07% in 2008 and 99.62% in 1988. TE in the Qassim branch experienced a dramatic decrease from 97.11% in 2006 to 83.07% in 2008 (Figure 5.5 and Appendix 16). This also exists in 2007 and 2008, as observed previously in other results.

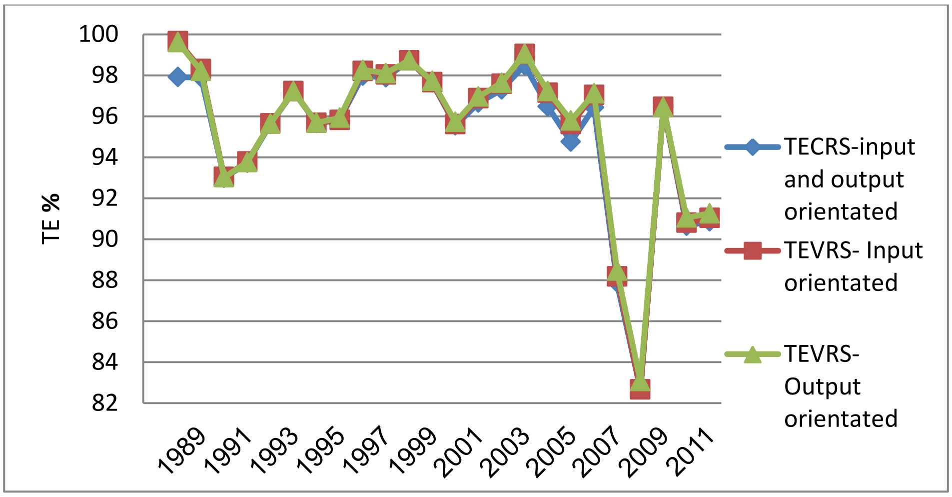

Figure 5.5: TE of the Qassim branch under CRS and VRS (1988-2011)

Alongside the Dammam and Qassim branches, the Khamis branch, which is one of the longest operating branches, had a TE under CRS that stood at 84.63% as a minimum in 2000 and 99.29% as a maximum in 2006 (Figure 5.6 and Appendix 17). In sum, under CRS, the TE of the Khamis Mushayt branch decreased from 93.33% in 1988 to 90.47% in 2011, as has been witnessed in the case for the Qassim branch. The Khamis branch was second to the Qassim branch in terms of the lowest TE under VRS-input orientated. It was 85.18% in 2000, and a high of 100% in 2005 and 2006 (Figure 5.6 and Appendix 17). As in the case of the Dammam branch, there seems to be a fluctuating trend for TE scores. The Khamis branch was also shown as one of the lowest in terms of TE; however, its TE was still higher than the Qassim branch, ranging between a minimum of 85.56% in 2000 and a maximum TE of 100% in 2005 and 2006 (Figure 5.6 and Appendix 17). Unlike the Qassim branch, however, there has been an improvement in the TE of the Khamis Mushayt branch under output-orientated VRS within the last few years. This reflects the variation and uncertainty as shown in the other branches.

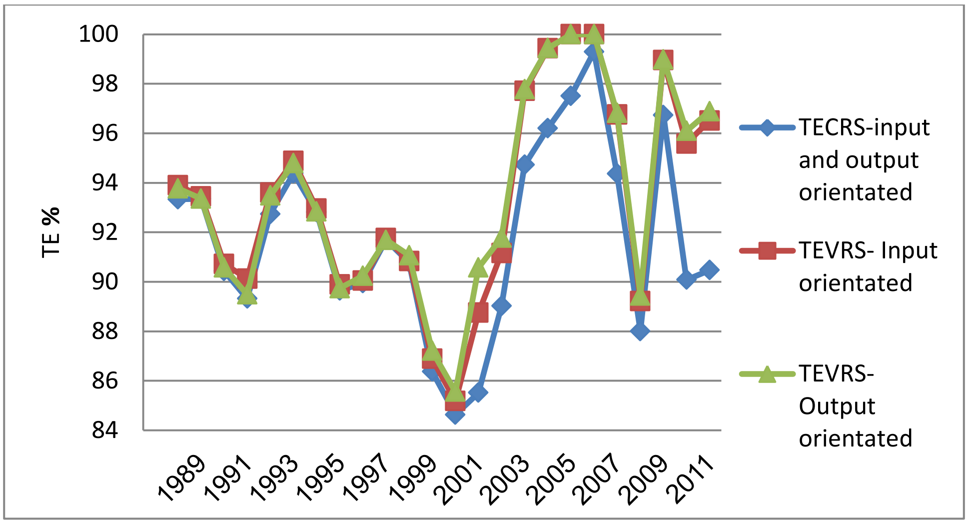

Figure 5.6: TE of the Khamis branch under CRS and VRS (1988-2011)

TE under CRS in the Tabuk branch, as the only branch operating medium term (13 years), was estimated between a minimum of 93.6% in 2008 and a maximum of 100% during the years 1999, 2004, 2005, and 2007 (Figure 5.7 and Appendix 18). Under CRS, there was generally an improvement in the TE of the branch, showing an increase from 95.42% in 1998 to 100% during the years 1999, 2004, 2005, and 2007, followed by a drop to 93.76% in 2011. On the other hand, TE in the Tabuk branch ranged from a minimum of 93.77% in 2008 to a maximum of 100% during the years 1998, 1999, 2004, 2005, and 2007, which indicates a similar trend to that in the Riyadh branch with the highest number of years during which the branch reached a 100% of efficiency. As the only branch operating medium term, TE under VRS-output orientated in the Tabuk branch has shown almost identical findings to those under CRS, except in 1995 when TE under CRS was 95.42% and under VRS was 100%. As in other branches, there appears to be some variation and uncertainty levels in the Tabuk branch.

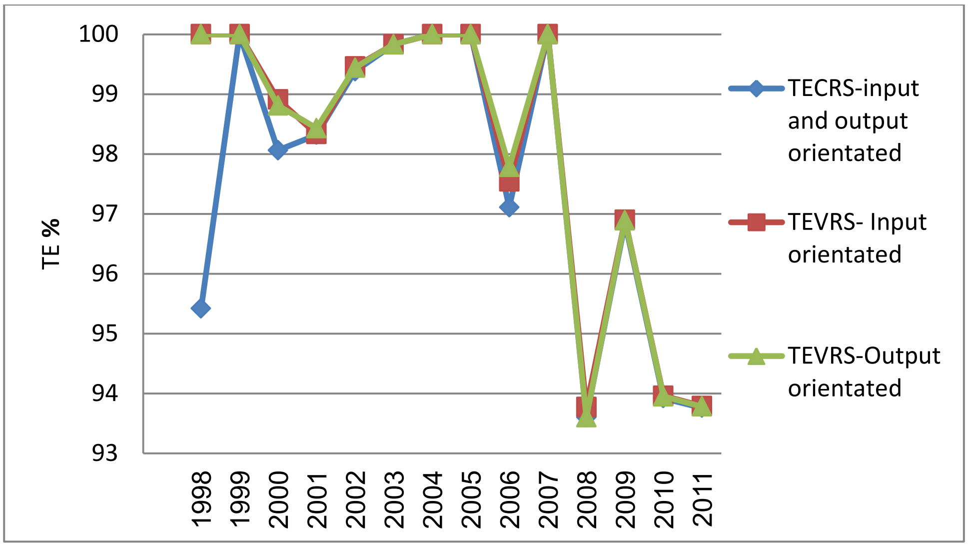

Figure 5.7: TE of the Tabuk branch under CRS and VRS (1988-2011)

Regarding short term operating branches; namely Almadinah, Hail, and Aljouf, which started operating in 2008, the four year study (2008-2011) showed that Hail had the lowest TE, which ranged from as low as 92.89% in 2010 to 96.86% in 2009 (Figures 5.8-5.10 and Appendix 18). Generally, TE under CRS declined from 94.63% in 2008 to 93.11% in 2011. Following the Aljouf branch, the data provided in the same table regarding TE under CRS clearly shows that TE ranged between a minimum of 92.94% in 2010 and a maximum of 97.08% in 2009 compared to Hail and Aljouf branches. However, Almadinah branch achieved 100% TE in 2008, and had a minimum of 96.28% in 2010.

Focusing on the branches operating over the short term, the study of TE under VRS-input orientated in Almadinah, Aljouf and Hail branches presents similar trends to that under CRS. As indicated earlier in the case of TE under CRS, the Hail branch also had the lowest TE with a minimum of 92.91% in 2010 and a maximum of 96.89% in 2009 (Figures 5.8-5.10 and Appendix 18).

Further, TE in the Aljouf branch ranged between 92.98% in 2010 and 100% in 2008. Under input-orientated VRS, there was generally a decrease in the TE of the branch from a total of 100% in 2008 to 93.7% in 2011 (Figures 5.8-5.10 and Appendix 18). TE under input-orientated VRS in the Almadinah branch varied from a minimum of 96.29% in 2010 to a maximum of 100% in 2008.

The findings for TE under VRS-output orientated in Almadinah, Hail, and Aljouf branches were similar to the results of TE under VRS-input orientated, with one exception in the output orientated where the branches have to increase the amount of output using the same inputs. Lastly, TE under VRS was shown to perform better than its counterpart under CRS during the period of study for all branches. After exploring TE results using DEA in this previous section, the following section presents TE results using SFA.

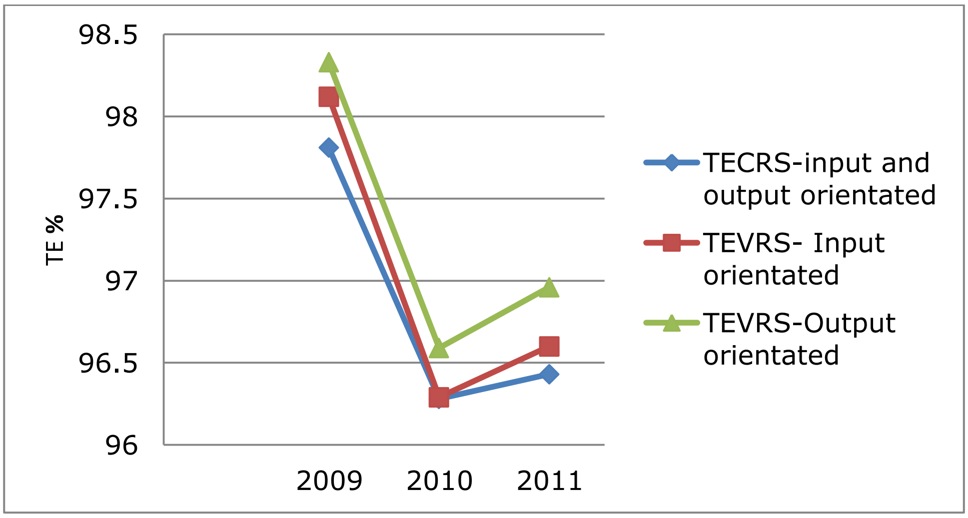

Figure 5.8: TE of the Almadinah branch under CRS and VRS (1988-2011)

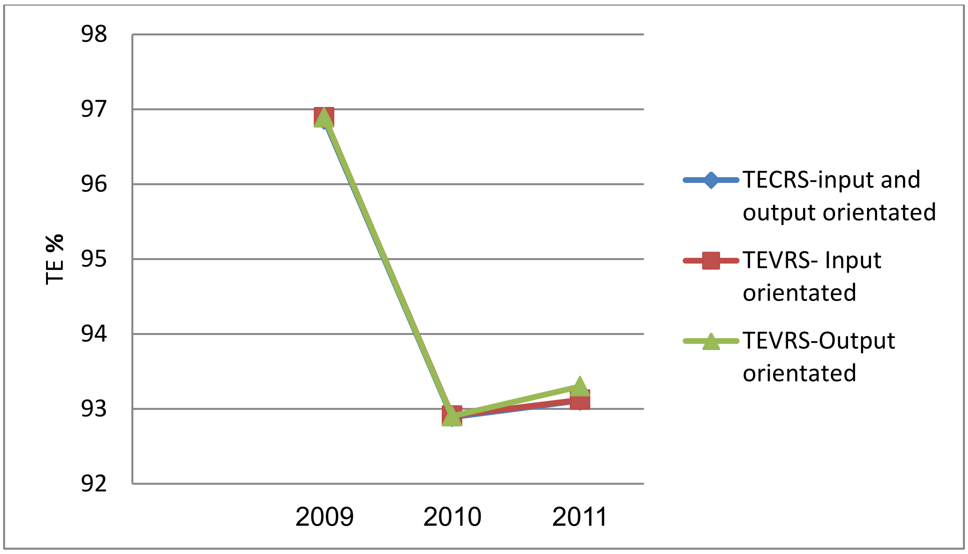

Figure 5.9: TE of the Hail branch under CRS and VRS (1988-2011)

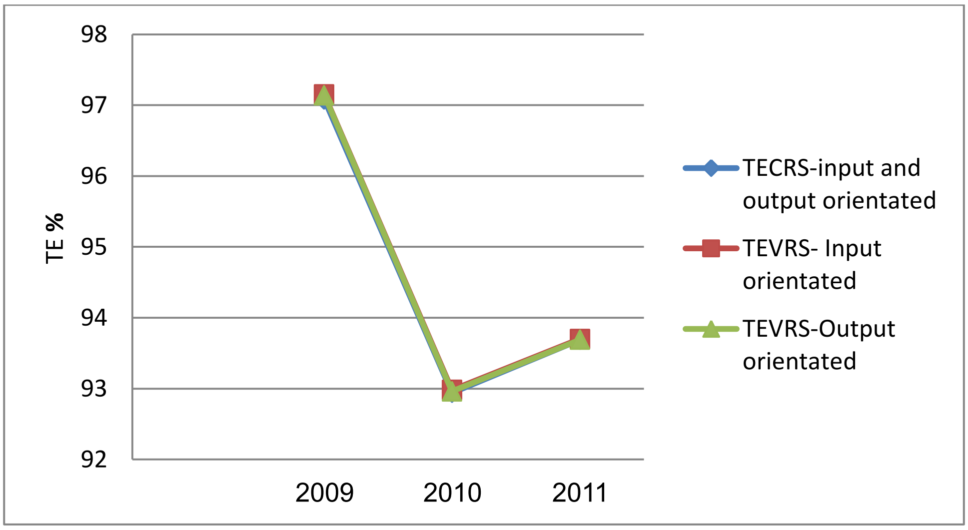

Figure 5.10: TE of the Aljouf branch under CRS and VRS (1988-2011)

5.3. Results of Technical Efficiency (TE) using SFA

5.3.1. SFA Analysis

The results from the DEA analysis indicated considerable variation and uncertainty in efficiency estimates from year to year. One of the reasons for this may have to do with stochastic issues in the production process, such as variation in temperature.

SFA analysis is a technique designed to cope with stochastic factors influencing the production process.

SFA analysis performed in this study calculates efficiency using a pooled SFA method with both Cobb-Douglas and Translog production functions. In estimating inefficiency in pooled SFA, the study utilises both exponential and half-normal distribution assumptions. On each method, Jump Markov Linear System (JMLS) and Battese-Coelli (BC) estimators are used to estimate TE. The TE results from all methods and all distributions are compared and analysed. Nevertheless, before SFA is calculated, the parsimonious model of Cobb-Douglas and Translog production functions for the dataset are constructed by utilising three important statistical diagnostic tests of Breusch-Pagan test for heteroskedasticity, Variable Inflation Factor (VIF) test for multicollinearity and Ramsey RESET test for misspecification in order to identify the robust model.

5.3.2. Cobb-Douglas Production Function

For this production function, the model tested was as follows:

$$\ln F_i = A_i + \beta_1 \ln Wh_i + \beta_2 \ln Mh_i + \beta_3 \ln M_i + t_i \qquad (25)$$

Where subscript i is the individual grain and flour mills so $\ln F_i$ is the natural logarithm of the amount of flour, $\ln Wh_i$ is the natural logarithm of the amount of wheat, $\ln Mh_i$ is the natural logarithm of the number of man-hours, $\ln M_i$ is the natural logarithm of the number of machine hours and t_i is time for a particular grain and flour mill i. Time is included in this model by codifying it as 1 = 1988 until 24 = 2011.

It is found that t is insignificant; however, after removing t to build a parsimonious model, as suggested by Anderson *et al.* (2010), the parsimonious model is found to be:

$$\ln F_i = A_i + \beta_1 \ln Wh_i + \beta_2 \ln Mh_i + \beta_3 \ln M_i \qquad (26)$$

As can be seen from Table 5.2 below under Cobb-Douglas estimation, $\ln Wh_i$ is significant at 99.99% confidence interval, $\ln Mh_i$ is significant at 95% confidence interval and $\ln M_i$ is significant at 90% confidence interval.

Table 5.2: Production Function Regression Coefficients

	Cobb-Douglas	Translog
R^2 Adjusted R^2	0.9959 0.9958	0.9970 0.9968
A	-0.2419** (p=0.045)	-5.8819 (p=0.525)
LnWh	0.9618* (p=0.000)	2.0539** (p=0.005)
LnMh	0.0217** (p=0.044)	2.2446** (p=0.001)
LnM	0.0233*** (p=0.093)	-3.1576* (p=0.000)
$LnWh^2$		-0.0845 (p=0.646)
$LnMh^2$		-0.3045* (p=0.465)
LnM^2	-	-0.08321 (p=0.000)
LnWhLnMh	-	-0.0549 (p=0.446)
LnWhLnM	-	0.0647 (p=0.645)
LnMhLnM	-	0.2480* (p=0.000)
t	-	0.0006 (p=0.347)
F	11443.99* (p=0.000)	4504.09* (p=0.000)

From diagnostic tests in Table 5.3, it was found that the Cobb-Douglas model passed the Breusch-Pagan test for heteroskedasticity. The result of this test shows a probability of more than 0.05 so that the H_0 model, which has constant variances, is accepted. The Variable Inflation Factor (VIF) test shows that variables in the model do not have severe multicollinearity since there are no VIF values above 10, which means independent variables in the model are not closely correlated with each other so the influence of each independent variable to the dependent variable can be observed. However, the model failed the Ramsey RESET test for misspecification, which shows whether the model excludes independent variables that can explain changes in the dependent variable. The probability resulting from this test is less than 0.05, which means that the H_0 model which has no omitted variables, is rejected. However, on the basis that these data are the best data available, then Cobb-Douglas function can be used, but with a note made on misspecification.

Table 5.3: Diagnostic Tests for Cobb-Douglas Model

Diagnostic Tests	Diagnose	Testing for	Results
Breusch-Pagan	Heteroskedasticity	H_0 = Constant variances	Prob > Chi2 = 0.7377
Ramsey RESET Test	Misspecification	H_0 = model has no omitted variables	Prob > F = 0.0011
Variable Inflation Factor	Multicollinearity	Ln Wh LnM LnMh	VIF= 9.36 VIF= 8.94 VIF=1.85

5.3.3. Translog Production Function

The initial Translog production function specification tested was as follows:

$$\ln F_i = A_i + \beta_1 \ln Wh_i + \beta_2 \ln Mh_i + \beta_3 \ln M_i + 0.5\beta_{11} (\ln Wh_i)^2 + 0.5\beta_{22} (\ln Mh_i)^2 + 0.5\beta_{33} (\ln M_i)^2 + \beta_{12} \ln Wh_i \ln Mh_i + \beta_{13} \ln Wh_i \ln M_i + \beta_{23} \ln Mh_i \ln M_i + t_i \qquad (27)$$

Where $\ln Wh_i \ln M_i$ is the interaction or cross product of variable $\ln Wh_i$ and $\ln Mh_i$ from previous function, $\ln Wh_i \ln M_i$ is the interaction or cross product of variable $\ln Wh_i$ and $\ln M_i$; whilst $\ln Mh_i \ln M_i$ is the interaction or cross product of variable $\ln Mh_i$ and $\ln M_i$.

Regression results of this model, which are presented in Table 5.2, show that $(\ln Wh_i)^2$, $(\ln M_i)^2$, $\ln Wh_i \ln Mh_i$, $\ln Wh_i \ln M_i$, and t are not significant. However, since Translog production function requires all these variables to be included to retain its theoretical properties and form, these insignificant variables are retained in model. All other independent variables are significant at the 99.99% confidence interval, except for $\ln Wh_i$ which is significant at 95% confidence interval.

Table 5.4: Diagnostic Tests Result – Translog Production Function

Diagnostic Tests	Diagnose	Testing for	Results
Breusch-Pagan	Heteroskedasticity	H_0 = Constant variances	Prob > Chi2 = 0.6136
Ramsey RESET Test	Misspecification	H_0 = model has no omitted variables	Prob > F = 0.2481
Variable Inflation Factor	Multicollinearity	lnWhlnM	VIF= 459551.75
		$lnWh^2$	VIF= 219448.33
		lnWhlnMh	VIF= 91242.31
		lnMhlnM	VIF= 85380.16
		lnM^2	VIF= 65663.28
		lnM	VIF= 28321.66
		lnWh	VIF= 23813.99
		$lnMh^2$	VIF=18211.92
		lnMh	VIF= 8999.34
		t	VIF= 2.84
			Mean VIF=100063.56

Diagnostic tests in Table 5.4 show that the Translog model also passed the Breusch-Pagan test for heteroskedasticity and the Ramsey RESET test for misspecification since the probabilities for these tests are larger than 0.05 so that H_0 in these tests are accepted. However the Translog model has an issue with multicollinearity in the VIF test. However, this is expected since there are second order effects and interactions in the Translog which are naturally correlated. Nevertheless, since the VIF mean is very high, while the data are the best available, this model can still be used for pooled SFA but with a note made on the presence of multicollinearity. Since this model passed the Ramsey RESET test, this means that the model can explain the relationship between independent and dependent variables. It also means that the model is not misspecified.

5.3.4. Pooled SFA

5.3.4.1. Pooled SFA using Cobb-Douglas

Since the data observed is multiyear data, the SFA model used in the study is pooled SFA. Initially, the pooled SFA model is used with the Cobb-Douglas production function. The steps undertaken in utilising this model are as follows:

1. Generate residuals from the parsimonious Cobb-Douglas function constructed before,
   $\ln F_i = A_i + \beta_1 \ln Wh_i + \beta_2 \ln Mh_i + \beta_3 \ln M_i$, using "predict YYYY, r" function on STATA where YYYY is any name assigned to the residuals from a model. In this study, the name "res" is assigned to the Residuals generated from the above Cobb-Douglas function.
2. Observe the skewness of the data from the summary residuals. Since the model is a production function, the skewness needed is negative skewness (since the error term will be $u_j - v_j$). From the summary residuals of the above function, it can be observed that there is a negative skewness of -0.6043 in this model. However, because the skewness was low, the result of this skewness had to be tested by using the skewness test for Normality.
   If probability for skewness in the Skewness test for normality test is greater than 0.05, H_0 (that the distribution is normal) is accepted and the skewness is insignificant. However, the result of the normality test shows that probability for skewness is 0.0036; hence H_0 is rejected, which means the skewness in the model is significant, the distribution is non-normal and skewed to the left. As pooled SFA requires the production function to have negative skewness, then this model is valid and can be used for pooled SFA methodology.
3. The distribution graph is then observed to confirm the result. In Figure 5.11, it can be seen that the distribution of the data is not normal and skewed to the left (negatively skewed) so the model is valid to be used for pooled SFA.

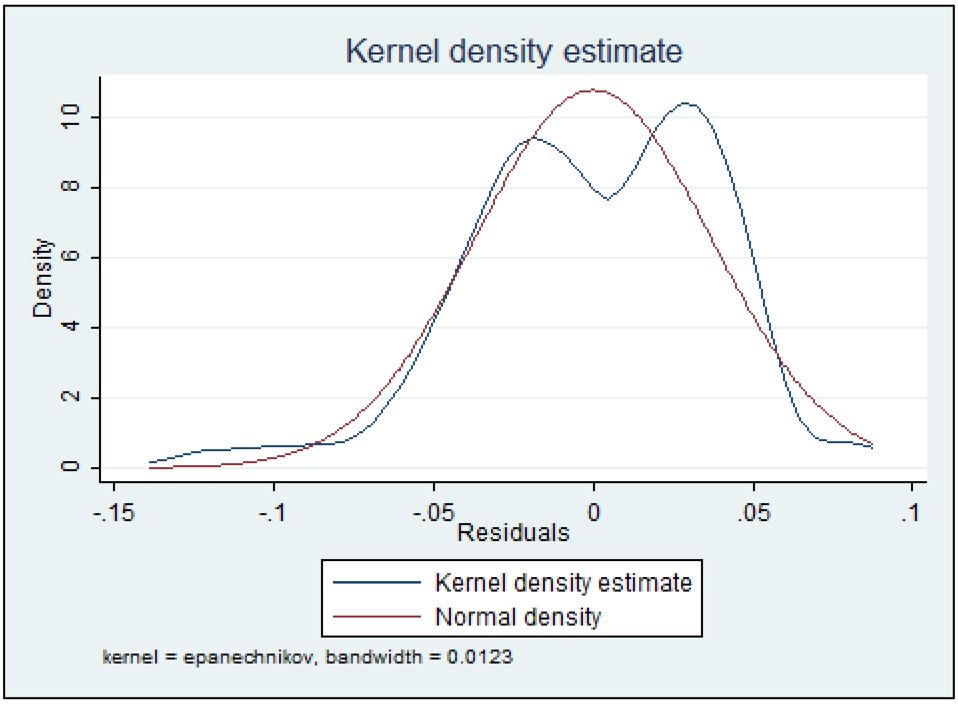

Figure 5.11: Cobb-Douglas Distribution Compared to Normal Distribution

In order to estimate error terms (inefficiency and noise) in pooled SFA, two assumptions of exponential distribution and half-normal distribution are used.

5.3.4.1.1. Pooled SFA with Cobb-Douglas function using exponential distribution

Assuming the inefficiency follows an exponential distribution, the result for frontier estimation is presented in Table 5.5. From the original model, lnM parameter is statistically insignificant; thus eliminated from the model using general to specific iteration as in Anderson *et al*. (2010). First of all, H_0 from the Likelihood-ratio test of σ_u (that σ_u = 0) is rejected (p = 0.001), showing that the model demonstrates inefficiency. By removing lnM from the model, all variables are now significant; lnWh is significant under 99.99% confidence interval, while lnMh is significant under 95% confidence interval.

Table 5.5: Summary of Pooled SFA – Cobb-Douglas Production Function

	Cobb-Douglas	
	Model I Exponential	Model II Half-Normal
Wald Chi^2	38751.16 (p=0.000)	38450.98 (p=0.000)
A	-0.3405* (p=0.000)	-0.2419* (p=0.010)
LnWh	0.9899* (p=0.000)	0.9871* (p=0.000)
LnMh	0.0218** (p=0.034)	0.01835*** (p=0.094)
σ_v	0.0249	0.0126
σ_u	0.0284	0.0596
Log Likelihood	278.0509	280.4192
Likelihood-ratio test of σ_u =0	10.64 (p=0.001)	15.38 (p=0.000)

Second, JMLS estimator is used to estimate inefficiency for exponential distribution using STATA software. To estimate TE for exponential distribution, Batesse-Coelli (BC) estimator is used as alternative. In comparison to JMLS, BC estimator is calculated directly into TE using STATA software. The summary of TE from JMLS and BC estimators is presented in Table 5.6.

Table 5.6: Summary of TE for Pooled SFA Cobb-Douglas - Exponential Distribution

Tehnical Efficiency	Observation	Mean	Std Deviation	Min	Max
TE using JMLS estimator	146	0.9722	0.0209	0.8745	0.9921
TE using BC estimator	146	0.9724	0.0209	0.8748	0.9921

From the summary above, efficiency estimates resulting from BC and JMLS estimators are very similar for all units as shown in Figures (5.12 and 5.13) and appendices (19 and 20).

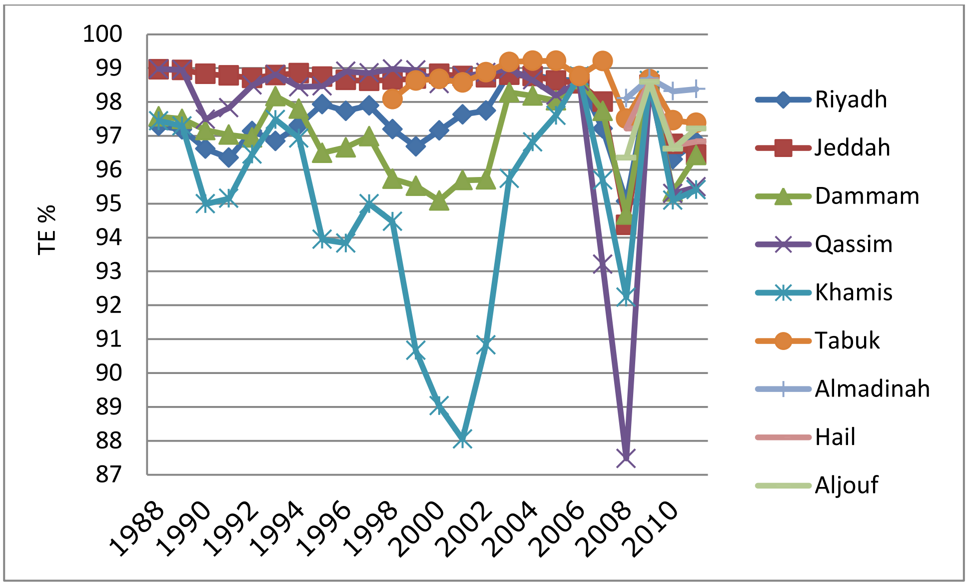

Figure 5.12: TE of all branches using SFA Cobb-Douglas under Exponential distribution BC estimator

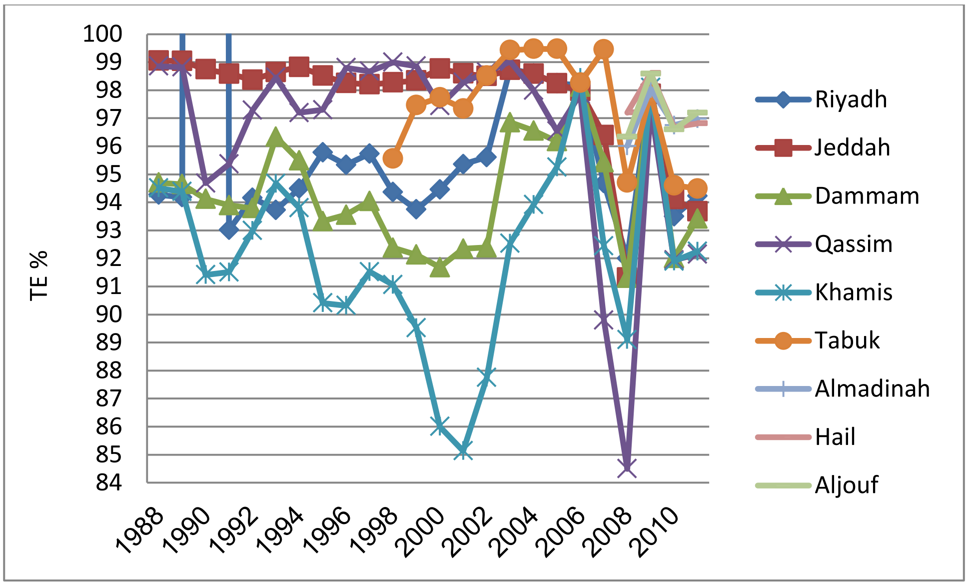

Figure 5.13: TE of all branches using SFA Cobb-Douglas under Exponential Distribution JMLS estimator

5.3.4.1.2. Pooled SFA with Cobb-Douglas function using half-normal distribution

Assuming that inefficiency follows a half-normal distribution, the result of regression analysis for frontier estimation without lnM is presented in Table 5.5. From the original model, it is found that lnM is statistically insignificant and that it is removed using general to specific method as in exponential model. The H_0 from the Likelihood-ratio test of σ_u for this model is also rejected (p=0.000), which means that the model explains variance in inefficiency. All variables are also significant in this model; thus lnWh is significant at 99.99% confidence interval, while lnMh is significant at 90% confidence interval.

The next step involves calculating TE under half-normal distribution using JMLS and BC estimators as in exponential distribution going through the same process as before.

As in TE from the exponential distribution, TE values calculated from these estimators are also very similar (Table 5.7). The complete list of TE values for all units for Pooled SFA Cobb-Douglas under half-normal distribution JMLS and BC estimators is presented in Figures (5.14 and 5.15) and appendices (21 and 22).

Table 5.7: Summary of TE for Pooled SFA Cobb-Douglas - Half-Normal distribution

Tehnical Efficiency	Observation	Mean	Std Deviation	Min	Max
TE using JMLS estimator	146	0.9536	0.0314	0.8449	0.9948
TE using BC estimator	146	0.9536	0.0314	0.8450	0.9948

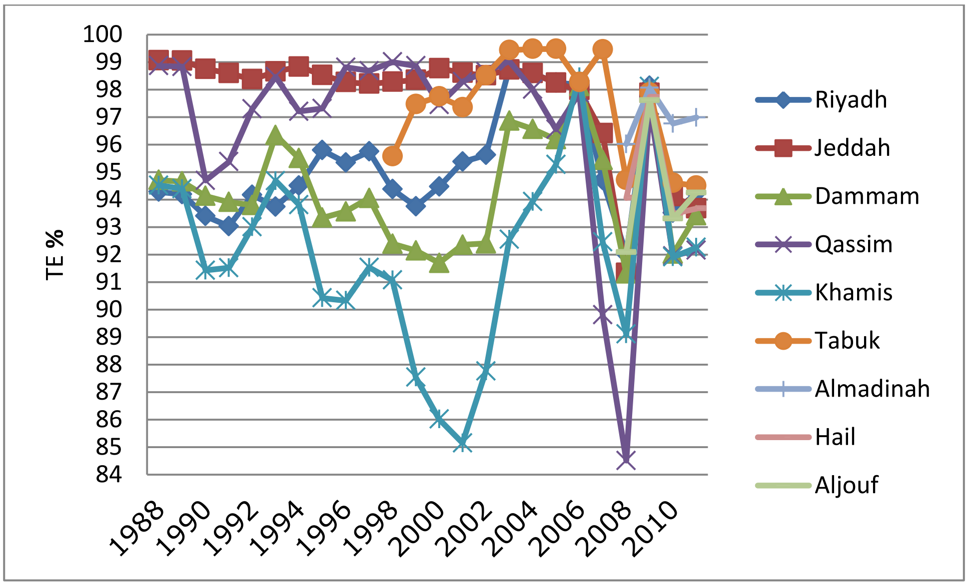

Figure 5.14: TE of all branches using SFA Cobb-Douglas under Half-Normal Distribution BC estimator

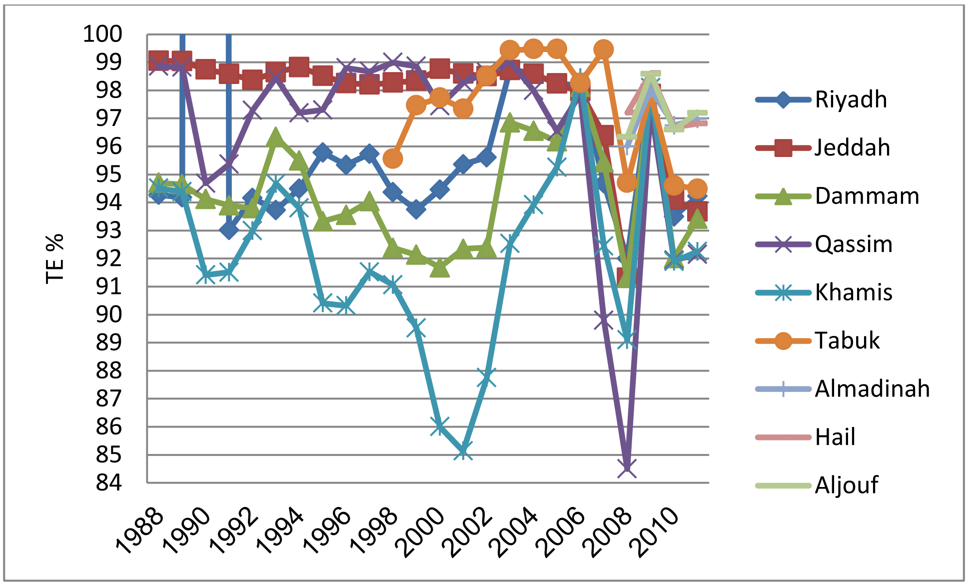

Figure 5.15: TE of all branches using SFA Cobb-Douglas under Half-Normal distribution JMLS estimator

5.3.4.1.3. Comparison of TE Results using Exponential and Half-Normal Distribution

Examining Table 5.8, TE under exponential distribution for all branches ranged between 87.45% and 99.21%; however, it varied from 84.49% to 99.48% under half-normal distribution. Even though TE under half-normal distribution is lower than TE under exponential distribution; the correlation is very strong at 95.23%, which means that both are explaining the same range and order of results.

The complete lists of TE results from exponential and half-normal distribution using JMLS and BC estimators for each unit are presented in Appendices (19-22). The summary of statistics for TE using BC and JMLS estimator from exponential and from half-normal distribution is presented in Table 5.8. It is noted from the results of TE using SFA (Figures 5.13, 5.14, and 5.15) that there is variation and uncertainty from year to year, which will be explored more in detail when discussing the second stage regression.

Whilst undertaking efficiency estimates using SFA, specifically designed to capture stochastic elements within the production processes, and therefore uncertainty in production, very similar TE results can be observed between DEA and SFA. It is important to note that the estimates observed in SFA still demonstrate this large variability in results, which in turn demonstrate uncertainty in the production process. The results between SFA and DEA are broadly comparable as will be explored in detail later.

Table 5.8: TE Comparison Summary of statistics for Pooled SFA Cobb-Douglas with exponential and half-normal distribution

TE	Observation	Mean	Std Deviation	Min	Max
TE Pooled SFA Cobb-Douglas - exponential distribution - JMLS	146	0.9722	0.0209	0.8745	0.9921
TE Pooled SFA Cobb-Douglas - exponential distribution - BC	146	0.9724	0.0209	0.8748	0.9921
TE Pooled SFA Cobb-Douglas - half-normal distribution - JMLS	146	0.9536	0.0314	0.8449	0.9948
TE Pooled SFA Cobb-Douglas - half-normal distribution - BC	146	0.9536	0.0314	0.8450	0.9948

Furthermore, it can be calculated that the correlation between TE from pooled SFA with Cobb-Douglas production function calculated using exponential and half-normal distribution is very high at the range of 0.9522 to 1.000 (Table 5.9), which means that both distribution assumption resulted in a very similar TE values demonstrated by the findings in Tables 5.8 and Table 5.9 considered together.

Table 5.9: TE Correlation for Pooled SFA Cobb-Douglas

	TE Pooled SFA Cobb-Douglas - exponential distribution - JMLS	TE Pooled SFA Cobb-Douglas - exponential distribution - BC	TE Pooled SFA Cobb-Douglas - half-normal distribution - JMLS	TE Pooled SFA Cobb-Douglas - half-normal distribution - BC
TE Pooled SFA Cobb-Douglas - exponential distribution - JMLS	1.0000			
TE Pooled SFA Cobb-Douglas - exponential distribution - BC	1.0000	1.0000		
TE Pooled SFA Cobb-Douglas - half-normal distribution - JMLS	0.9527	0.9522	1.0000	
TE Pooled SFA Cobb-Douglas - half-normal distribution - BC	0.9528	0.9523	1.0000	1.0000

5.3.4.2. Pooled SFA using Translog Production Function

As in pooled SFA using Cobb-Douglas, the initial steps before the analysis are as follows:

1. Generating residuals from Translog production function (27) constructed before, $\ln F_i = A_i + \beta_1 \ln Wh_i + \beta_2 \ln Mh_i + \beta_3 \ln M_i + 0.5\beta_{11} (\ln Wh_i)^2 + 0.5\beta_{22} (\ln Mh_i)^2 + 0.5\beta_{33} (\ln M_i)^2 + \beta_{12} \ln Wh_i \ln Mh_i + \beta_{13} \ln Wh_i \ln M_i + \beta_{23} \ln Mh_i \ln M_i + t_i$, using STATA software.
2. Skewness of the data is observed. As previously shown, since the study is working on production function, negative skewness is required by pooled SFA. From the summary residuals, a skewness of -0.8419 is observed. However, since it is quite small, further skewness test would be needed. The result of Normality Test shows that Probability for Skewness is 0.0001 so that H_0 (the distribution is normal) is rejected, which means that the skewness here is significant. This means that translog function (27) is valid to be used in pooled SFA in further analysis since its production function requires distribution that is skewed to the left.

3. Check the distribution graph to reconfirm the result.

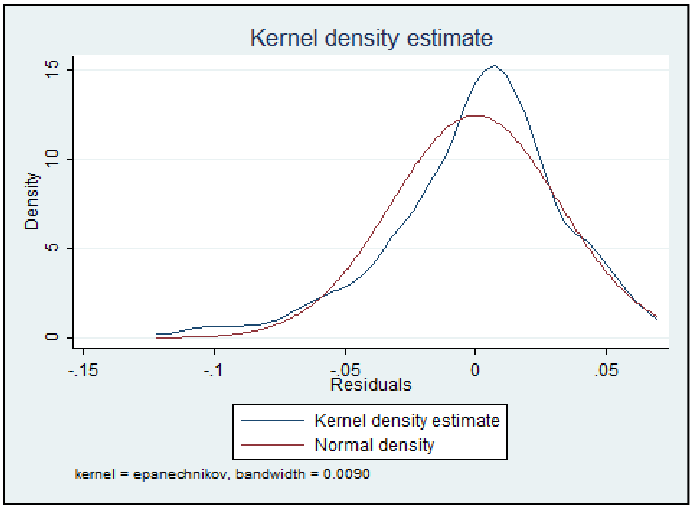

Figure 5.16: Translog Distribution Compared to Normal Distribution

According to Figure 5.16 above, it can be observed that the distribution from the residuals generated is skewed to the left (negatively skewed) and different to normal distribution, which means that the residuals and data are valid for further pooled SFA analysis.

The pooled SFA using exponential and half-normal distributions as assumptions for inefficiency terms are analysed in the following section.

5.3.4.2.1. Pooled SFA with Translog Production Function using Exponential and Half-Normal Distribution

Unfortunately, when pooled SFA is run with Translog production function (27) using both exponential and half-normal distributions, this model suffers from a non-convergence problem. The model failed to find optimal solutions for both distributions due to this non-convergence problem which causes a perpetual iteration processes.

In conclusion, the pooled SFA with Cobb-Douglas production function is more suitable for use in this study to estimate TE since the Translog model specifications suffer from non-convergence problems.

After estimating TE, the influence of the variables affecting TE of the GSFMO branches, such as temperature, condition of machinery, managers' age, experience, number of mills and the quality of infrastructure were estimated drawing on data between 2008 and 2011. This will be explained in detail in the following section which is the second stage regression.

5.4. Second Stage Regression

5.4.1. Second stage regression for all branches (2008-2011)

In the two-stage DEA process, TE scores are initially estimated as a first stage, while in the second stage, they are regressed against the factors thought to have an effect on efficiency. As such, this study examines factors which may have an influence on the GSFMO branches' efficiency. As a result of the limited range of efficiency (0-1), Tobit regression analysis was used being more appropriate than OLS (Coelli *et al.,* 2002, Tingley *et al.,* 2005). For this purpose, regression analysis is performed for the period between 2008 and 2011 (four years), as in the case of Wilson *et al.* (2001) in which the management data was collected in 1997 but was assumed to refer to the whole five year study period (1993-1997). In this study, this period is selected because all branches have different operational ages: the Riyadh, the Jeddah, the Dammam, the Qassim, and the Khamis branches have been operating for 24 years, while the Tabuk branch has been operating for 13 years. The Hail, the Almadinah and the Aljouf branches, however, have been operating only for four years. Therefore, to keep the data balanced, the period of 2008-2011 was selected. In addition, the type of data does not allow the researcher to ask the current branch managers about infrastructure and machinery condition in previous years such as during the 1990s.

The variables that will be analysed as possible factors which might have an influence on GSFMO efficiency, are branch manager's age, branch manager's experience, temperature in branch locations and period of observation (time). Moreover, this study will examine the effect of the number of mills in each branch (Riyadh and Jeddah five milling machines, Dammam and Khamis three mills, Qassim two mills and Tabuk, Almadinah, Aljouf and Hail one mill for each) and the age of machines used in the branch; whether the branch uses new, old or mixture of new and old machines. The last variable to be analysed is the quality of infrastructure surrounding the branch; whether it can be classified as 'good', 'average', or 'bad' infrastructure.

The data regarding the level of education for branch managers in all branches during this period was also collected; however, it was not used in the second stage regression because all branch managers share the same level of education (Bachelor Degree), except for one branch manager (Baccalaureate).

In the second stage regression, three models have been examined as follows:

1. $TE_i crs = a + b_1 Age_i + b_2 Experience_i + b_3 Temperature_i + b_4 MillNo + b_5 Time_i + b_6 NewMachine_i + b_7 MixMachine_i + b_8 GoodInf_i + b_9 BadInf_i$ (28)
2. $TE_i vrsin = a + b_1 Age_i + b_2 Experience_i + b_3 Temperature_i + b_4 MillNo + b_5 Time_i + b_6 NewMachine_i + b_7 MixMachine_i + b_8 GoodInf_i + b_9 BadInf_i$ (29)
3. $TE_i vrsout = a + b_1 Age_i + b_2 Experience_i + b_3 Temperature_i + b_4 MillNo + b_5 Time_i + b_6 NewMachine_i + b_7 MixMachine_i + b_8 GoodInf_i + b_9 BadInf_i$ (30)

Where in all models above, a is constant, TE_i represents the efficiency scores for branch i under CRS, input-orientated VRS and output-orientated VRS, which has been analysed separately. $NewMachine_i$ and $MixMachine_i$ are dummy variables that represent the condition where a branch has a new machine or a mixture of new and old machines, respectively. While $GoodInf_i$ and $BadInf_i$ are dummy variables to show whether the infrastructure surrounding the branches are good or bad, respectively.

$MillNo$ is number of mills in each branch and the temperature recorded the highest temperature point (peak temperature) experienced by branch *i* in time of observation.

The results of the second stage regression are as follows:

In the analysis performed for efficiency level under CRS, VRA-input orientated and VRS-output orientated conditions, it has been found that branch managers' age, temperature, mills number, new machine condition and bad infrastructure conditions have significant effects on the efficiency levels, while experience, time, mixed machine condition and good infrastructure are found to be statistically insignificant. Branch manager's age, temperature, and bad infrastructure have a negative relationship with TE, while mills number and new machine condition have a positive relationship with TE (Table 5.10).

More specifically, it is found from Model 1 under CRS that the younger the branch managers by one year, the higher the efficiency level of the branches by 0.34%, with the other factors remaining constant. The higher the peak temperature by one degree Celsius, TE of the branches will be reduced by 0.85%. Also, if the branch has one mill more than the other branch, TE of this branch will be increased by 2.87%. Moreover, if the machinery in a branch is new, the TE will be 4.94% higher than if the machine age in a branch is old. When the infrastructure in a branch is in a bad condition, the TE of this branch will be lower by 11.15% than TE when the infrastructure is in an average condition. On the other hand, good infrastructure condition and mixed machines were not found to have a significant relationship with TE. Model 1 can explain 55.8% variation in TE values. In Model 2 under input-orientated VRS condition, if the branch manager's age or peak temperature increase by one year, or one degree Celsius respectively, the TE of this branch is estimated to be lower by 0.44% or 0.78%, respectively. Moreover, TE of the branches will be increased by 3.72% if the branch has one mill more than the other branches. A branch that uses new machinery will have TE of 5.73% higher than a branch with only old machinery. Finally, a branch faced with bad infrastructure will have lower TE by 10.61% than a branch with an average infrastructure condition. In terms of the model fit, this model can explain 53.2% of variation in TE.

In Model 3 under output-orientated VRS condition, Table 5.10 shows that the results on branch manager's age, branch manager's experience, branch infrastructure condition, and the use of new machine and mixture of old and new machine in a branch are quite similar to results from Model 2 under input-orientated VRS. Branch manager's age has a significant negative relationship with TE (0.44%), while the relationship of branch manager's experience with TE is again shown to be not statistically significant. Bad condition of infrastructure in a branch causes it to have a significantly lower TE than a branch with an average infrastructure condition (10.09%); however, a good infrastructure condition does not have a statistically significant effect on TE. The use of both old and new machinery in a branch is shown to be not statistically significant. The branch that uses new machines has a more significant effect on TE than a branch with old machines (5.76%). In terms of the number of mills used, the branch which has one more mill than the other branch will have higher TE by 3.69%. Regarding the model fit, this model can explain 53.9% of variation in TE. From the R^2 value of all models for TE second stage, it can be observed that Model 1 under CRS has a higher R^2 than others (55.8%).

Table 5.10: Second stage regression results under CRS, input-orientated VRS, and output-orientated VRS conditions

	TE CRS	TE VRS-input	TE VRS-output
	Model 1	Model 2	Model 3
A	1.412 (13.300)*	1.406 (10.600)*	1.391 (10.750)*
Age	-0.0034 (-3.730) *	-0.0044 (-3.870)*	-0.0044 (-3.980)*
Experience	-0.0005 (-0.550)	-0.0008 (-0.730)	0.0008 (-0.700)
Temperature	-0.0085 (-3.630)**	-0.0078 (-2.680)**	-0.0075 (-2.630)
Mills number	0.0287 (2.220)**	0.0372 (2.300)**	0.0369 (2.330)**
Time	-0.0043 (-1.100)	0.0003 (0.050)	0.0008 (0.160)
NewMachine	0.0494 (2.920)**	0.0573 (2.720)**	0.0576 (2.800)**
MixMachine	-0.055 (-1.350)	-0.0367 (-0.730)	-0.0352 (-0.710)
GoodInf	-0.0203 (-1.940)	-0.0141 (-1.060)	-0.0142 (-1.090)
BadInf	-0.1115 (-4.500)*	-0.1061 (-3.410)**	-0.1009 (-3.320)**
R^2	0.558	0.532	0.539
F	3.650**	3.290**	3.380**

* = Significant at 99.9% confidence interval, ** = Significant at 95% confidence interval, *** = Significant at 90% confidence interval and (   ) = Not significant

5.4.2. Summary from Second Stage Regression

From the results of three models under CRS, input-orientated VRS (I-O VRS) and output-orientated VRS (O-O VRS) conditions, Model 1 under CRS provides the best explanation of the variation in TE (55.8%). Therefore, it is argued that Model 1 is more suitable to be used in explaining factors related to efficiency variation in GSFMO flour mills. From Model 1, branch manager's experience is found to have no statistical significant relationship with TE, mixed machine and good infrastructure condition also does not have a significant effect on TE. There is also no significant relationship of time on TE.

The Model 1 specification is as follows:

$$TE_i crs = a + b_1 Age_i + b_2 Experience_i + b_3 Temperature_i + b_4 MillNo + b_5 Time_i + b_6 NewMachine_i + b_7 MixMachine_i + b_8 GoodInf_i + b_9 BadInf_i$$

Branch manager's age has a significant negative relationship with TE, where a one year reduction in age will lead to TE being higher by 0.34%. Furthermore, a one degree Celsius increase in peak temperature will lower TE by 0.85%. Also, if the number of mills in a branch increases by one mill, TE of the branch will be increased by 2.87%. Bad infrastructure condition will lower TE by 11.15%% , while new machinery is estimated to increase TE by 4.94%.

Other significant factors in this study to be explored are CE and AE results. The following section will explore all results found for all branches especially under CRS and VRS input-orientated.

The issues emanating from the second stage regression that have had an impact on TE, such as bad infrastructure, high temperature, age of branch manager, and new machinery, will be addressed in the recommendations section. One of these issues having an effect on TE is bad infrastructure, which will require a considerable investment to correct and improve. Whilst it has been shown that bad infrastructure has an impact on efficiency, recommendations to improve the efficiency need to bear in mind that capital investment will be required to correct for that condition.

5.5. Cost Efficiency (CE) and Allocative Efficiency (AE) results for all branches

Utilising input and output price data for all the branches in the dataset, CE and AE can further be calculated. Thanassoulis (2001) stated that AE represents the distance of the lowest input costs at which a branch can produce its outputs (for the input-orientated model), or output combination, that can be produced with the highest revenues from given inputs (for the output-orientated model), when the branch is fully technical efficient. However, CE is the distance of the combination of inputs with minimum costs or output with maximum revenues mentioned above, relative to the current costs of input combinations used by the branch (for the input-orientated model), or current revenues of output combination produced by the branch (for the output-orientated model). AE and CE may be different for input-orientated and output-orientated only under VRS condition, while they will be the same for both models under CRS condition. CE is also mentioned in a wider meaning as Economic Efficiency (Farrell, 1957) or also Overall Efficiency (Thanassoulis, 2001) since in the output-orientated model, this type of efficiency calculates revenue rather than costs. However, this current study focuses on the input-orientated model since the flour price is already fixed by Saudi Arabian government; for that reason, the output-orientated model is not relevant. Therefore, this study will use CE rather than EE or Overall Efficiency.

In reality, CE is more important than just TE for a branch since it takes costs or revenues into consideration. CE is also more important than AE since it calculates the distance of minimum costs from real production points rather than ideal fully technical efficient points (Thanassoulis, 2001). In the input-orientated model, CE shows the costs inefficiency that exists from using current input combinations in producing given outputs in a DMU. In the output-orientated model, CE shows the shortage of revenues that are suffered by a DMU by producing current output which is considered unsuitable from the view of output price.

5.5.1. Mean CE and AE under CRS and VRS input-orientated for all branches

As shown in Table 5.11, under CRS, the Riyadh branch ranked first in the CE of the flour milling, with an average CE of 63.13%. This means that the Riyadh branch could have achieved the same level of production while reducing costs by 36.87% of the current costs for flour production during the period spanning from 1990 to 2011. The Qassim branch is estimated to have the lowest CE of the branches, with an average CE of 53.9%, which indicates that, the branch could have reduced costs by 46.1%. Under VRS input-orientated approaches, the CE of the GSFMO branches ranged from a minimum of 56.29% in the Qassim branch to a maximum rate of 67.67% in Riyadh during the period between 1990 and 2011.

As identified by the results in Table 5.11, the Riyadh branch has also ranked first in AE, with an average AE of 66.51%. This suggests that if the Riyadh branch had been operating at fully TE levels, the average costs which could be saved would have been 33.49% between 1990 and 2011. Lowest ranking was the Qassim branch with an average AE of 56.76%. In terms of VRS input-orientated, AE of the GSFMO branches ranged from a minimum of 58.55% in the Qassim branch to a maximum of 70.24% in the Riyadh branch. Hence, the Riyadh branch could have reduced total costs of flour production by 29.76%, while it would have been possible for the Qassim branch to reduce costs by 41.45%. Note that there is no branch in the dataset with 100% CE or AE, indicating that there is significant scope to reduce inputs costs in the production process.

Table 5.11: Mean CE and AE for all branches under CRS and VRS-input orientated

Branch	Cost Efficiency CRS	Allocative Efficiency CRS	Cost Efficiency VRSinput	Allocative Efficiency VRSinput
Riyadh	63.13	66.51	67.67	70.24
Jeddah	62.33	64.98	65.94	67.63
Dammam	58.19	61.28	60.95	63.27
Qassim	53.9	56.76	56.29	58.55
Khamis	56.77	60.26	58.88	61.65
Tabuk	56.87	60.1	59.22	61.79
Almadinah	56.35	59.52	58.68	61.21
Hail	55.61	58.74	58	60.52
Aljouf	54.75	57.83	57.39	59.87

5.5.2. CE and AE under CRS for all branches

When examining the growth of CE and AE under CRS for all branches, Table 5.12 clearly shows that the mean CE in the Riyadh branch ranged from a minimum of 36.32% in 1999 to 100% in 2005. This means that in 1999, the Riyadh branch could have reduced production costs by 63.68% to produce the same level of output. In general, there was a decline in the CE of the Riyadh branch between 1998 and 2002, followed by an improvement between 2003 and 2005, reaching 100% and decreasing again to 65.19% in 2006.

A review of mean AE in the Riyadh branch under CRS shows that the AE ranged from a minimum of 39.03% in 2000 to a maximum of 100% in 2005. This indicates that in 2000 the Riyadh branch could have reduced production costs by 60.97% if it had operated at fully TE level. In general, there has been an improvement in AE of the Riyadh branch during the period 1990-1998, which then deteriorated during the period 1999-2002, and improved again between 2004 and 2005, but then achieving 66.74% in 2006.

With regard to CE and AE of the Jeddah branch under CRS, it can be seen that it ranged between a minimum of 50.53% and 54.84% respectively in 2011, with respective maximums of 75.75% and 78.39% in 2007.

It should be noted, however, that within branches that have been operating for a long time, the Dammam and Qassim branches achieved lower efficiency levels compared to the Riyadh, Jeddah and Khamis branches. The CE and AE of the Dammam branch during the 1990-2011 periods ranged from a minimum of 29.21% and 32.2%, to a maximum of 57.73% and 61.42% respectively. The Qassim branch performed worst compared to other long-established branches since it had the lowest CE (28.88%) and AE (31.81%) (Table 5.13).

It was also found that the only medium- length established branch (Tabuk), performed similar to longer-established branches like Riyadh, Jeddah and Khamis with CE and AE of around 33% and 35% respectively, with its best performance in 1999 when CE was 95.11% (Table 5.14). CE was the lowest in new branches in the year of establishment (2008) (Figure 5.15), such as the Hail branch (19.88%) and the Aljouf branch (1.48%). These low CE percentages show that there is a large opportunity to reduce production costs (Table 5.15).

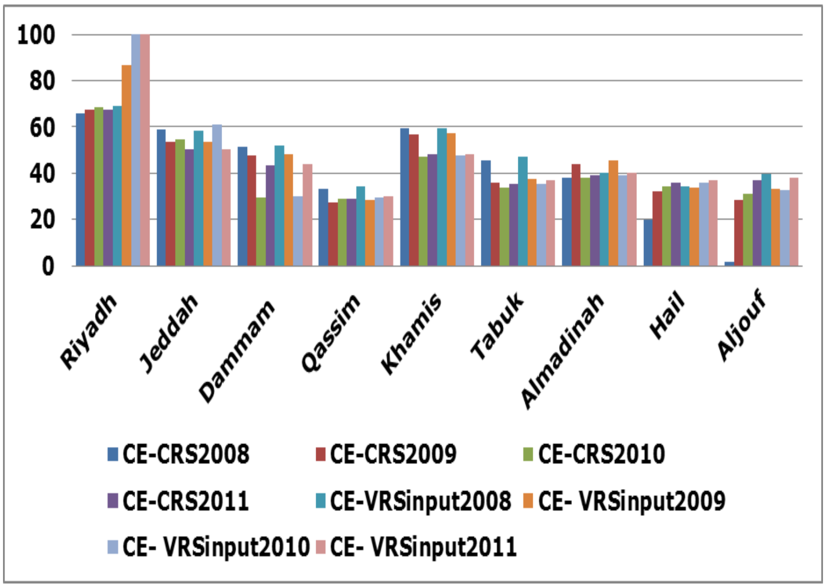

Figure 5.17: CE under CRS and VRS input - orientated for all branches (2008-2011)

5.5.3. CE and AE under VRS input-orientated for all branches

Under VRS input-orientated, it can be seen (Table 5.12) that the CE of the Riyadh branch was at a minimum of 36.87% during 1999 and 2000, however, Riyadh achieved 100% CE in 2005. It is also seen that the AE in the Riyadh branch reached a minimum of 39.11% in 2000, then achieving full AE in 2005. CE and AE of the Jeddah branch, was estimated at a minimum of 50.53% and 53.33%, in 2011, respectively, while achieving 100% CE and AE in 2007

In VRS input-orientated, the Qassim branch in 2009 had the lowest CE (28.34%) and AE (29.39%), falling from 41.78% (CE) and 47.35% (AE) just two years earlier. These low CE and AE estimates continued on this level until 2011, which shows that with respect to production costs, this branch was approximately 70% inefficient in 2011 (CE = 29.74%). Even if the Qassim branch had reached 100% TE in 2011, the wasted costs in its production could have been 67.34% in 2011 since its AE was 32.66%. With respect to the Dammam branch, the lowest CE and AE estimates under VRS input orientated were 30.01% and 32.97% for CE and AE in 2010 respectively. The maximum performance of the Dammam branch was in 2004 when it is estimated to be 58.47% and 60.93% in CE and AE respectively (Table 5.13).

The Khamis branch was estimated to achieve lowest CE and AE in 2010, respectively estimated at 47.45% and 49.65%. In the Khamis' best year (2005), CE and AE were both 91.23%, indicating that this branch had only 8.77% excess costs in its production process. The Tabuk branch also had its lowest performance in 2010, where CE and AE estimates were 35.43% and 37.7% respectively. This branch had its best years in 1998 and 1999 where CE and AE were 100% for both years, and also 100% CE and AE, where production was achieved at the minimum production costs possible. However, from 2000 until 2011, it did experience a consistent fall (Table 5.14).

The performances in the newer branches are generally low and moreover there is little variation between their efficiency performance in their best and worst years during the 2008-2011 period. The Almadinah, Hail, and Aljouf branches had CE of about 36%-46% in their best year and 32%-39% in their worst year, while these branches had AE of around 39%-46% in their best year and 34%-40% in their worst year. All these figures show that there is low cost efficiency in the newer branches as well as in the older branches (Figures 5.17 and 5.18).

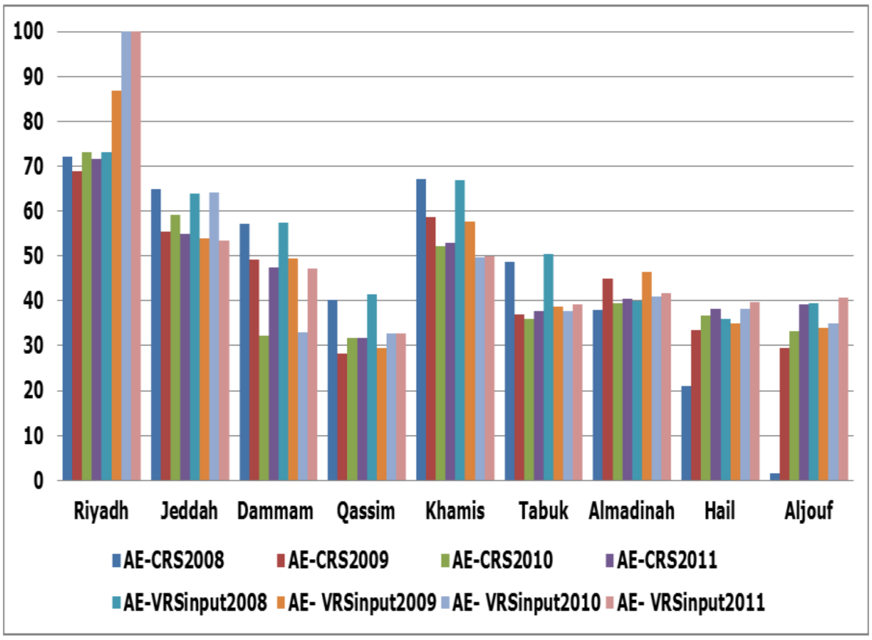

Figure 5.18: AE under CRS and VRS input - orientated for all branches (2008-2011)

Table 5.12: CE and AE for Riyadh and Jeddah branches under DEA-CRS and VRS

Branch	Cost Efficiency CRS	Allocative Efficiency CRS	Cost Efficiency VRSinput	Allocative Efficiency VRSinput
Riyadh1990	62.31	67.56	63.63	68.95
Riyadh1991	58.08	63.52	59.47	64.96
Riyadh1992	69.29	74.08	70.67	75.44
Riyadh1993	61.37	66.36	62.63	67.63
Riyadh1994	68.07	72.57	69.26	73.83
Riyadh1995	60.61	64.21	61.72	65.16
Riyadh1996	66.73	70.58	67.81	71.62
Riyadh1997	67.21	70.74	68.14	71.54
Riyadh1998	56.98	61.47	57.93	62.03
Riyadh1999	36.32	39.34	36.87	39.42
Riyadh2000	36.33	39.03	36.87	39.11
Riyadh2001	39.22	41.76	39.70	41.62
Riyadh2002	42.02	44.65	42.45	44.36
Riyadh2003	67.87	68.74	68.34	68.76
Riyadh2004	93.72	93.72	93.99	93.99
Riyadh2005	100.00	100.00	100.00	100.00
Riyadh2006	65.19	66.74	65.26	65.57
Riyadh2007	68.50	72.59	68.56	71.54
Riyadh2008	66.00	72.05	68.76	73.02
Riyadh2009	67.35	68.77	86.73	86.73
Riyadh2010	68.40	73.19	100.00	100.00
Riyadh2011	67.32	71.61	100.00	100.00
Jeddah1990	59.48	60.76	59.69	59.86
Jeddah1991	54.55	55.95	54.84	55.18
Jeddah1992	64.85	66.32	65.08	65.78
Jeddah1993	62.39	63.63	62.55	62.83
Jeddah1994	61.31	62.37	61.44	61.44
Jeddah1995	59.83	61.30	59.94	60.26
Jeddah1996	68.09	69.42	73.85	74.46
Jeddah1997	55.25	56.95	55.28	55.65
Jeddah1998	54.79	56.44	54.90	55.28
Jeddah1999	61.42	62.99	61.55	62.06
Jeddah2000	66.85	67.68	66.90	66.90
Jeddah2001	66.12	67.18	66.13	66.32
Jeddah2002	70.24	71.20	77.84	78.17
Jeddah2003	70.67	71.33	79.98	79.98
Jeddah2004	69.17	70.09	72.74	72.96
Jeddah2005	57.61	59.31	57.62	58.00
Jeddah2006	56.93	58.85	56.96	57.55
Jeddah2007	75.75	78.39	100.00	100.00
Jeddah2008	58.64	64.97	58.65	63.86
Jeddah2009	53.45	55.35	53.46	53.97
Jeddah2010	54.79	59.12	61.07	64.15
Jeddah2011	50.53	54.84	50.53	53.33

Table 5.13: CE and AE for Dammam and Qassim branches under DEA-CRS and VRS

Branch	Cost Efficiency CRS	Allocative Efficiency CRS	Cost Efficiency VRSinput	Allocative Efficiency VRSinput
Dammam1990	47.31	51.42	49.00	53.13
Dammam1991	47.60	51.87	49.29	53.57
Dammam1992	50.93	55.53	52.56	57.27
Dammam1993	55.72	58.99	57.10	60.22
Dammam1994	53.81	57.48	54.88	58.20
Dammam1995	46.81	51.23	47.77	51.82
Dammam1996	49.39	53.91	50.33	54.44
Dammam1997	47.61	51.69	48.51	52.15
Dammam1998	42.94	47.44	43.91	48.18
Dammam1999	45.49	50.45	46.51	51.22
Dammam2000	48.13	53.67	49.11	54.31
Dammam2001	47.84	52.94	48.77	53.47
Dammam2002	52.45	57.94	53.30	58.32
Dammam2003	57.19	60.09	57.91	60.13
Dammam2004	57.73	60.82	58.47	60.93
Dammam2005	55.75	59.02	56.47	59.10
Dammam2006	53.93	55.83	54.64	55.85
Dammam2007	57.63	61.42	58.40	61.64
Dammam2008	51.13	57.19	51.95	57.52
Dammam2009	47.47	49.23	48.23	49.41
Dammam2010	29.21	32.20	30.01	32.97
Dammam2011	43.58	47.51	44.07	47.12
Qassim1990	35.98	38.69	37.58	40.40
Qassim1991	35.17	37.53	36.79	39.23
Qassim1992	39.67	41.49	41.28	43.16
Qassim1993	39.75	40.89	41.16	42.33
Qassim1994	37.91	39.63	39.16	40.93
Qassim1995	37.31	38.93	38.48	40.16
Qassim1996	39.31	40.12	40.40	41.12
Qassim1997	35.24	36.00	36.26	36.97
Qassim1998	32.72	33.14	33.83	34.26
Qassim1999	54.22	55.53	55.87	57.21
Qassim2000	55.13	57.69	56.77	59.37
Qassim2001	56.57	58.52	58.07	59.92
Qassim2002	57.99	59.60	59.48	60.92
Qassim2003	41.62	42.25	42.58	42.95
Qassim2004	44.83	46.47	45.76	47.03
Qassim2005	46.63	49.21	47.50	49.61
Qassim2006	41.15	42.68	42.05	43.28
Qassim2007	40.71	46.32	41.78	47.35
Qassim2008	33.27	40.25	34.34	41.54
Qassim2009	27.32	28.33	28.34	29.39
Qassim2010	28.88	31.85	29.71	32.71
Qassim2011	28.91	31.81	29.74	32.66

Table 5.14: CE and AE for Khamis and Tabuk branches under DEA-CRS and VRS

Branch	Cost Efficiency CRS	Allocative Efficiency CRS	Cost Efficiency VRSinput	Allocative Efficiency VRSinput
Khamis1990	64.87	71.73	66.53	73.34
Khamis1991	49.25	55.14	51.18	56.78
Khamis1992	77.52	83.59	79.86	85.32
Khamis1993	75.68	80.19	77.46	81.65
Khamis1994	65.33	70.40	66.86	71.93
Khamis1995	67.04	74.78	68.52	76.22
Khamis1996	67.14	74.65	68.54	76.11
Khamis1997	76.30	83.22	77.47	84.42
Khamis1998	70.67	77.85	71.57	78.79
Khamis1999	59.09	68.40	59.87	68.91
Khamis2000	56.09	66.28	56.93	66.84
Khamis2001	61.52	71.94	62.22	70.11
Khamis2002	77.37	86.90	77.80	85.34
Khamis2003	88.79	93.74	89.11	91.19
Khamis2004	90.85	94.44	91.15	91.68
Khamis2005	90.95	93.28	91.23	91.23
Khamis2006	78.08	78.64	78.52	78.52
Khamis2007	85.83	90.96	86.28	89.18
Khamis2008	59.14	67.19	59.57	66.76
Khamis2009	56.65	58.56	57.05	57.66
Khamis2010	47.03	52.21	47.45	49.65
Khamis2011	47.92	52.96	48.28	50.03
Tabuk1998	68.53	71.82	100.00	100.00
Tabuk1999	95.11	95.11	100.00	100.00
Tabuk2000	72.47	73.90	75.88	76.72
Tabuk2001	76.64	77.95	79.98	81.34
Tabuk2002	74.81	75.27	77.89	78.31
Tabuk2003	48.74	48.82	50.26	50.34
Tabuk2004	54.13	54.14	55.83	55.83
Tabuk2005	52.54	52.54	54.18	54.18
Tabuk2006	53.01	54.59	54.64	56.02
Tabuk2007	60.27	60.27	62.13	62.13
Tabuk2008	45.60	48.72	47.35	50.50
Tabuk2009	35.77	36.93	37.51	38.72
Tabuk2010	33.78	35.96	35.43	37.70
Tabuk2011	35.31	37.66	36.89	39.33

Table 5.15: CE and AE for Almadinah, Hail and Aljouf branches under DEA-CRS and VRS

Branch	Cost Efficiency CRS	Allocative Efficiency CRS	Cost Efficiency VRSinput	Allocative Efficiency VRSinput
Almadinah2008	38.02	38.02	39.90	39.90
Almadinah2009	44.02	45.01	45.53	46.40
Almadinah2010	37.98	39.44	39.32	40.84
Almadinah2011	38.96	40.41	40.29	41.71
Hail2008	19.88	21.00	34.17	36.05
Hail2009	32.38	33.43	33.86	34.94
Hail2010	34.22	36.84	35.62	38.34
Hail2011	35.60	38.23	36.95	39.68
Aljouf2008	1.48	1.55	39.56	39.56
Aljouf2009	28.54	29.40	33.09	34.06
Aljouf2010	30.91	33.25	32.43	34.88
Aljouf2011	36.81	39.29	38.24	40.81

5.6. Productivity growth results for all branches using DEA

In this section, the mean total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) for the period 2008 to 2011 will be explored. This will be followed by the estimated TFPG, TC, and EC for all branches during periods (2008– 2009), (2009-2010), and (2010-2011). The rationale for this analysis is to explore differences between periods with respect to productivity growth.

5.6.1. Mean total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) (2008 -2011)

The results generated are only for the studied period of four years (2008-2011), and therefore, these estimated results would not be expected to necessarily replicate results from the previous period (1988-2011). With regard to the year 2009, for example, all branches achieved 100% efficiency when examining the studied period data 2008-2011 (Table 5.16); meanwhile, efficiency for the same year (2009) was found to vary across branches when examining the overall period (1988-2011). This highlights the importance of placing the following results within context of the more limited time period of analysis.

Reviewing the productivity growth in all branches of the GSFMO during the period from 2008 to 2011 under CRS, it is shown that there is no change in TC in the Riyadh, Qassim, Tabuk, Almadinah and Hail branches, while there was an increase for Jeddah, Dammam and Khamis branches with an average rate of 0.67% per annum for each. On the other hand, TE decreased in the Hail branch with a rate of 0.33% (Table 5.17).

With respect to the EC in the various branches, there was no change in terms of efficiency in the Riyadh, Jeddah, Dammam and Almadinah branches, while an increase in the Qassim and Khamis branches of 3% and 0.33% respectively was estimated. However, EC decreased at rate of 0.67% for the Tabuk branch and 0.68% for the Aljouf branch, while it also declined at the Hail branch (0.33%).

It has been observed that the Riyadh and Almadinah branches witnessed no change in TFPG during the period, while TFPG increased at an identical rate (0.67%) for the Jeddah, Dammam and Khamis branches, and 3.33% in the Qassim branch. Finally, TFPG decreased by 0.67% in the Tabuk branch and 0.70% in the Aljouf branch, and also in the Hail branch by 1.0%. As already shown, the period spanning from 2008 to 2011 did not see any change in terms of TC, EC, and TFPG in the Riyadh and Almadinah branches, while it increased in Khamis Mushayt branch and declined in the Hail branch.

Table 5.16: Efficiency for all branches (2008 -2011)

Branch	Efficiency 2008	Efficiency 2009	Efficiency 2010	Efficiency 2011
Riyadh	100	100	100	100
Jeddah	98.66	100	99.84	98.41
Dammam	97.54	100	95.36	97.27
Qassim	87.83	100	95.27	95.29
Khamis	96.17	100	96.63	96.53
Tabuk	100	100	97.72	97.34
Almadinah	100	100	100	100
Hail	98.73	100	96.53	97.04
Aljouf	99.85	100	97	97.88

5.6.2. TFPG, TC, and EC for all branches (2008 – 2009)

As illustrated by the data contained in Table 5.17, the years 2008 and 2009 witnessed no change in TC for Riyadh, Almadinah, and Hail branches, while there was an increase by a similar rate of 3% for the Jeddah, Dammam, and Khamis branches. It also increased with an equal rate of 1% for the Qassim and Tabuk branches. It also increased by 0.99% for the Aljouf branch.

In view of the estimated efficiency in the various branches, it has been shown that in 2008 efficiency ranged between a minimum of 87.83% in the Qassim branch and a maximum of 100% in the branches of Riyadh, Tabuk and Almadinah. No change in efficiency for the Riyadh, Tabuk, Aljouf, and Almadinah branches were found, while there was an increase of 1% in each of the Jeddah and Hail branches. In the Dammam, Qassim and Khamis branches, EC increased with rates reaching 3%, 14%, and 4% respectively.

With reference to TFPG, there was no change witnessed in the Riyadh and Almadinah branches, while TFPG increased by 5% for the Jeddah and Dammam branches. It also increased by 1% for the Tabuk and Hail branches, and by 0.99% for the Aljouf branch. Finally, in the Qassim and Khamis branches, TFPG increased at higher rates of 15% and 7% respectively. As clearly shown in the studied period (2008-2009), there was no decrease in EC, TC, and TFPG in all branches compared to the other periods (2009-2010) and (2010-2011).

5.6.3. TFPG, TC, and EC for all branches (2009-2010)

As clearly indicated in the period (2009-2010), there was a decrease in TC, EC and TFPG in all branches except the Riyadh and Almadinah branches for which there was no change in these measurements; whereas, the Jeddah branch witnessed no change in EC, but a decrease in TC and TFPG (Table 5.17).

Concerning TC, this decreased by 1% for each of the Dammam, Qassim, Tabuk, and Hail branches. It also decreased in each of the Jeddah and Khamis branches at a rate of 2% for both. It also decreased by 1% for the Aljouf branch.

As for the estimated efficiency in the various branches in 2010, this ranged between a minimum of 95.27% in the Qassim branch and a maximum of 100% in the Riyadh and Almadinah branches. Regarding EC, this declined by 5% for each of the Dammam and Qassim branches. It also decreased at an equal ratio of 3%

for the Khamis, Hail and Aljouf branches; for the Tabuk branch, EC decreased by 2%.

An estimation of the TFPG in the various branches indicates that there is clearly a decrease in TFPG at an equal rate of 5% for the Dammam, Qassim and Khamis branches. There is also a decrease in Hail (4%) and Aljouf (4.08%) branches. Finally, TFPG declined for each of the Jeddah and Tabuk branches to reach 2% and 3% respectively.

5.6.4. TFPG, TC, and EC for all branches (2010 – 2011)

Table 5.17 illustrates no change in TC, EC, and TFPG during the period (2010-2011) for the Riyadh, Qassim, Tabuk, and Almadinah branches. Accordingly, this period included the highest number of branches (four out of nine) where there was no change in TC, EC, and TFPG compared to previous periods (2008-2009) and (2009-2010). In the meantime, TC increased by 1% for both Jeddah and Khamis Mushayt branches. TFPG increased in the Dammam and Aljouf branches by 2% and 0.99% respectively, while it declined in the Jeddah branch by 1%.

An overview of efficiency in the various branches in 2011 shows that it ranged from a minimum of 95.29% in the Qassim branch to a maximum of 100% in the Riyadh and Almadinah branches. In addition, EC has increased in the Hail (1%) and Aljouf (0.99%) branches, while there was an increase with a rate of 2% in the Dammam branch. Finally, EC decreased in the Jeddah branch by 1%.

Table 5.17: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) for all branches (2008-2011)

Branch	Year	TC	EC	TFPG	TC%	EC%	TFPG%
Riyadh	2008-2009	1	1	1	0	0	0
	2009-2010	1	1	1	0	0	0
	2010-2011	1	1	1	0	0	0
	Mean	1	1	1	0	0	0
Jeddah	2008-2009	1.03	1.01	1.05	3	1	5
	2009-2010	0.98	1	0.98	-2	0	-2
	2010-2011	1.01	0.99	0.99	1	-1	-1
	Mean	1.0067	1	1.0067	0.67	0	0.67
Dammam	2008-2009	1.03	1.03	1.05	3	3	5
	2009-2010	0.99	0.95	0.95	-1	-5	-5
	2010-2011	1	1.02	1.02	0	2	2
	Mean	1.0067	1	1.0067	0.67	0	0.67
Qassim	2008-2009	1.01	1.14	1.15	1	14	15
	2009-2010	0.99	0.95	0.95	-1	-5	-5
	2010-2011	1	1	1	0	0	0
	Mean	1	1.03	1.0333	0	3	3.33
Khamis	2008-2009	1.03	1.04	1.07	3	4	7
	2009-2010	0.98	0.97	0.95	-2	-3	-5
	2010-2011	1.01	1	1	1	0	0
	Mean	1.0067	1.0033	1.0067	0.67	0.33	0.67
Tabuk	2008-2009	1.01	1	1.01	1	0	1
	2009-2010	0.99	0.98	0.97	-1	-2	-3
	2010-2011	1	1	1	0	0	0
	Mean	1	0.9933	0.9933	0	-0.67	-0.67
Almadinah	2008-2009	1	1	1	0	0	0
	2009-2010	1	1	1	0	0	0
	2010-2011	1	1	1	0	0	0
	Mean	1	1	1	0	0	0
Hail	2008-2009	1	1.01	1.01	0	1	1
	2009-2010	0.99	0.97	0.96	-1	-3	-4
	2010-2011	1	1.01	1	0	1	0
	Mean	0.9967	0.9967	0.99	-0.33	-0.33	-1
Aljouf	2008-2009	1.01	1	1.01	0.995	0	0.995
	2009-2010	0.99	0.97	0.96	-1	-3.05	-4.08
	2010-2011	1	1.01	1.01	0	0.995	0.995
	Mean	1	0.9933	0.9933	-0.00167	-0.685	-0.70

5.7. Productivity growth results for all branches using SFA

The scope of this study is limited with respect to the estimation of productivity growth using DEA since it was based on a small balanced sample size (four years only), while the results could have been made more robust if the DEA facilitated productivity growth using unbalanced data. To compensate for the small sample size restrictions under DEA, productivity growth was also estimated using SFA for 24 years (1988-2011).

The production frontier was used in which TFPG = technical change (TC) + efficiency change (EC) + scale efficiency change (SEC) (Kumbhakar and Lovell, 2000). TC is equal to the coefficient of the time variable; however, because the time variable in the Cobb-Douglas model is insignificant, then its coefficient is effectively equal to zero. However, this means that we cannot detect any technological change in the industry (TC = 0) using this approach. In fact, this was expected as responding branch managers stated that no significant changes were experienced in technology over the years. EC refers to efficiency in time t+1 divided by efficiency in time t. The STATA software was used to test whether the scale efficiency under the Cobb-Douglas model should be specified as CRS or VRS. The test showed that the Cobb-Douglas assuming CRS was accepted because the probability was more than 0.05. If the model is under a CRS assumption, the scale efficiency component is not needed. However, if the probability is less than 0.05, this means that the model should be specified under VRS; in this latter case, it is essential to estimate SEC.

5.7.1. The total factor productivity growth (TFPG) and efficiency change (EC) of all branches using SFA (1988-2011)

Table 5.18 shows a negative percentage in the mean TFPG in long term operating branches, which indicates a decline in TFPG as a result of the decreasing EC. These percentages stood at -0.220% in the Qassim and the Jeddah branches, accounting for the highest decrease in TFPG mean, -0.020% in Dammam, -0.040% in the Khamis , and -0.050% in the Tabuk branches. In contrast, the Riyadh branch demonstrated an increased TFPG (0.020%).

In relation to the short term operating branches (Almadinah, Hail, and Aljouf branches), Table 5.18 shows that the Almadinah and the Aljouf branches have an increased TFPG (0.339% and 0.866% respectively). The latter mean TFPG percentage (0.866%) represents the highest TFPG compared to the remaining branches, while Hail branch has a negative TFPG (-0.080%).

Presenting TFPG for all branches separately, the Riyadh and Jeddah branches, being older branches, showed an increase in TFPG in 2009 with 6.444% and 6.934% respectively, and a decrease with -4.830% in 2010 for the Riyadh branch (Table 5.19) and -5.414% in 2008 for the Jeddah branch (Table 5.20).

The Dammam branch is also one of the oldest branches, with 7.074% increase in TFPG scores in 2009 as the third highest branch. In addition, it was third lowest in TFPG scores after the Qassim and the Khamis branches with -6.283% in 2010 (Table 5.21). The Qassim branch as one of the older branches had the highest TFPG score (14.211%) in 2009. However the same branch achieved the lowest TFPG score (-8.588%) in 2007, which can be ascribed to the decrease in TC (Table 5.22). Following the Qassim branch with respect to the highest TFPG, the Khamis branch was estimated to have TFPG of 9.618% during the same year (2009). However, the Khamis branch was estimated to have a TFPG of -6.526% in 2010 (Table 5.23).

While the Tabuk branch, (medium term operating), had a 1.183% TFPG increase in 2009 and a -1.725% TFPG decrease in 2008 (Table 5.24), the results for short term operating branches showed that Almadinah achieved an increase in TFPG with 2.104% in 2009 but then a decrease of -1.335% in 2010 (Table 5.25).

The Hail branch achieved an increase in TFPG of 3.825% in 2009 but a decrease of -4.443% in 2010 (Table 5.26); the Aljouf branch, which had the highest TFPG with 5.823% in 2009, also had the lowest TFPG scores with -4.510% in 2010 (Table 5.27).

Generally, any increase and decrease in TFPG is observed to be attributed to an increase or decrease in TC. In addition, it is shown that the Qassim branch has the highest number of years (12 years) during which there was an increase in TFPG, followed by the Khamis branch (11 years), while Jeddah branch has the highest number of years (16 years) in terms of negative TFPG, followed by the Khamis branch (12 years). This indicates that long term operating branches achieved both the highest and lowest scores in TFPG.

Table 5.18: Mean total factor productivity growth (TFPG) and efficiency change (EC) of all branches using SFA (1988-2011).

DMUs	Period	EC	TFPG	EC%	TFPG%
Riyadh	1988-2011	1.0002	1.0002	0.0200%	0.0200%
Jeddah	1988-2011	0.9978	0.9978	-0.2202%	-0.2202%
Dammam	1988-2011	0.9998	0.9998	-0.0200%	-0.0200%
Qassim	1988-2011	0.9978	0.9978	-0.2202%	-0.2202%
Khamis	1988-2011	0.9996	0.9996	-0.0400%	-0.0400%
Tabuk	1998-2011	0.9995	0.9995	-0.0500%	-0.0500%
Almadinah	2008-2011	1.0034	1.0034	0.3394%	0.3394%
Hail	2008-2011	0.9992	0.9992	-0.0800%	-0.0800%
Aljouf	2008-2011	1.0087	1.0087	0.8662%	0.8662%

Table 5.19: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Riyadh branch using SFA (1988-2011)

	Riyadh TE	EC	EC %	TFPG	TFPG (%)
1988	94.275				
1989	94.191	0.99911	-0.0890%	0.99911	-0.0890%
1990	93.394	0.99154	-0.8496%	0.99154	-0.8496%
1991	93.024	0.99604	-0.3968%	0.99604	-0.3968%
1992	94.163	1.01224	1.2166%	1.01224	1.2166%
1993	93.733	0.99543	-0.4580%	0.99543	-0.4580%
1994	94.497	1.00815	0.8117%	1.00815	0.8117%
1995	95.789	1.01367	1.3577%	1.01367	1.3577%
1996	95.342	0.99533	-0.4681%	0.99533	-0.4681%
1997	95.744	1.00422	0.4211%	1.00422	0.4211%
1998	94.367	0.98562	-1.4484%	0.98562	-1.4484%
1999	93.748	0.99344	-0.6582%	0.99344	-0.6582%
2000	94.461	1.00761	0.7581%	1.00761	0.7581%
2001	95.367	1.00959	0.9544%	1.00959	0.9544%
2002	95.614	1.00259	0.2587%	1.00259	0.2587%
2003	98.767	1.03298	3.2448%	1.03298	3.2448%
2004	98.586	0.99817	-0.1832%	0.99817	-0.1832%
2005	98.249	0.99658	-0.3426%	0.99658	-0.3426%
2006	98.168	0.99918	-0.0820%	0.99918	-0.0820%
2007	94.693	0.96460	-3.6042%	0.96460	-3.6042%
2008	92.01	0.97167	-2.8739%	0.97167	-2.8739%
2009	98.134	1.06656	6.4439%	1.06656	6.4439%
2010	93.507	0.95285	-4.8298%	0.95285	-4.8298%
2011	94.227	1.00770	0.7671%	1.00770	0.7671%

Table 5.20: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Jeddah branch using SFA (1988-2011)

	Jeddah TE	EC	EC %	TFPG	TFPG (%)
1988	99.059				
1989	99.042	0.9998	-0.0200%	0.9998	-0.0200%
1990	98.746	0.9970	-0.3005%	0.9970	-0.3005%
1991	98.592	0.9984	-0.1601%	0.9984	-0.1601%
1992	98.369	0.9977	-0.2303%	0.9977	-0.2303%
1993	98.651	1.0029	0.2896%	1.0029	0.2896%
1994	98.828	1.0018	0.1798%	1.0018	0.1798%
1995	98.526	0.9969	-0.3105%	0.9969	-0.3105%
1996	98.262	0.9973	-0.2704%	0.9973	-0.2704%
1997	98.209	0.9995	-0.0500%	0.9995	-0.0500%
1998	98.277	1.0007	0.0700%	1.0007	0.0700%
1999	98.347	1.0007	0.0700%	1.0007	0.0700%
2000	98.769	1.0043	0.4291%	1.0043	0.4291%
2001	98.601	0.9983	-0.1701%	0.9983	-0.1701%
2002	98.508	0.9991	-0.0900%	0.9991	-0.0900%
2003	98.723	1.0022	0.2198%	1.0022	0.2198%
2004	98.59	0.9987	-0.1301%	0.9987	-0.1301%
2005	98.244	0.9965	-0.3506%	0.9965	-0.3506%
2006	97.973	0.9972	-0.2804%	0.9972	-0.2804%
2007	96.404	0.9840	-1.6129%	0.9840	-1.6129%
2008	91.322	0.9473	-5.4139%	0.9473	-5.4139%
2009	97.878	1.0718	6.9339%	1.0718	6.9339%
2010	94.119	0.9616	-3.9157%	0.9616	-3.9157%
2011	93.678	0.9953	-0.4711%	0.9953	-0.4711%

Table 5.21: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Dammam branch using SFA (1988-2011)

	Dammam TE	EC	EC %	TFPG	TFPG (%)
1988	94.709				
1989	94.649	0.9994	-0.0600%	0.9994	-0.0600%
1990	94.124	0.9945	-0.5515%	0.9945	-0.5515%
1991	93.905	0.9977	-0.2303%	0.9977	-0.2303%
1992	93.793	0.9988	-0.1201%	0.9988	-0.1201%
1993	96.343	1.0272	2.6837%	1.0272	2.6837%
1994	95.497	0.9912	-0.8839%	0.9912	-0.8839%
1995	93.333	0.9773	-2.2962%	0.9773	-2.2962%
1996	93.561	1.0024	0.2397%	1.0024	0.2397%
1997	94.05	1.0052	0.5187%	1.0052	0.5187%
1998	92.385	0.9823	-1.7859%	0.9823	-1.7859%
1999	92.141	0.9974	-0.2603%	0.9974	-0.2603%
2000	91.687	0.9951	-0.4912%	0.9951	-0.4912%
2001	92.353	1.0073	0.7273%	1.0073	0.7273%
2002	92.398	1.0005	0.0500%	1.0005	0.0500%
2003	96.86	1.0483	4.7170%	1.0483	4.7170%
2004	96.563	0.9969	-0.3105%	0.9969	-0.3105%
2005	96.183	0.9961	-0.3908%	0.9961	-0.3908%
2006	98.122	1.0202	1.9999%	1.0202	1.9999%
2007	95.435	0.9726	-2.7782%	0.9726	-2.7782%
2008	91.303	0.9567	-4.4265%	0.9567	-4.4265%
2009	97.992	1.0733	7.0738%	1.0733	7.0738%
2010	92.023	0.9391	-6.2833%	0.9391	-6.2833%
2011	93.422	1.0152	1.5086%	1.0152	1.5086%

Table 5.22: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Qassim branch using SFA (1988-2011)

	Qassim TE	EC	EC %	TFPG	TFPG (%)
1988	98.859				
1989	98.828	0.9997	-0.0300%	0.9997	-0.0300%
1990	94.689	0.9581	-4.2803%	0.9581	-4.2803%
1991	95.372	1.0072	0.7174%	1.0072	0.7174%
1992	97.294	1.0202	1.9999%	1.0202	1.9999%
1993	98.464	1.0120	1.1929%	1.0120	1.1929%
1994	97.201	0.9872	-1.2883%	0.9872	-1.2883%
1995	97.303	1.0010	0.1000%	1.0010	0.1000%
1996	98.803	1.0154	1.5283%	1.0154	1.5283%
1997	98.675	0.9987	-0.1301%	0.9987	-0.1301%
1998	98.996	1.0033	0.3295%	1.0033	0.3295%
1999	98.859	0.9986	-0.1401%	0.9986	-0.1401%
2000	97.445	0.9857	-1.4403%	0.9857	-1.4403%
2001	98.28	1.0086	0.8563%	1.0086	0.8563%
2002	98.642	1.0037	0.3693%	1.0037	0.3693%
2003	99.026	1.0039	0.3892%	1.0039	0.3892%
2004	98.001	0.9896	-1.0454%	0.9896	-1.0454%
2005	96.549	0.9852	-1.4911%	0.9852	-1.4911%
2006	97.861	1.0136	1.3508%	1.0136	1.3508%
2007	89.806	0.9177	-8.5885%	0.9177	-8.5885%
2008	84.504	0.9410	-6.0812%	0.9410	-6.0812%
2009	97.408	1.1527	14.2107%	1.1527	14.2107%
2010	91.946	0.9439	-5.7735%	0.9439	-5.7735%
2011	92.155	1.0023	0.2297%	1.0023	0.2297%

Table 5.23: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Khamis branch using SFA (1988-2011)

	Khamis TE	EC	EC %	TFPG	TFPG (%)
1988	94.516				
1989	94.389	0.99866	-0.1341%	0.99866	-0.1341%
1990	91.42	0.96855	-3.1955%	0.96855	-3.1955%
1991	91.517	1.00106	0.1059%	1.00106	0.1059%
1992	92.996	1.01616	1.6031%	1.01616	1.6031%
1993	94.678	1.01809	1.7928%	1.01809	1.7928%
1994	93.807	0.99080	-0.9243%	0.99080	-0.9243%
1995	90.414	0.96383	-3.6840%	0.96383	-3.6840%
1996	90.326	0.99903	-0.0970%	0.99903	-0.0970%
1997	91.529	1.01332	1.3232%	1.01332	1.3232%
1998	91.066	0.99494	-0.5073%	0.99494	-0.5073%
1999	87.532	0.96119	-3.9583%	0.96119	-3.9583%
2000	86.011	0.98262	-1.7533%	0.98262	-1.7533%
2001	85.142	0.98990	-1.0151%	0.98990	-1.0151%
2002	87.758	1.03073	3.0267%	1.03073	3.0267%
2003	92.545	1.05455	5.3114%	1.05455	5.3114%
2004	93.923	1.01489	1.4780%	1.01489	1.4780%
2005	95.264	1.01428	1.4179%	1.01428	1.4179%
2006	98.458	1.03353	3.2980%	1.03353	3.2980%
2007	92.455	0.93903	-6.2908%	0.93903	-6.2908%
2008	89.105	0.96377	-3.6903%	0.96377	-3.6903%
2009	98.101	1.10096	9.6183%	1.10096	9.6183%
2010	91.903	0.93682	-6.5264%	0.93682	-6.5264%
2011	92.256	1.00384	0.3833%	1.00384	0.3833%

Table 5.24: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Tabuk branch using SFA (1998-2011)

	Tabuk TE	EC	EC %	TFPG	TFPG (%)
1998	98.083				
1999	98.635	1.0056	0.5584%	1.0056	0.5584%
2000	98.678	1.0004	0.0400%	1.0004	0.0400%
2001	98.572	0.9989	-0.1101%	0.9989	-0.1101%
2002	98.872	1.0030	0.2996%	1.0030	0.2996%
2003	99.183	1.0031	0.3095%	1.0031	0.3095%
2004	99.212	1.0003	0.0300%	1.0003	0.0300%
2005	99.214	1.0000	0.0000%	1.0000	0.0000%
2006	98.763	0.9955	-0.4510%	0.9955	-0.4510%
2007	99.207	1.0045	0.4490%	1.0045	0.4490%
2008	97.507	0.9829	-1.7248%	0.9829	-1.7248%
2009	98.671	1.0119	1.1830%	1.0119	1.1830%
2010	97.455	0.9877	-1.2376%	0.9877	-1.2376%
2011	97.382	0.9993	-0.0700%	0.9993	-0.0700%

Table 5.25: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Almadinah branch using SFA (1998-2011)

	Almadinah TE	EC	EC %	TFPG	TFPG (%)
2008	96.017				
2009	98.058	1.0213	2.1037%	1.0213	2.1037%
2010	96.758	0.9867	-1.3349%	0.9867	-1.3349%
2011	96.982	1.0023	0.2317%	1.0023	0.2317%

Table 5.26: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Hail branch using SFA (2008-2011)

	Hail TE	EC	EC %	TFPG	TFPG (%)
2008	94.055				
2009	97.722	1.0390	3.8249%	1.0390	3.8249%
2010	93.475	0.9565	-4.4433%	0.9565	-4.4433%
2011	93.673	1.0021	0.2118%	1.0021	0.2118%

Table 5.27: Total factor productivity growth (TFPG), technical change (TC) and efficiency change (EC) of Aljouf branch using SFA (2008-2011)

	Aljouf TE	EC	EC %	TFPG	TFPG (%)
2008	92.085				
2009	97.606	1.0600	5.8231%	1.0600	5.8231%
2010	93.302	0.9559	-4.5102%	0.9559	-4.5102%
2011	94.247	1.0101	1.0079%	1.0101	1.0079%

5.8. Findings of the interviews with branch managers

Upon a close examination of the milling industry in the Kingdom of Saudi Arabia from the standpoint of branch managers, a number of observations have arisen, as summarised in Table 5.28. Most branch managers (88.89%) have very limited experience in the milling industry due to lack of access to training courses related to their profession, with the exception of the Almadinah branch manager who did receive one training course in the field of Technology of Milling Industry.

In addition, there is poor communication amongst branch managers in terms of exchanging expertise in the milling industry. As for communication between branch managers and the Director-General of the GSFMO, this takes place though field visits, email and telecommunication. The majority of branch managers stated that visits are often paid once a year (77.78%), except for managers in the Riyadh branch (11.11%) who pointed out that the process of visiting takes place twice a year and the Jeddah branch (11.11%) who reported that such visits take place according to the needs and requirements of work inside the mills.

There are seemingly some benefits as far as the milling industry is concerned, emanating from replacing local wheat with an imported alternative. These benefits comprise cleanness of imported wheat, lack of impurities and high extraction rates compared to local wheat. In addition, the increased percentage of moisture in the imported wheat helps in the milling process. However, there are several problems voiced by consumers especially in terms of how to use imported flour due to the bakers’ lack of knowledge when it comes to the types of ingredients to be added; not to mention the low protein content in imported wheat, while the increased moisture makes imported wheat more susceptible to insects.

The GSFMO incurs huge losses, which can be attributed to several factors as stated by the respondents, including the fact that the state sets the selling price of produced flour, while the price of imported wheat and some production inputs have increased considerably in recent years. One can also list the high operating costs and the number of breakdown hours, in addition to the lack of specialised expertise in the milling industry. According to 44.45% of the branch managers, machinery is quite old, while 44.44% stated that branch facilities and infrastructure are poor.

As suggested by the respondents, one can overcome the problems and difficulties facing the milling industry by increasing the financial allocation to the branches and by preparing a list of incentives which can attract specialised cadres in the milling industry. In addition, old machinery and equipment should be modernised in some branches, and the procedures of privatisation of the mills speeded up, while the private sector should be allowed to exercise a more active role in the milling industry. In the end, attending more training courses has been well underscored by the branch managers for more efficient workers.

It should be pointed out that four of the 13 interviews were conducted with General Managers in the GSFMO who are not directly linked to the branches. All four interviewees had views similar to those reported in the abovementioned discussion of the branch managers' findings.

Table 5.28: Summary of the interviews results with branch managers

	(%)		(%)
Attending courses	11.11	benefits from replacing local wheat with imported	66.67
Received courses after being manager	44.44	losses attributed to industry-specifics such as fixing of the flour selling price by the government and rising prices of imported wheat and some production inputs	88.89
Frequent communication between branch managers and the Director-General of the GSFMO through visits/phone calls/emails or all.	100	losses attributed to branch-specifics such as Lack of expertise in the milling industry and increasing the number of breakdown hours	100
Increased financial support is required	55.55	Machines used in the milling industry are new	55.55
Branch facilities are excellent, such as roads and services	44.44	Machinery used in the milling industry is old	44.45

5.9. Summary

In conclusion, this chapter has provided an overview of the TE results for all the branches of the GSFMO using DEA and SFA approaches. As for DEA, emphasis was on the average TE covering the years from 1988 to 2011, as well as the TE under CRS and VRS-input and output orientated for all branches. By contrast, the SFA used both Cobb-Douglas and Translog production functions to estimate TE using exponential distribution and half-normal distribution. The study concluded that the Cobb-Douglas Production function is more appropriate than the Translog Production functions in the pooled SFA because the Translog model suffers from a non-convergence estimation problem. In addition, the second stage regression was presented in this chapter. According to the findings of the second stage regression, the mangers' age, bad infrastructure, and temperature have been shown to have a significant negative relationship with TE, while experience did not have any significant relationship with TE. On the other hand, number of mills in each branch and new and mix (new and old) machine conditions have been shown to have significant positive relationship with TE.

One of the limitations for the second stage regression is that the data was confined to a four-year period given the braches different operational ages and as the type of data does not allow the researcher to ask the current branch managers about infrastructure and machinery condition in previous years such as during the 1990s.

Furthermore, the CE and AE results under CRS and VRS input-orientated for all branches were illustrated in detail. As shown in the results, there is a significant scope to decrease inputs costs in the production process. One may ascribe the losses incurred by the organisation to the decline in CE and AE in all branches, among other factors. One limitation in relation to the estimation of CE and AE is that only the input-orientated assumption was utilised because the flour price is fixed by the Saudi government.

When using DEA and SFA methods, the productivity growth using DEA has been explored in two different ways. First by taking the average results of the years from 2008 to 2011, followed by taking the results yearly (2008-2009, 2009-2010, and 2010-2011) for TC, EC and TFPG.

However, the scope of this paper is limited with respect to the estimation of productivity growth since it was based on a small sample size (four years only), while results could have been made more robust if the DEA-PIM software allowed unbalanced data. To compensate for the small sample size, productivity growth was estimated using SFA for 24 years (1988-2011).

To avoid the DEA disadvantages, such as balanced data requirement resulting in the limitation of short duration (4 years) of analysis, the SFA method was chosen because it does not impose these restrictions and hence it covers the whole period of the study (24 years) from 1988 to 2011. Results, which were slightly different from the DEA results, showed that most of the older branches have decreased EC and TFPG. As revealed in the DEA findings, TFPG is ascribed to an increase or decrease in TC and EC, while the SFA findings can be attributed to EC only with no improvement in TC.Also, this chapter included findings pertaining to the branch managers' interviews, which indicated that there is a very limited managerial experience in the milling industry due to lack of access to training courses. In addition, there appears to be poor communication between branch managers in terms of exchanging expertise in the milling industry. As for the GSFMO huge losses, the interviewees attributed them to several factors, such as the flour price fixing by the government to keep it low for the population and the rise in the price of imported wheat and some production inputs. Also, respondents pointed out to the high operating costs and the number of breakdown hours, in addition to the poor infrastructure and the lack of specialised expertise in the milling industry.

6. DISCUSSION CHAPTER

6.1. Introduction

The approach taken throughout the study has been to estimate efficiency using different techniques in order to provide robust results. More specifically, efficiency has been estimated using the DEA and SFA, under different returns to scale conditions and assumptions, and in a different production function assumptions within the SFA approach. Then, via a second stage analysis, the preferred approach was examined to improve the performance of the GSFMO in Saudi Arabia, given the public ownership and monopolistic nature of flour mills.

In this chapter, the main findings with regard to the study objectives are summarised and general conclusions based on the findings are analysed and described in detail.

Specifically, the chapter sets out the main results of TE using DEA and SFA, and highlights the impact of managerial, machine condition, infrastructure condition number of mills in each branch and temperature on TE levels. It also sheds light on the main results of CE and AE. This is followed by analysis of productivity growth results using DEA and SFA.

6.2. The Main Results of TE Using DEA

The GSFMO has 11 branches distributed all over the KSA. Nine of these branches accommodate 22 mills; each branch achieved different levels of TE. In this discussion, the main goal is to explain these differences by comparing and contrasting the results in the areas of CRS, VRS-input orientated and VRS-output orientated approaches. For the sake of having robust results from all branches, individual branches were brought together into wider groups for the purpose of this discussion. Branches are divided into three groups, with the first group consisting of branches operating over the long term (24 years), such as Riyadh, Jeddah, Dammam, Qassim and Khamis. The second group refers to the only branch operating over the medium term (13 years), which is the Tabuk branch. The third group involves branches operating over the short term (only four years), including Almadinah, Hail and Aljouf. The comparison and contrast will be conducted within each group rather than between different groups because every group has different characteristics.

Starting with TE under CRS for all branches, the average TE ranged between 91.72% in the Khamis branch and 97.63% in the Almadinah branch. When considering each of the three groups, TE under CRS for the first group, it shows that the Khamis branch achieved the lowest TE of 91.71% while the Jeddah branch achieved the highest TE of 97.07% (Table 5.1). As the only branch in the second group, the Tabuk branch has an average TE under CRS of 97.59%. In the third group, which includes Almadinah, Hail and Aljouf branches, the branch with the highest mean TE is Almadinah with 97.63%, while the Hail branch has the lowest mean TE with 94.37%.

Under VRS input-orientated, the average TE varies between 93.16% in the Dammam branch and 98.77% in the Jeddah branch. By considering each of the three groups, the average TE for the first group (long term branches) ranges from 93.16% (Dammam branch) to 98.77% (Jeddah branch). In the second group (medium term; the Tabuk branch only), the average TE under VRS-input orientated is 98.04%. Within the third group, the average TE under VRS-input orientated was found to vary from 94.43% (Hail branch) to 97.75% (Almadinah branch). The average TE under VRS output-orientated ranges between 93.21% in the Dammam branch and 98.79% in the Jeddah branch as noted in VRS input orientated results.

When considering branches in each of the three groups, the average TE under VRS output-orientated ranges from 93.21% in the Dammam branch to 98.79% in the Jeddah branch (first group). The average TE is 93.40% in the Tabuk branch (second group). The average TE ranges from 94.47% in the Hail branch to 97.97% in the Almadinah branch (third group).

While the above results provide an overview of TE across the groups, this does not demonstrate the full range of TE estimates across all years and all branches. Through an examination of TE in every year, it was possible to find the lowest and highest TE scores and identify peer branches achieving 100% TE which could become a benchmark for the least efficient branches, and thus provide the optimal input and output amounts which could be achieved by the inefficient branches to enable them to operate on the efficient frontier, as explored in Chapter 5. This is consistent with the findings of Mulwa *et al*. (2009) and Dhungana *et al.* (2004). Dhungana *et al.* estimated economic inefficiency of Nepalese rice farms using DEA noting that benchmarking against the efficient branches can be extremely useful in terms of setting targets and identifying defects in existing practices. Moreover, the comparatively efficient branches can still enhance their efficiency levels by adopting the best allocation decisions of other efficient branches. For instance, when the average TE is estimated under CRS, the Khamis branch has the lowest average TE (91.72%), and the Jeddah branch has the highest average TE (97.07%). When TE is estimated for each branch yearly under CRS, it ranges from 82.66% in the Qassim branch in 2008 (first group) to 100% in the Riyadh branch in 2004 and 2005 (first group). In addition to exploring average and yearly results, the need arises for more discussion of the results to consider the difference in TE estimates between branches under both DEA- CRS and VRS.

The study also found that the mean TE under CRS is less than the mean TE under VRS assumptions, which can be observed in all results presented in Chapter 5.

For instance, the mean TE under CRS in the Khamis branch is 91.72%, whilst the mean TE under VRS input and output orientated for the Dammam branch is 93.16% and 93.21% respectively; these two branches represent the lowest mean TE among all branches. These results are consistent with previous literature such as Bhagavath (2009), and Alrwis and Francis (2003). It has also been observed that TE estimated under VRS is greater than TE under CRS when branches were analysed every year during the period of study; this conforms with results obtained by Abatania *et al.* (2012).

With respect to the third group (new branches; Almadinah, Hail and Aljouf) TE under CRS or VRS does not fall below 92%. On the other hand, the first group, which includes old branches (Riyadh, Jeddah, Dammam, Qassim and Khamis), has achieved the lowest TE under CRS and VRS. For example, in 2011, the Qassim branch was inefficient in terms of man hours. In order to achieve 100% TE, the branch should reduce the number of man hours by 70.49% to produce the same output, or to increase its output by 66.29%, utilising the same inputs (Figure 6.1).

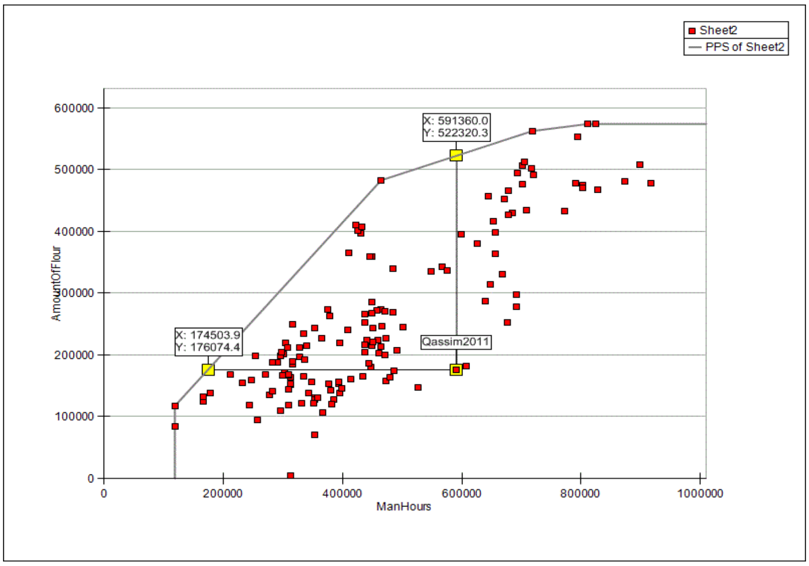

Figure 6.1: TE of the Qassim branch in terms of man hours (2011)

The TE reduction in the first group suggests that older branches can show lower TE than newer branches. This corresponds with the results of Zhou (2014) when estimating the impact of foreign direct investment (FDI) in firms' TE on the manufacturing firms of five African countries where it was confirmed that the older firms have lower TE than the younger firms.

6.3. The Main TE Results Using SFA

In addition to using DEA, SFA analysis was undertaken to calculate efficiency using pooled SFA method with both Cobb-Douglas and Translog production functions. Both exponential and half-normal distribution assumptions were specified. To estimate TE, Jump Markov Linear System (JMLS) and Battese-Coelli (BC) were used. Prior to a calculation of SFA, the parsimonious model of Cobb-Douglas and Translog production functions for the dataset was evaluated by utilising three important statistical diagnostic tests of Breusch-Pagan test for heteroskedasticity, Variable Inflation Factor (VIF) test for multicollinearity and Ramsey RESET test for misspecification in order to identify the robust model.

When testing Cobb-Douglas and Translog production functions, the Cobb-Douglas form passed the Breusch-Pagan test for heteroskedasticity. The second test Variable Inflation Factor (VIF) clarifies that variables in the model do not have severe multicollinearity. Because there are no VIF values above 10 for the Cobb-Douglas model, this means that the independent variables in the model are not closely correlated with each other so that the influence of each independent variable to the dependent variable can be observed. However, the model failed the third test (Ramsey RESET test) for misspecification, which observes whether the model excluded independent variables that can explain changes in the dependent variable.

The same three tests were applied to the Translog production function, and the result shows that the model passed the Breusch-Pagan test for heteroskedasticity, and the Ramsey RESET test for misspecification. The model failed the multicollinearity test in the VIF test. However, this is expected because there are second order effects and interactions in the Translog which are naturally correlated. Regardless of the Cobb-Douglas production function model's failure in the misspecification tests, and the Translog failure of the multicollinearity test, both models were chosen for this study because the data used was the only data available to the researcher. However, in interpreting the result, it is important to consider the failure of the models under these tests.

In order to estimate TE using pooled SFA with Cobb-Douglas and Translog production functions, two assumptions of exponential distribution and half-normal distribution were used. When Cobb-Douglas is used, TE under exponential distribution for all branches varies between 87.45% and 99.21% using JMLS estimator, and between 87.48% and 97.24% using the BC estimator. Moreover, TE under half-normal distribution ranges from 84.49% to 99.48% using JMLS estimator, and from 84.50% to 95.36% using the BC estimator (Table 5.8). This shows that TE under half-normal distribution is lower than TE under exponential distribution when using both JMLS and BC. It is also noticed that the correlation between results under exponential and half-normal distribution using JMLS and BC is very high as it ranges between 0.9522 and 1.000 (Table 5.9). This means that both distribution assumptions have resulted in very similar TE values. Examining both assumptions, the pooled SFA Cobb-Douglas function under half-normal distribution using the BC estimator was chosen since the results in both assumptions and estimators (exponential and half-normal distribution using JMLS and BC) are very similar. In addition, the BC estimator is more widely used because of its simplicity and availability (Kutlu, 2010) and as it calculates TE values directly, compared to JMLS estimator which has to calculate inefficiency first before efficiency. TE appears to be high, but there is still scope for further increase in the various branches, which is consistent with the results of Kehinde and Awoyemi (2009).

Unfortunately, when the Translog production function is run with pooled SFA using exponential and half-normal distribution, this translog model specification suffers from non-convergence issues. This problem caused a perpetual iteration processes so the model could not find optimal solutions under both exponential and half-normal distribution assumptions. Due to this problem, it is concluded that pooled SFA with Cobb-Douglas production function is more suitable to be used for this study.

6.4. The main Findings of Second Stage Regression

Not only is the study of TE important, but also the factors affecting variation in efficiency. Therefore, in this section, the factors affecting TE of the GSFMO branches such as managerial factors (branch managers' age, experience and education level), machine condition, number of mills, infrastructure and temperature are considered. To keep the data balanced, regression analysis is performed on all nine branches for four years only (2008-2011) because of the differences in operational ages of branches. Wilson *et al.* (2001) also carried out a short period study (five years) when they estimated the influence of management characteristics on TE. Also, it was found that the required type of data to be collected would be too difficult to obtain since current branch managers may not be able to recall or have a background idea about machines and infrastructure condition in previous years. Concerning the educational level of the branch managers in all branches, the researcher found a similarity in the level of education except for one manager, which has been omitted from the second stage regression.

When estimating the second stage regression, Tobit regression analysis was used because it is more suitable than Ordinary Least Squares (OLS) (Coelli *et al.*, 2002; Tingley *et al*., 2005). The findings obtained from the effect of branch managers' age, experience, age of machine, number of mills, temperature and infrastructure conditions on TE may in part, explain the reason for the decrease in

TE in the GSFMO branches. Relating to the branch managers' age, a significant negative relationship with TE was found. This means that, *ceteris paribus*, if managers are younger by one year, this will result in TE being higher by 0.34% under CRS. Furthermore, under input-orientated and output-orientated VRS, when managers are one year younger, this leads to a higher TE by 0.44% for both estimated TE approaches. This indicates that the younger branch managers are more technically efficient than their elder counterparts, which is consistent with findings of Tingley *et al.* (2005), Kehinde *et al.* (2010), Dlamini *et al*. (2010) and Amaechi *et al.* (2014). Arguably younger managers are likely to be more receptive to new technology and new practices. This conforms to the findings attained by Coelli and Battese (1996), Wadud and White (2010) and Akinbode *et al*. (2011). Concerning experience, the branch managers' experience was found to have no statistical significant relationship with TE although estimates indicate negative relationship with TE. Contrary to this study, other researchers have found that experience has a significant and positive effect on TE, such as Wilson *et al.* (2001), Begum *et al*. (2009), Narala and Zala (2010) and Khai and Yabe (2011).

In relation to machine condition, these were divided into three categories; new, old and mixed. Under CRS and VRS assumptions, branch use of new machinery has a positive relationship with TE. For example, the branch which has new machinery is expected to have a higher TE by 4.94% compared to a branch with old machinery under CRS. While under VRS input and output-orientated, this branch is expected to have a higher TE by 5.73%, and 5.76% respectively with new machines. As for branch use of mixed machines (new and old), this has an insignificant relationship with TE under CRS and VRS assumptions. Regarding the branch number of mills, if a branch has an additional mill, TE will be increased by 2.87%, 3.72% and 3.69% under CRS, VRS-input orientated and VRS-output orientated, respectively. This signifies that the number of mills has an effect on efficiency of the branches. In other words, if a branch has more than one mill, this can lead to an increase in efficiency. This is consistent with the findings of a number of studies, including Ferrantino and Ferrier (1995), Wilson *et al.* (2001) and Bekele and Belay (2007) where larger firm size was positively linked to TE.

In terms of infrastructure condition, 'good infrastructure' condition does not have a significant effect on TE, while 'poor infrastructure' has a negative significant relationship with TE. For instance, a branch will have a lower TE by 11.15% compared to a branch with an average infrastructure condition under CRS. Under input and output-orientated VRS, a branch with bad infrastructure is estimated to have a lower TE by 10.61% and 10.09% respectively in comparison to branch with an average infrastructure. These results are consistent with Coelli *et al.* (2002) who found that poor infrastructure has negative effects on both TE and AE. The temperature element was selected based on the highest degree Celsius experienced in each branch in every year. This factor is found to have a negative significant relationship with TE. For example, one degree Celsius increase in peak temperature will lead to lower TE by 0.85% under CRS. On the other hand, under input and output-orientated VRS, high temperature can lower TE by 0.78% and 0.75% respectively. In support of this finding the lowest TE in the first group is 82.66% under CRS and VRS input orientated, and 83.07% under output orientated in 2008 in the Qassim branch when the temperature was highest compared with the other years.

In regard to the second group, the Tabuk branch has the lowest TE of 93.60% under CRS, 93.77% under VRS input orientated and 93.60% under VRS output orientated in 2008. It is observed that TE in the first and second groups was low in the year 2008. The low TE in these groups could be due to the high temperature identified for that year compared to the other years (Riyadh 46.8 degrees, Jeddah 48 degrees, Dammam 49 degrees, Qassim 47 degrees and Khamis 43.4 degrees, and Tabuk 45 degrees), which might have affected the machinery and labour leading to several breakdowns. This is consistent with Jeffers and Rubenthaler (1977) who studied the effect of temperature on flour yield. They found that as mill temperature increased because of friction and usage of the mill, there was a decrease in flour yield.

There are additional reasons for the increase and decrease of efficiency for all branches which was taken from the interviews with branch managers. For instance, the respondents reported that the high TE identified in some branches during some years in the study period, could be attributed to the fact that the branch managers depend on attracting local, as well as foreign expertise when seeking access to relevant information regarding the milling industry. Also, the respondents reported that one of the reasons for the high efficiency could be related to the very good condition of the facilities, roads and support services associated with the milling industry as mentioned above. In addition, the high efficiency achieved in some branches during certain years can be ascribed to the internal and external training received by the branch managers. This result is consistent with the suggestion of Narala and Zala (2010) that training programmes could improve practices, thus leading to greater efficiency.

On the other hand, the low efficiency in some branches was attributable to the lack of training, experience and specialisation for the majority of managers in the milling industry. Furthermore, the decrease in the efficiency of some branches in some of the years is largely due to the lack of technical manpower specialised in the milling industry as one of the major reasons, followed by an increase in the number of breakdown hours experienced by the mills. Another major issue causing the inefficiency is the lack of financial incentives to attract high quality labour and the lack of spare parts for machinery and equipment. Finally, the branch managers claim that the decrease of efficiency in some branches is probably due to the lack of communication and exchange of skills between branch managers. This finding is consistent with Akinbode *et al.* (2011) when they assert that contact between farmers and the more educated farmers has contributed to an increase in TE. Other branch managers ascribed the financial losses to the fixed government price and lack of competitive environment as the flour production is not under the private sector. Figure 6.2 explains some of the reasons for the declining TE and financial losses incurred by the organisation when interviews were conducted with the branch managers. While almost half the respondents reported old machinery as one of the reasons, almost all participants highlighted increased machine breakdowns, lack of training in the field of milling industry and the fixed flour price by the government as the key factors for low efficiency and financial losses.

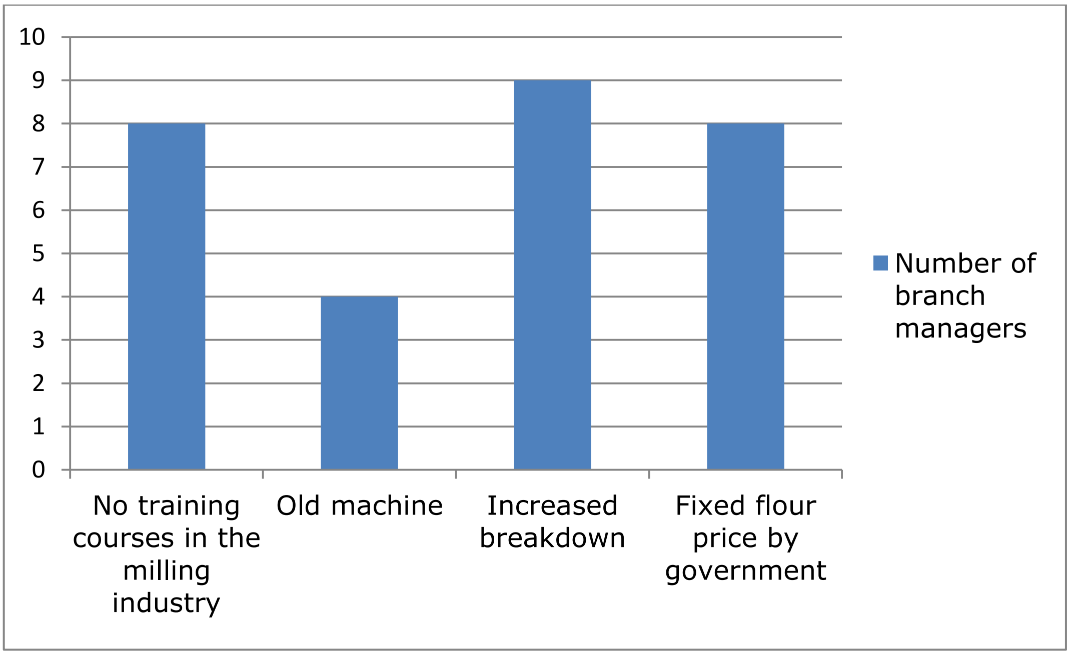

Figure 6.2: The reasons for the declining TE and the financial losses in the branches

6.5. The main results of CE and AE for all branches

In relation to the objective of this study, CE and AE estimation for all branches was carried out to clarify reasons behind the financial losses of the organisation.

Since Saudi Arabian government has fixed the flour price, the focus of this study has excluded the output-orientated approach for CE and AE estimation because it is not relevant. Thus, the input-orientated assumption has been used. By estimating the average CE and AE for the groups' branches, it showed that the average CE under CRS ranges between a minimum of 53.90% in the Qassim branch and a maximum of 63.13% in the Riyadh branch. While under VRS input-orientated, the Qassim branch has the lowest average CE (56.29%), and the Riyadh branch has the highest average CE (67.67%).

When considering each of the three groups, the average CE is found to range between 53.90% in the Qassim branch and 63.13% in the Riyadh branch under CRS (first group). While under VRS input-orientated in the same group, the average CE is low in the Qassim branch (56.29%), and high in the Riyadh branch (67.67%). Regarding the average CE in the second group, the Tabuk branch has an average CE under CRS of 56.87%, while the average CE under VRS input-orientated is 59.22%. Finally, the third group has an average CE under CRS that ranges between 45.75% in the Aljouf branch, and 56.35% in the Almadinah branch, while the average CE under VRS input-orientated ranges between 57.39% in the Aljouf branch and 58.68% in the Almadinah branch.

In regard to the average of the AE under CRS and VRS input-orientated, this ranges between 56.76% in the Qassim branch and 66.51% in the Riyadh branch under CRS (first group). However, under VRS input-orientated in the same group, the average CE is low in the Qassim branch (58.55%) and high in the Riyadh branch (70.24%).

The Tabuk branch has an average CE under CRS of 60.26%, whereas the average CE under VRS input-orientated is 61.65% (second group). In the last group, the average CE under CRS ranges between 57.83% in the Aljouf branch and 59.52% in the Almadinah branch, whilst the average CE under VRS input-orientated ranges between 59.87% in the Aljouf branch and 61.21% in the Almadinah branch.

When examining the average CE and AE scores, as an old branch, Qassim has the lowest average CE and AE. However, when CE and AE are estimated for each branch separately during the whole period of study, it is shown that new branches (Almadinah, Hail and Aljouf) have the lowest CE and AE compared with older branches.

From the decrease of the CE and AE scores in the majority of the branches, there is a scope for production cost reduction, which is consistent with the results of Singh *et al.* (2000) when estimating efficiency and productivity analysis of cooperative dairy plants in Haryana and Punjab states of India. The significant lower estimates for CE and AE relative to TE in all branches can be described as one of the reasons for the losses incurred by the organisation since CE and AE are substantially lower than TE. This is consistent with Elhendy and Alkahtani (2013) when studying the resource use efficiency of conventional and organic date farms in Saudi Arabia using DEA. In conclusion, there should be more attention and focus on CE and AE estimation than on TE for the GSFMO to avoid financial losses every year. This result is confirmed by Thanassoulis (2001) when asserting that CE and AE are more important than TE alone for a branch since they take costs or revenues into consideration. This is also consistent with Ogundari and Ojo (2006) when they reported that estimation of efficiency should not only be confined to TE, but should also include AE and CE. The significant decrease in CE and AE could also be explained by the fact that the inputs are utilised in the wrong proportions. As such, AE could be improved by better use of resources in ideal proportions in terms of their price and state of technology (Elhendy and Alkahtani, 2013). In addition, being publicly owned by the Saudi government, the GSFMO is expected to be less efficient than other similar companies in the private sector, which has been confirmed in a number of studies (Ferrantino and Ferrier, 1995; Meibodi, 1998; Alabi and Mafimisebi, 2004; Bekele and Belay, 2007; See and Coelli, 2012 and Makuyana and Odhiambo, 2014). There are a number of factors which can lead to inefficiency of state owned enterprises, including the laws and regulations imposed by the government like fixed flour prices in the case of the GSFMO. Some management decision-making processes can also restrict efficiency in terms of the general administration and policies of the organisation and reduce the latter's speed and flexibility to respond to market and other developments in the business world, which has also been confirmed by Bekele and Belay (2007).

6.6. The Main Results of Total Factor Productivity Growth (TFPG) for all Branches Using DEA and SFA

In this section, the main TFPG results using DEA and SFA approaches are described. These results facilitate explanation of whether there has been a decrease or increase in technical change (TC) and efficiency change (EC), as these two elements (TC and EC) contribute directly to increased or decreased TFPG.

6.6.1. The Main TFPG results using DEA

In estimating productivity growth using DEA, which requires balanced data the researcher has chosen a four year period (2008-2011). Reviewing the average productivity growth in the three groups of the GSFMO during this period, it has been shown that there is no change in the average TC in the Riyadh and the Qassim branches, while there is an increase for the Jeddah, the Dammam and the Khamis branches with an average rate of 0.67% per annum for each (first group). The average EC in the same group shows that there are no changes in the Riyadh, the Jeddah and the Dammam branches, while there is an increase in the Qassim branch (3%), and the Khamis branch (0.33%). The average TFPG has experienced no change in the Riyadh branch contrary to other branches in the same group. However, some branches in the first group have witnessed an increase in the average TFPG such as the Jeddah and the Dammam and the Khamis branches (0.67%), and the Qassim branch (3.33%).

As for the second group, the productivity growth shows that the Tabuk branch has no change in TC, while there is a decrease in both EC and TFPG by the same ratio (0.67%). On the other hand, the third group shows that the Almadinah branch has not incurred any change in TC, EC or TFPG, while the Hail branch has shown a decrease in TC and EC (0.33%) and TFPG (1.00%). As for Aljouf, it has a decrease in TC (0.00167%), EC (0.33%) and TFPG (0.70%). These results show that EC is smaller than TC in most instances. This is consistent with Headey *et al.* (2010) when they estimated agricultural productivity growth for 88 countries and with Odeck (2007) in an analysis of TE and productivity growth by comparing DEA and SFA assessment of Norwegian grain producers. Finally, when the average TFPG has been estimated in all branches, the TFPG in older branches is higher than in new branches.

6.6.2. The Main TFPG results using SFA

When estimating productivity growth using DEA, this study has been limited in scope because it is based on a small balanced data (four years only) set. Also, the results could have been made more robust if the DEA facilitated productivity growth using unbalanced data during the period of the study. To overcome the small size restrictions under DEA, it was decided to also estimate productivity growth using SFA for 24 years (1988-2011). To estimate productivity growth using SFA, the approach taken followed Kumbhakar and Lovell (2000) where the production frontier in which TFPG = technical change (TC) + efficiency change (EC) + scale efficiency change (SEC). Estimating and especially decomposing TFPG is essential for a number of factors, with the latter providing valuable insights into the sources of TFPG and allowing policy makers to take into account the most significant sources (Vencappa *et al.,* 2008).

Since the coefficient of the time variable is equal to zero, this means that there is no technological change in the industry detected using this approach (TC = 0).

The productivity growth for the three groups shows that in the first group, the average EC and TFPG have decreased in all the branches except for the Riyadh branch, in which it has increased. The second group also shows a decrease in the average of EC and TFPG. In the third group, the average EC and TFPG has increased in the Almadinah and the Aljouf branches, while the Hail branch average has decreased in both EC and TFPG. This indicates that most branches' average EC and TFPG has decreased. However, EC and TFPG have decreased more older branches than new branches.

6.7. Comparison of TE Results and Productivity Growth Using DEA and SFA

To be specific in a comparison of TE results and productivity growth using DEA and SFA approaches, the study has chosen pooled SFA Cobb-Douglas under half-normal distribution-BC estimator against DEA TE results. As shown in the results of TE using SFA and DEA, estimated TE results were quite similar in all branches (Appendices 23-29). When comparing the long term operating branches (the first group), the Riyadh branch shows that TE ranged between a maximum of 98.77% under SFA and 100% under DEA (both CRS and VRS) and a minimum of 92.01% under SFA and 91.44% (DEA-CRS), and 91.56% and 91.71% respectively for DEA VRS-input orientated and DEA VRS-output orientated (Appendix 23). It is also clear from Appendix 24 that the Jeddah branch has the highest mean TE under SFA (97.74%); under DEA-CRS (97.07%); under VRS-input orientated (98.77%), and under VRS-output orientated (98.79%). According to Appendix 25, the Dammam branch has a higher TE under SFA than under DEA. For example, TE varies from a maximum of 98.12% under SFA and 96.60% under

DEA-CRS. As for TE under VRS-input orientated and VRS-output orientated, it has reached 97.59% and 97.64% respectively. These results are comparable to Tingley *et al*. (2005) when estimating factors affecting TE in the English Channel Fisheries. Tingley *et al.* found that SFA TE results are greater than DEA TE results.

However, in contrast, for the Tabuk branch, which is a medium term operating branch (second group), TE has been shown to be higher under DEA than under SFA. For example, TE reached 100% under DEA (both CRS and VRS) and 99.48% under SFA (Appendix 27). This is consistent with Cullinane *et al*.'s (2006) findings which confirm that SFA TE results are lower than DEA TE results when estimating TE for the world's largest container ports.

Regarding short term operating branches, it is clear that the Almadinah branch is similar to the Tabuk branch in that TE was higher under DEA (100%) than SFA (98.06%). Unlike the Almadinah branch, the Hail branch has shown different results in the mean TE whereby TE is greater under SFA (94.73%) than under DEA (94.37% under CRS; 94.43% under VRS-input orientated; 94.47% under VRS-output orientated). On the other hand, the Aljouf branch results have shown quite significant differences compared with other branches. Notably, the maximum TE scores has reached 100% under DEA VRS-input and output orientated; however, TE is lower under DEA CRS (97.08%) than SFA (97.61%) (Appendix 28).

Overall, and as anticipated, TE scores under SFA have not reached 100% while DEA TE results have reached 100% in some of the branches. Also, Table 6.1 shows a correlation between TE results using DEA and SFA methods, indicating that there is a significant correlation between them at 95% confidence interval, which means that there is a slight difference between TE calculated from both methods DEA and SFA. These finding have been observed by Iraizoz *et al*. (2003)

when assessing TE of horticultural production in Navarra, Spain. In their study, Iraizoz *et al*. found that there are strong similarities between DEA and SFA results for TE in Spanish farms.

Table 6.1: The correlation between TE results using DEA and SFA

		TE under SFA	TE under CRS	TE under VRS input	TE under VRS output
TE under SFA	Correlation Coefficient	1	0.883**	0.867**	0.867**
	Sig. (2-tailed)	-	0.002	0.002	0.002
	N	9	9	9	9

** Correlation is significant at 95% confidence interval.

In regard to comparing the average TFPG results using DEA and SFA, the first group under DEA has increased for all branches except the Riyadh branch which remains unaffected, while the first group under SFA has decreased in average TFPG for all branches except for the Riyadh branch which has increased. Under DEA and SFA, the second group (the Tabuk branch only) has decreased when both methods have been applied. As for the third group under DEA, the Almadinah branch has seen no changes in average TFPG, while the Hail branch has decreased, and the Aljouf branch has increased in average TFPG. On the other hand, regarding the third group using SFA, the Almadinah and the Aljouf branches have increased, while the Hail branch has decreased in the average TFPG. In relation to the average TFPG using DEA and SFA from the results mentioned above, similarities have been noticed in some results as in the second group in which a decrease is found in the average of TFPG in the Tabuk branch. Also in the Hail branch, as one of the third group branches, there has been a decrease under both models DEA and SFA.

Among the differences in results of TFPG using DEA and SFA is the length of the period of data used. Under DEA, a four year period was chosen because DEA requires balanced data (Anders, 2007), whilst under SFA the period chosen is 24 years. The findings using DEA reveal that TFPG is attributed to an increase or decrease in TC and EC, and the results under SFA can be ascribed to EC only with no improvement in TC.

Examining the study objectives and research questions, this study has identified that the problems facing the milling industry in Saudi Arabia, include the monopoly of the organisation of the milling industry and the storage capacity of wheat silos which has been the same for many years even though there could be an increase in the wheat used, which is likely to lead to extra transportation costs due to the movement of the wheat between branches. Also there was an increase in the cost of production per tonne of flour from the salaries and wages, operating costs, and maintenance costs.

With respect to the losses incurred by the GSFMO, some of the reasons for the losses include the low CE and AE in all branches. Also the high temperature in the summer season has affected the performance of machine and human productivity. Lastly, the bad infrastructure condition along with old machinery has reduced the efficiency of the mills which in turn affected the TE levels. There are also additional factors like breakdown of machines, lack of skilled workers in the milling industry and lack of worker training which have had an impact on the performance and have caused losses. The fixed government price could have also counted towards the financial losses, as reported by the respondents.

Concerning the resources question which could be used to lower the production cost and achieve 100% TE, there are lists of targets calculated from DEA approach for each branch which can be used to determine inputs and outputs to lower the cost of production and give 100% TE. Another question is concerned with the best methodological approach to be taken; it is argued here that the answer is the DEA method because it is more appropriate based on the advantages it offers.

The researcher's suggestions are related to the appropriate technique of measuring efficiency in different settings (Table 6.2). These suggestions draw upon the review of literature and the empirical results in Chapters 3 and 5, respectively. When selecting the appropriate technique, it is imperative to keep in mind different issues; first, the economic performance of the country in which the study is undertaken as well as any sector-specific institutional context. Second, the availability and quality of the data are of those important factors in determining the most appropriate measures of efficiency. As a result, the focus here will be on suggesting measures for different situations in the agricultural sector. This sector choice as a focal point of the discussion is based on the application in the current study since the milling industry is part of the agricultural sector in Saudi Arabia. For example, in the case of developed countries, it is expected to have a better quality data over a longer period of time compared to developing countries. In addition, the agricultural sector is likely to be market-oriented. Given these circumstances, the researcher suggests the SFA method as the more appropriate technique. If this holds true, one can benefit from the advantages offered by the SFA technique and separate any deviations from efficiency into two parts; systematic errors and inefficiency, which is more realistic in practice due to measurement errors, and in agriculture due to uncontrolled factors in the production process. On the other hand, in the case of developing countries where data are less available and its quality is more questionable, and if the agricultural sector is under the government control, it is highly recommended to apply the DEA method. According to the findings of this study, the DEA was more preferred for a number of reasons.

The DEA approach has been used in this study because it gives a clear estimation of the performance of each branch with detailed measurement of efficient and inefficient branches. In addition, DEA is known for the simplicity of its results with estimates derived directly from the information examined. Also, DEA provides a list of target values to improve insufficient branches by using these targets (Schaffnit *et al*. 1997). Other research has indicated that DEA is a popular tool for measuring efficiency (Barnes *et al*. 2009).

Moreover, it is argued here that, for this current study, the use of DEA approaches and results are more appropriate because the sample size available is small (Khan and Uzma, 2014). Moreover, the DEA approach facilitates the provision of extensive managerial information by giving a list of targets which can be used to increase TE and decrease production costs. The DEA methods can also be used in almost any industry and are able to accommodate multiple outputs and inputs, in addition to their ease of calculation and interpretation (Coelli *et al.*, 2002). In addition, DEA allows for careful observation of peer groups and enables management to gain further insights on how to improve the performance of each branch compared with benchmarking (efficient) branches. This approach was followed by Thanassoulis (2001) and Ebnerasoul *et al*. (2009) when they stated that because DEA estimates each DMU against its own benchmark(s) that possess similar features, sources of inefficiency can be evaluated and measured, while target performance can be determined. Based on DEA efficiency score results, managers can identify factors impacting on performance (e.g. old vs. new machinery) by estimating the second stage regression. Through DEA results, it is possible to use the most efficient branches to reassess job responsibilities and provide training for managers, especially in the milling industry. For example, managers from high efficient branches can be moved to less efficient branches to help raise their efficiency levels. In the case of the GSFMO, when using the DEA to estimate TE, the VRS input-orientated can be suggested because the GSFMO has been facing financial losses; thus, the objective is to reduce costs by reducing inputs, while keeping the same amount of output. If the VRS output-orientated approach is used by GSFMO, however, this may increase outputs, but still incur losses as inputs cannot be reduced and the price of output (flour) is fixed by the government. As a developing country, Saudi Arabia should introduce privatisation programs and implement an independent regulatory system to monitor the process of transition from publicly owned ownership to the private sector.

Table 6.2: The appropriateness of DEA and SFA techniques

Country	Context	Data set	Market	Recommend
Developing	Agriculture	Large	Free	DEA or SFA
			Monopoly	DEA or SFA
		Small	Free	DEA
			Monopoly	DEA
Developed	Agriculture	Large	Free	SFA
			Monopoly	NA
		Small	Free	DEA
			Monopoly	DEA

6.8. Summary

This section provides a summary of the main findings with regard to the general research study and objectives. In particular, the chapter shows the average results of TE and productivity growth using DEA and SFA, as well as the average CE and AE results. The impact of managerial, machine condition, infrastructure condition, number of mills and temperature on TE levels has also been estimated.

In terms of TE results using DEA, it was found that the mean TE under CRS is less than the mean TE under VRS assumptions. Another significant result is that older branches were shown to have lower TE than newer branches. In respect to TE results using SFA, the Cobb-Douglas was more appropriate for this study than the Translog production function because the latter model specification was found to suffer from non-convergence issues.

Discussing the second stage regression results, the findings obtained from the effect of branch managers' old age, old machine, high temperature and bad infrastructure conditions have a negative significant relationship with TE, while new and mixed machinery and number of mills have positive significant impact on TE in the GSFMO branches. As for experience, it was found that it has no significant impact on TE. Based on the estimated CE and AE in most of the branches, it seems that there is a scope for production cost reduction, which has been a major reason for the losses incurred by the organisation.

Furthermore, the empirical findings point to a clear variation in efficiency across branches. The robust approaches employed identified the key reasons underlying variation in efficiency across branches. Moreover, in light of the suggested recommendations, which will be explored in more detail in Chapter 7, it is recognised that there may be cost implications for investing in infrastructure and managerial challenges of changing the number of workers or machinery usage, as these inputs are often related to each other and to their level of overall usage. Therefore, any recommendations that might be drawn need to be based upon both the results generated and how practical they may be to implement.

The empirical findings generated also have implications for policy makers in that if Saudi Arabia wishes to have a stable and cost effective supply of flour, policy makers may need to put in place the conditions to help the GSFMO undertake these recommendations. For example, policy makers may provide incentives to invest in new machinery and/or new infrastructure. This can be done through offering subsidised investments to enable the GSFMO to improve the infrastructure, given that the milling industry needs to be improved for security reasons. As a result, policy makers have to support the GSFMO in order to facilitate the delivery of these recommendations.

The chapter also compared the results of TE and TFPG using DEA and SFA. Concerning TE results using SFA and DEA, they were shown to be quite similar in all branches. As for TFPG, under DEA, the study included a four year period because the model requires balanced data, whilst under SFA the period covered a 24 year period. While findings using DEA reveal that TFPG was attributed to increase or decrease TC and EC, the results under SFA were ascribed to EC and no improvement in TC. The next chapter provides some concluding thoughts and touches on some recommendations and limitations based on the aforementioned discussion of the findings.

7. CONCLUSION, LIMITATIONS AND RECOMMENDATIONS CHAPTER

7.1. Conclusion

Given the lack of previous studies on the milling industry in Saudi Arabia, combined with the future prediction of shortages of, and a decline in agricultural activities in the Kingdom, this study aims to estimate and explain variation in efficiency and productivity in order to make the GSFMO more efficient and therefore assist the national economy in general. In addition, a study of the current situation of flour mills in the GSFMO unveiled a number of issues, including the monopoly of the organisation of the milling industry in the Kingdom of Saudi Arabia and the losses incurred by the organisation every year in spite of the governmental annual financial support.

Specifically, this research has set out to estimate TE, CE, AE and TFPG of the flour mills of the GSFMO in Saudi Arabia using both DEA and SFA approaches and to explain the efficiency variation levels between the various branches. This has been achieved by drawing on data on the production activities of the GSFMO for a period of 24 years from 1988 to 2011. In addition to measuring the TE, AE and CE of the GSFMO's branches, using DEA and SFA, the other objectives included an estimation of productivity growth using DEA (2008-2011) and SFA (1988-2011).

The thesis has motivated this study by introducing a background discussion of the agriculture sector and production of wheat in Saudi Arabia. An extensive discussion of the theoretical framework was presented in chapter 2. The literature review was approached in terms of efficiency measurement studies in developing and developed countries, by using DEA, SFA or a combination of both (DEA and SFA). This study used primary data, including interviews with 13 managers, and secondary data produced by the GSFMO for a period of 1988-2011 to cover the nine milling branches. For the sake of consistency, the researcher has grouped these milling branches into three distinct groups according to their life, to long term (24 years), medium term (13 years) and short term (4 years).

Using the PIM software in the DEA analysis, the findings of this study showed that input- and output-orientated TE was estimated under the specifications of CRS and VRS. TE under CRS yielded lower scores than TE under VRS. As for TE results using SFA, this study used the pooled SFA with Cobb-Douglas because when running the Translog production function with pooled SFA, some non-convergence issues were encountered. Applying the Cobb-Douglas production function, TE under half-normal distribution was thus shown to be lower than TE under exponential distribution when using both JMLS and BC. It was also noticed that the correlation between results under exponential and half-normal distribution using JMLS and BC was very high as it ranged between 0.95 and 1.00. Both distribution assumptions were shown to have very similar TE scores. The study opted for the pooled SFA Cobb-Douglas function under half-normal distribution using BC estimator because the results in both assumptions and estimators (exponential and half-normal distribution using JMLS and BC) were very similar. Moreover, BC estimator is more widely used and estimates TE scores directly, in comparison to JMLS estimator which has to compute inefficiency first before efficiency. In summary, the SFA results were quite similar to those using DEA.

Regarding the CE and AE results, the results show that there is a significant scope to reduce inputs costs in the production process. It can be said that losses incurred by the organisation may be ascribed to a large extent to the declining CE and AE in all branches, among other factors. To analyse TFPG in the various branches of the GSFMO, the DEA-PIM software was also utilised for a four year period (2008-2011). The mean results of TFPG confirmed that in spite of the increase in TFPG, TC, and EC in some branches, there was no change in TFPG, TC, and EC for both the first group (the Riyadh branch) and the third group (the

Almadinah branch). In contrast, there was a decrease in the TC, EC and TFPG in the third group (the Hail branch). However, the scope of this paper is limited with respect to the estimation of productivity growth since it was based on a small sample size (four years only), while results could have been made more robust if the DEA-PIM software allowed unbalanced data. To compensate for the small sample size, productivity growth was estimated using SFA for 24 years (1988-2011). Results, which were slightly different from the DEA results, showed that most of the older branches have decreased EC and TFPG. As opposed to findings using DEA, which revealed that TFPG was ascribed to an increase or decrease in TC and EC; the results under SFA were comparatively attributed to EC and no improvement in TC.

In terms of the second stage regression, which was used to estimate the effect of mangers' age, experience, temperature, machine condition, number of mills in each branch and bad infrastructure on TE, it was found that while mangers' age, experience, and bad infrastructure had significant negative relationship with TE, experience did not have any significant relationship with TE. However, number of mills in each branch and new and mix (new and old) machine conditions were shown to have significant positive relationship with TE.

7.2. Limitations

A number of limitations have been encountered while carrying out the research study. One of these limitations pertains to the data, which has been grouped according to the duration of operation. For example, when estimating productivity growth under DEA, the sample was confined to four years only because the model has to be based on balanced data, which has not been possible since three of the nine branches have only been operational since 2008.

In addition, there are also limitations related to the number of observations in the data sample overall, especially within the SFA approach, due to the relatively small number of milling branches and their operational age: the small number of observations is arguably why the Translog production function run with pooled SFA failed to achieved convergence. This resulted in a perpetual iteration process due to the limited number of observations.

Also, when estimating CE and AE using DEA, the input orientated assumption only was used, and not the output orientated approach, because the flour price is fixed by the government in order to make it affordable for the local population. Another limitation is that this study does not estimate CE and AE using SFA, which can be achieved in the future when the data is available for more observations. Finally, the interviews have only been restricted to the branch managers and have not taken into account a more diverse sample of workers.

7.3. Recommendations for the GSMFO and for Future Research

In order to improve efficiency and productivity growth in the milling industry in Saudi Arabia, a number of recommendations and suggestions are drawn from the results of this study. The branches of the GSFMO have to lower their costs of production, which can be guided by targets calculated from DEA for each branch. For example, the first group (the old branches of Riyadh, Jeddah, Qassim, Dammam, and Khamis) has the lowest average TE. For the Qassim branch which was inefficient under CRS- input orientated in 2011 to be efficient (100% TE), it should reduce the amount of wheat used by 9.13%; machine hours by 26.52%; and man hours by 44.56% with the same output (Table 7.1 and Appendix 27).

With respect to the second group (Tabuk) under CRS-input orientated in order for it to be efficient from the 2011 reference point, it should reduce the amount of wheat used by 6.24%; machine hours by 6.24%, and man hours by 28.02% while producing the same output (Table 7.1 and Appendix 31). In addition, under CRS- input orientated, the Hail branch (one of the third group of new branches) should reduce the amount of wheat used by 6.89%; machine hours by 6.89%;

and man hours by 26.63% from the 2011 reference point while producing the same output (Table 7.1 and Appendix 32).

Table 7.1: All branches target under CRS-input orientated (2011)

Branch	TE%	Amount of wheat %	Machine hour %	Man hour %
Riyadh	94.01	-5.99	-5.99	-5.99
Jeddah	92.14	-7.86	-33.33	-7.86
Dammam	91.73	-8.27	-25.57	-16.45
Qassim	90.87	-9.13	-26.52	-44.65
Khamis	90.47	-9.53	-10.99	-9.53
Tabuk	93.76	-6.24	-6.24	-28.02
Almadinah	96.43	-3.57	-3.57	-20.37
Hail	93.11	-6.89	-6.89	-26.63
Aljouf	93.69	-6.31	-6.31	-24.16

Another recommendation for the GSFMO is to use the peers group identified in this study as a benchmark for less efficient branches. Therefore, those groups which consist of branches that have characteristics similar to the inefficient ones under examination can be used for comparison for less efficient branches to imitate. As such, branches which define the best practice frontier can be used as a reference set for the less efficient ones. For example, the Riyadh branch in 2011 was inefficient; however, the peer group or benchmark for the Riyadh branch in 2011 were the Riyadh branch in 2004, 2005 and the Tabuk branch in 1999 (Appendix 46).

Also, since high temperature has had a significant negative relationship with efficiency in all branches, the GSFMO is advised to improve the condition of the milling industry by using air conditioners where machines are located, especially in the summer season which can affect the level of machine performance. In addition, the GSFMO should develop its milling infrastructure to eliminate bad infrastructure condition.

Given that managers who were younger had a positive relationship with efficiency, it is important that the organisation provides adequate training for older managers and workers in order for them to keep abreast of the latest technological developments, and how to use such technology, to improve the overall efficiency of the industry.

Even though education level was not used as a variable in this study considering that all participants had the same educational level (Bachelor's Degree) except for one (high school diploma), it is equally essential to note that this variable has had a significant positive relationship with efficiency as shown in several studies (Wilson *et al.,* 2001; Tingley *et al.,* 2005; Begum *et al.,* 2009 and Ogundari 2010). Therefore, branch managers should seek to attain higher qualifications, especially if such qualifications are related to the milling industry. Studying the current situation of the flour mills, it was found that the storage capacity of the silos has remained the same size for many years, while the amount of wheat used has kept increasing due rising demand. As such, the GSFMO should expand its silos' capacity in order to minimise the movement of wheat used in between branches and the transportation costs resulting from such movement.

One of the additional factors mentioned by the branch managers was the lack of spare parts as often these parts have to be ordered from outside the Kingdom, which can take a long time; thus affecting the milling process. In the light of such deficiency, the organisation should either agree with the supplying companies to have a spare parts branch in Saudi Arabia or hold these parts for emergencies. Also, the branch managers stated the shortage of incentives offered to employees. Therefore, the organisation should offer incentives for these workers to avoid demotivated workers that may leave their jobs once they have gained sufficient experience.

It is also recommended that the Government of Saudi Arabia does not fix the flour price, while at the same time encouraging the private sector to enter the milling industry and create a competitive industry. According to the results, the GSFMO, which falls under the public sector, has been found to be inefficient. This suggests that the process of privatising the milling industry be speeded up and the public GSFMO be transferred into the private sector. This recommendation is consistent with Chirwa (2000) who studied privatisation and technical efficiency with evidence from Malawi manufacturing. As confirmed in the findings, privatisation in Malawi is associated with high mean TE in privatised enterprises and competing state-owned enterprises and private enterprises. Other studies also confirmed that public firms are less efficient than the private ones (Ferrantino and Ferrier, 1995; Meibodi, 1998; Alabi and Mafimisebi, 2004; Bekele and Belay, 2007; See and Coelli, 2012 and Makuyana and Odhiambo, 2014). Finally, the government should reconsider the actual operation of the mills and how it can achieve optimum performance based on the results of this research, which can minimise the production costs and lead to reduced losses for the organisation. Given that this is the first study which has been conducted on the milling industry in Saudi Arabia, it is paramount that the GSFMO should make data regarding the organisation in general, and the individual mills in particular, accessible for future researchers.

For future research, attention should be paid to a number of issues, including the time period of the study, especially for the newly established branches. Since the present research only involved a period of four years (2008-2011) for these branches, it is now possible to extend the duration of the data collection. In addition, once the organisation makes the data available by prior to 1988, which is the starting year of the current study, the number of observations will increase in return, thus making it potentially possible to use alternative efficiency measurement methods such as the translog production function. Moreover, future studies may consider using DEA output orientated approaches to estimate CE and AE if the government ceases fixing the price of flour, following privatisation of the GSMFO. Another equally important department is the human resources sector of the GSFMO, which may also redistribute workers according the needs of the branches.

8. REFERENCES

Abatania, L. K.; Hailu, A.; and Mugera, A. W. (2012) "Analysis of farm household TE in Northern Ghana using bootstrap DEA". Paper presented at the 56th annual conference of the Australian Agriculture and Resource Economics Society, School of Agricultural and Resource Economics, The University of Western Australia.

Adhikari, C. B. and Bjorndal, T. (2012) "Analyses of TE using SDF and DEA models: evidence from Nepalese agriculture". *Applied Economics*, 44, 3297-3308.

Afriat, S. N. (1972) "Efficiency estimation of production functions." *Inter. Econ. Rev.* 13: 568-98.

Agricultural Development Fund (2010), Research and Studies Department. Riyadh, Saudi Arabia.

Aigner, D.J., Lovell, C.A.K., and Schmidt, P. (1977) "Formulation and estimation of Stochastic Frontier Production Function Models". *Journal of Econometrics* 6: 21-37.

Akinbode, O. S.; Dipeolu, O. A., and Ayinde, A. I. (2011) "An examination of technical, allocative and economic efficiencies in Ofada rice farming in Ogun State, Nigeria''*. African Journal of Agricultural Research*. Vol. 6(28), pp. 6027-6035.

Alabi, R. A., and Mafimisebi, T. E. (2004) "Increasing private participation in agriculture through privatization". Paper prepared for presentation at the Farm Management Association of Nigeria Conference, Abuja, Nigeria.

Ali, M. and Chaudhry, M.A., (1990) "Inter-regional Farm Efficiency in Pakistan's Punjab: A Frontier Production Function Study". *Journal of Agricultural Economics,* 41(1): 62-74.

AlKhathlan, K. (2010) "Are Saudi Banks Efficient? Evidence Using Data Envelopment Analysis (DEA)". *International Journal of Economics and Finance*. Vol. 2, No. 2.

Al-Obeid, A. A. (2002) "Future plan for the agricultural sector in the light of local and global developments". A Paper submitted to an International Conference on the Future Vision on the Saudi Economy until 2020.

Alrwis, K. N. and Francis, E. (2003) "Technical, Allocative, and Economic Efficiencies of Broiler Farms in the Central Region of Saudi Arabia: Data Envelopment Analysis Approach". J. Saudi Soci. of Agric. Sci., Saudi Arabia, 1(2):pp., (73-99).

Amaechi, E. C. C.; Ewuziem, J. E., and Agunanna (2014) "Estimation of Technical Efficiency in the Translog Stochastic Production Function Model: An Application to the Oil Palm Produce Mills Industry in Nigeria". *Advances in Applied Science Research*. 5(3), pp. 230-236. Pelagia Research Library.

Amirteimoori, A. and Kordrostami, S. (2012) "A Distance-based Measure of super efficiency in Data Envelopment Analysis: an Application to Gas Companies". *J Glob Optim*. 54: 117-128.

Amungwa, F. A. (2009) "Appraisal of privatisation of agricultural extension services in Cameroon" *Journal of Agricultural Extension and Rural Development* Vol. 1(3). pp. 085-092.

Anders, I. (2007) "World Productivity Database: a technical description" United Nations, Industrial Development Organisation, Research and Statistics Branch Staff Working Paper, Vienna.

Anderson, D. R.; Sweeney, D. J.; Williams, T. A.; Freeman, J.; and Shoesmith, E. (2010) *Statistics for Business and Economics* (2^{nd} Ed.). Hampshire: Cengage Learning EMEA.

Anouze, A. (2010) "Evaluating productive efficiency comparative study of commercial banks in Gulf countries". Thesis submitted to the University of Aston in part fulfillment of the requirements of the degree of Doctor of Philosophy.

Assaf, A. G.; Barros, C. P. and Matousek, R. (2010) "Technical efficiency in Saudi bank". *Expert Systems with Applications*. Elsevier Ltd.

Avkiran, N.K. (2001) ''Investigating technical and scale efficiencies of Australian Universities through data envelopment analysis'', *Socio-Economic Planning Sciences* 35 (2001) 57-80.

Banaeian, N; Omid, M.; and Ahmadi, H. (2011) "Application of Data Envelopment Analysis to Evaluate Efficiency of Commercial Greenhouse Strawberry". *Research Journal of Applied Sciences, Engineering, and Technology* 3(3): 185-193.

Banker, R. D.; Potter, G.; and Schroeder, R. G. (1993) "Reporting manufacturing performance measures to workers: an empirical investigation", *Journal of Management Accounting Research*, vol. 3. pp. 33-55.

Banker, R.D.; Charnes, A.; and Cooper, W.W. (1984) "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis", *Management Science*, 30, 1078-1092.

Barnes, A. (2008) "TE Estimates of Scottish Agriculture: A Note". *Journal of Agricultural Economics*, Vol. 59, No. 2, 370-376.

Barnes, A.P.; Moran, D., and Topp, K. (2009) "The scope for regulatory incentives to encourage increased efficiency of input use by farmers". *Journal of Environmental Management*. 90, 808-814. Elsevier.

Battese, G. E. and Corra, G. S. (1977) "Estimation of a Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia". *Australian Journal of Agricultural Economics,* 21: 167-179

Bauer, P. W., Berger; A. N.; Ferrier, G. D.; and Humphrey, D. B. (1998) "Consistency conditions for regulatory analysis of financial institutions: A comparison of frontier efficiency methods", *Journal of Economics and Business*, forthcoming.

Begum, I.A; Buysse, J.; Alam, M.J.; and Huylenbroeck, G.V. (2009) “An Application of Data Envelopment Analysis (DEA) to Evaluate Economic Efficiency of Poultry Farms in Bangladesh”. Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.

Bekele, T. and Belay, K. (2007) "TE of the Ethiopian Grain Mill Products Manufacturing Industry". *Journal of Rural Development* 29(6): 45-65.

Bhagavath, V. (2009) "TE Measurement by Data Envelopment Analysis: An Application in Transportation". *AJBR Alliance Journal of Business Research*.

Bhat, R., Bhushan, B. and Reuben. E., (2001) An empirical analysis of district hospitals and grant-in-aid hospitals in Gujarat state of India. Ahmedabad: Indian Institute of Management.

Bogetoft, P. and Otto, L. (2011) *Benchmarking with DEA, SFA, and R.* New York: Springer

Castiglione, C. (2012) "TE and ICT investment in Italian manufacturing firms". *Applied Economics*, 44, 1749-1763. Routledge

Castiglione, C. (2012) "Technical efficiency and ICT investment in Italian manufacturing firms". *Applied Economics*, 44, 1749-1763. Routledge

Caves, D. W.; Christensen, L. R.; and Swanson, J. A. (1980) "Productivity in US railways 1951–1974". *Bell Journal of Economics* 11, 166–181.

Chambers, R. G. (1988) *Applied Production Analysis*. Cambridge: Cambridge University Press

Charnes, A.; Cooper, W.; Lewin, A. Y.; and Seiford, L. M. (1994) Data Envelopment Analysis. Theory, Methodology and Applications: Massachusetts: Kluwer Academics Publishers Group.

Charnes, A.; Cooper, W.W.; and Rhodes, E. (1978) "Measuring the efficiency of decision making units". *European Journal of Operational Research*. 2 (1978) 429-444. North-Holland Publishing Company.

Chirwa, E. W. (2000) "Privatisation and Technical Efficiency: Evidence from Malawi Manufacturing" Senior Lecturer in Economics University of Malawi, Chancellor College.

Christensen, L. R.; Jorgenson, D. W.; and Lau, L. J. (1973) "Transcendental Logarithmic Utility Functions". *The Review of Economics and Statistics*, Vol. 55, No. 1 (Feb., 1973), pp. 28-45.

Cobb, C. W. and Douglas, P. H. (1928) "A Theory of Production," *Americana Economic Review* 8 (Mar. 1928), 139-165.

Coelli, T. J. and Battese, G. E. (1996) "Identification of factors which influence the technical inefficiency of Indian farmers''. *Australian Journal of Agricultural Economics*. 40: 2, 103-128.

Coelli, T. J.; Rahman S.; Thirtle, C. (2002) "Technical, allocative, cost and scale efficiencies in Bangladesh rice cultivation: A non-parametric approach". *J. Econ.* 53(3): 607-626.

Coelli, T.; Rao, D.S. P.; and Battese, G.E. (1998) *An Introduction to Efficiency and Productivity Analysis.* London: Kluwer Academic Publishers.

Coelli, T.; Rao, D.S.P.; O'Donnell, C.J.; and Battese, G.E. (2005) *An Introduction to Efficiency and Productivity Analysis* (2^{nd} Ed.). New York: Springer

Collis, J. and Hussey, R. (2003) Business Research, (2nd Edition), UK: Palgrave Macmillan.

Cook, W. D. and Zhu, J. (2005) *Modeling Performance Measurement: Applications and implementations Issues in DEA*. New York: Springer

Cooper, W.W.; Seiford, L.M.; and Zhu, J. (Eds.). (2004) *Handbook on Data Envelopment Analysis*. Boston, MA: Kluwer Academic Publishing.

Cullinane, K.; Wang, T.F; Song, D. W.; and Ji, P. (2006) "The TE of container ports: comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part* A 40, pp. 354-374.

Debreu, G., (1951) "The coefficient of resource utilization", *Econometrica* 19, 273-292

Dhungana, R.B.; Nuthall, L. P., and Nartea, V. G. (2004) "Measuring the economic inefficiency of Nepalese rice farms using data envelopment analysis". *The Australian Journal of Agricultural and Resource Economics*. 48:2, pp. 347-369. Australian Agricultural and Resource Economics Society Inc. and Blackwell Publishing Ltd.

Dlamini, S.; Rugambisa, J. I.; Masuku, M. B.; and Belete, A. (2010) "TE of the small scale sugarcane farmers in Swaziland: A case study of Vuvulane and Big bend farmers". *African Journal of Agricultural Research*. Vol. 5(9), pp. 935-940.

Du, J.; Chen, C.; Chen, Y.; Wade, D.; Cook, D.; and Zhue, J. (2012) "Additive Super-efficiency in Integer-valued Data Envelopment Analysis". *European Journal of Operational Research*. 218. 168-192

Ebnerasoul, S. A. (2009) "Performance Evaluation of Organizations: An Integrated Data Envelopment Analysis and Balanced Scorecard Approach". International Journal of Business andManagement. Vol. 4, No. 4

Efron, B. (1979) Bootstrap methods: another look at the jackknife. *The Annals of Statistics 7*(1): 1 – 26*.*

Elhendy, A. M. and Alkahtani, S. H. (2013) "The Resource Use Efficiency of Conventional and Organic Date Farms in Saudi Arabia: A Date Envelopment Analysis Approach". *The Journal of Animal & Plant Sciences*, 23(2), pp. 596-602.

Fan, Y.; Li, Q.; and Weersink, A. (1996) ''Semiparametric estimation of stochastic production frontier models''. *Journal of Business and Economic Statistics* 14: 460–68.

Fare, R.; Grosskopf, S.; Norris, M.; and Zhang, Z. (1994) Productivity Growth, Technical Progress and Efficiency Change in Industrialised Countries. *The American Economic Review*. Vol. 84, No.1 pp. 66-83

Farrell, M.J. (1957) "The Measurement of productive Efficiency", *Journal of the Royal Statistical society.* Vol. 120, series A (General).

Felipe, J. and F. G. Adams. (2005) "A Theory of Production" The Estimation of the Cobb-Douglas Function: A Retrospective View," *Eastern Economics Journal* 31: 427-446.

Ferrantino, M.J. and Ferrier, G.D. (1995) ''The TE of vacuum-pan sugar industry of India: An application of stochastic frontier production function using panel data'', *European Journal of Operational Research* 80 (1995) 639-653.

Fuss, M. and McFadden, D. (Ed.) (1978) Production Economics: A Dual Approach to Theory and Application (Volume 2), North-Holland Publishing Company. [online]. Available from:

http://elsa.berkeley.edu/~mcfadden/prodecon/apps/front_matter2.pdf
[Accessed 17-05-2013].

Giraleas, D. (2011) "Stochastic Frontier Analysis". *BNM825 Econometric Approaches to Efficiency and Productivity Measurement*. Aston University, unpublished material.

Gorton, M. and Davidova, S. (2004) ''Farm productivity and efficiency in the CEE applicant countries: A synthesis of results''. *Agricultural Economics* 30: 1–16.

GSFMO in Saudi Arabia, Department of Finance, various issues, (1990-2011) Lists of Budgets and profit and Loss Accounts. Riyadh.

GSFMO in Saudi Arabia, Department of Public Relations, various issues, (1988-2011) Annual Reports. Riyadh.

Guiffrida, A. and Gravelle, H. (1997) Measuring Performance in Primary Care: Econometric Analysis and DEA. University of York. Working Paper.

Guzman, I.; Arcas, N.; and Rivaroli, S. (2009) "TE in the fresh fruit and vegetable sector: a comparison study of Italian and Spanish firms". *Fruits*, vol. 64, p. 243-252.

Headey, D.; Alauddin, M., and Prasada Rao, D. S. (2010) "Explaining agricultural productivity growth: an international perspective''*. Agricultural Economics*. International Association of Agricultural Economics.

Henningsen, A. and Kumbhakar, S. C. (2009) Semiparametric Stochastic Frontier Analysis: An Application to Polish Farms During Transition, Paper presented at the (EWEPA) in Pisa, Italy.

Hjalmarsson, H.; Gevers, M.; and De Bruyne, F. (1996) "For model-based control design, closed loop identification gives better performance". *Automatica* 32(12), 1659–1673.

Iraizoz, B.; Rapun, M.; and Zabaleta, I. (2003) "Assessing the TE of horticultural production in Navarra, Spain". *Agricultural Systems* 78, pp. 387-403.

Ishengoma, E.K. (2005) *Firm's Resources As Determinants of Manufacturing Efficiency in Tanzania. Managerial and Econometric Approach.* London: LIT Verlag. [Online]. Available from <http://books.google.co.uk/books?id=nOL6zira_gwC&pg=PA27&source=gbs_toc_r&cad=4#v=onepage&q&f=false> [Accessed 23-03-2012].

Javed, M.I.; Khurshid, W.; Adil, S.A; Hassan, I.; Nadeem, N.; Ali, A.; and Raza, M.A. (2011) "Analysis of Technical and Scale Efficiency of Smallholder Farms of Rice-Wheat System in Punjab, Pakistan". J. Agric. Res., 49(1).

Jeffers, H. C. and Rubenthaler, G. L. (1977) "Effect of Roll Temperature on Flour Yield with the Brabender Quadrumat Experimental Mills". *Cereal Chem.* 54(5). 1018–1025. American Association of Cereal Chemists.

Johnes, J.; Bradley, S.; and Little, A. (2012) "Efficiency in the Further Education Sector in England". *Open Journal of Statistics*. 2, pp. 131-140.

Kaur, M., Mahal, A.K., Sekhon, M.K., and Kingra, H.S. (2010) "TE of Wheat Production in Punjab: A Regional Analysis", *Agricultural Economics Research Review*. Vol. 23, January-June 2010 pp 173-179.

Kehinde, A.L. and Awoyemi, T.T. (2009) "Analysis of Economic Efficiency in Sawnwood Production in Southwest Nigeria". *J. Hum Ecol*, 26(3): 175-183. Kamala-Raj.

Kehinde, A.L.; Awoyemi, T.T.; Omonona, B.T. and Akande, J.A. (2010) "Technical Efficiency of Sawnwood Production in Ondo and Osun states, Nigeria". *Journal of Forest Economics 16 (2010) 11-18*.

Khai, H. V. and Yabe, M. (2011) "TE Analysis of Rice Production in Vietnam", *J. ISSAAS*. Vol. 17(1), pp. 135-146.

Khan, A. and Uzma, N. (2014) ''Estimation Measure of Insurance v/s *Takaful* Firms Using DEA Approach: A Case of Pakistan''. *Islamic Economic Studies*. Vol. 22, No. 1, (139-158).

Kibirige, D. (2014) ''Estimation of Technical Efficiency among Smallholder Maize Farmers in Uganda: A Case Study of Masindi District of Uganda''. *International Journal of Economics, Commerce and Management*. UK. Vol. II, Issue 5.

Kontodimopoulos, N.; Moschovakis, G.; Aletras, V.H.; and Niakas, D. (2007) ''The effect of environmental factors on technical and scale efficiency of primary health care providers in Greece''. *Cost Effectiveness and Resource Allocation* 2007, 5: 14.

Koopmans, T.C. (1951) An analysis of Production as an Efficient Combination of Activities, In T.C. Koopmans (ed.), *Activity Analysis of Production and Allocation*. Wiley.

Krasachat, W. (2003) "Technical efficiencies of Rice Farms in Thailand: A Non-Parametric Approach". *Hawaii International Conference on Business*, Honolulu, June 18-21.

Kumbhakar, S. C. and Lovell, K. C. A. (2000) *Stochastic Frontier Analysis*. Cambridge: Cambridge University Press.

Kutlu, L. (2010) "Battese-coelli estimator with endogenous regressors". *Economics Letters*, 2010, vol. 109, issue 2, pages 79-81.

Luo, D.; Yao, S.; Chen, J.; and Wang, J. (2011) "World Financial Crisis and Efficiency of Chinese Commercial Banks". *The World Economy*. Oxford/MA: Blackwell Publishing Ltd.

Makuyana, G., and Nicholas M. Odhiambo, N. M. (2014) "The "dynamics of public and private investment in Malawi". *Problems and Perspectives in Management*, Volume 12, Issue 2.

Meeusen, W. and van den Broeck, J. (1977) "Efficiency estimation from Cobb-Douglas production functions with composed error". *International Economic Review* 18(2):435-444.

Meibodi, A. E. (1998) "Efficiency considerations in the Electricity Supply Industry: the case of Iran" Economics Departmental Research Seminar, University of Surrey, July 1998.

Miller, E. (2008) "An Assessment of CES and Cobb-Douglas Production Functions" [Online]. Available from: <http://www.cbo.gov/sites/default/files/cbofiles/ftpdocs/94xx/doc9497/2008-05.pdf> [Accessed 29-04-2012].

Ministry of Agriculture (2002) 'Future Plan for the Agricultural Sector'. Department of Studies, Planning, and Statistics.

Ministry of Agriculture, Department of Studies, Planning and Statistics (2011) The Annual Agricultural Statistics Handbook, Vol. 24.

Ministry of Agriculture, Department of Studies, Planning, and Statistics, various issues of the Agricultural Statistical Yearbook (2000-2011).

Mousavi-Avval, S. H.; Mohammadi, A.; Rafiee, S.; and Tabatabaaeefar,A. (2012) "Assessing the TE of energy use in different barberry production systems". *Journal of Cleaner Production* 27 (2012) 126-132.

Mulwa, M.R.; Emrouznejad, A.; and Murithi, F. M. (2009) "Impact of liberalization on efficiency and productivity of sugar industry in Kenya". *Journal of Economic Studies.* Vol. 36 No. 3, 2009, pp 250-264.

Murillo-Zamorano, L. R. and Vega-Cervera, J. A. (2001) "The use of parametric and non-parametric frontier methods to measure the productive efficiency in the industrial sector: A comparative study". *Int. J. Production Economics* 69, pp. 265-275.

Narala, A. and Zala, Y. C. (2010) "TE of Rice Farms under Irrigated Conditions in Central Gujarat" *Agricultural Economics Research Review*. Vol. 23 July-December 2010. Pp 375-381.

Odeck, J. (2007) "Measuring TE and productivity growth: a comparison of SFA and DEA on Norwegian grain production data". *Applied Economics*, 39, 2617-2630.

Odhiambo, W.; Nyangito, H. O.; and Nzuma, J. (2004) "Sources and Determinants of Agricultural Growth and Productivity". In Kenya *KIPPRA Discussion Paper No. 34*.

Ogundari, K. (2010) "Estimating and analysing cost efficiency of sawmill industries in Nigeria''*. China Agricultural Economic Review*. Vol. 2 No. 4, pp. 420-432.

Ogundari, K., and Ojo, S. O. (2006) "An examination of Technical, Economic and Allocative efficiency of Small Farms: The Case Study of Cassava Farmers in Osun State of Nigeria''*. Journal Central European of Agriculture*. Vol. 7 (2006), No. 3 (423-432).

Oyewo, I. O. (2011) "Technical efficiency of maize production in Oyo state", *Journal of Economics and International Finance*. Vol. 3(4), pp. 211-216.

Radam, A.; Yacob, M. R.; and Mohd Muslim, H. F. (2010) "Technical Efficiency of the Malaysian Wooden Furniture Industry: A Stochastic Frontier Production Approach". *International Business Research*. Vol. 3, No. 3.

Rawson, B.R. (2001) "Data Envelopment Analysis of Technical Efficiency in the UK Insurance Industry". Thesis submitted to the University of Nottingham for the degree of Doctor of Business Administration.

Ray, S.C. (2004) Data Envelopment Analysis: Theory and Techniques for Economics and Operations Research. Cambridge: Cambridge University Press.

Reinhard, S.; Knox Lovell, C. A.; and Thijssen, G. J. (2000) "Environmental efficiency with multiple environmentally detrimental variables; estimated with SFA and DEA", *European Journal of Operational Research*, 121, 287–303.

Richmond, J. (1974) "Estimating the Efficiency of Production". *International Economic Review*, 15 (2): 515-521.

Rouse, P., and Putterill, M. (2005) Local Government amalgamation policy: A highway maintenance evaluation. *Management Accounting Research* 16, 438-463.

Saudi Arabian Map. [Online]. Available from Google at <http://maps-asia.blogspot.co.uk/2011/09/saudi-arabia-map-political-regional.html> [Accessed 18-11-2011].

Saudi Council of Ministers, General Secretariat (2007) Procedures of Consumption Rationalisation of Water Resources in Saudi Arabia (N. 335).

Schaffnit, C.; Rosen, D.; and Paradi, J.C. (1997) ''Best practice analysis of bank branches: An application of DEA in a large Canadian bank'', *European Journal of Operational Research* 98 (1997) 269-289

See, F. K., and Coelli, T. (2012) "an analysis of factors that influence the technical efficiency of Malaysian thermal power plants''. *Energy Economics*. 34, 677-685.

Seiford, L.M. (1997) "A bibliography for Data Envelopment Analysis (1978 – 1996)", *Annals of Operations Research*, vol. 73, no. 46, pp. 393-438

Simar, L.; Wilson W.P. (1998) “Sensitivity analysis of efficiency scores: how to bootstrap in nonparametric frontier models”, *Management Science*, Vol. 44, No. 1, pp. 49-61.

Singh, S.; Fleming, E., and Coelli, T. (2000) "Efficiency and Productivity Analysis of Cooperative Dairy Plants in Haryana and Punjab States of India''*. Working Paper Series in Agricultural and Resource Economics*. ISSN. 1442, 1909.

Tavares, G. (2002) A Bibliography of Envelopment Analysis (*1978-2001*) RRR 01-02, January, 2002. [Online]. Available from: <http://rutcor.rutgers.edu/pub/rrr/reports2002/1_2002.pdf> [Accessed 07/01/2013].

Thanassoulis, E. (1993) "A comparison of regression analysis and data envelopment analysis as alternative methods for performance assessments". *Journal of the Operational Research Society*, Vol. 44, No 11, pp. 1129-1144.

Thanassoulis, E. (2001) *Introduction to the Theory and Application of Data Envelopment Analysis: A foundation text with integrated software.* Massachusetts: Kluwer Academic Publishing

Tingley, D.; Pascoe, S; and Coglan, L. (2005) "Factors affecting TE in fisheries: stochastic production frontier versus data envelopment analysis approaches" *Fisheries Research* 73. Pp. 363-376

Tsekouras, K.; Papathanssopoulos, F.; Kounetas, K.; and Pappous,G. (2010) "Does the adoption of new technology boost productive efficiency in the public sector? The case of ICUs system". *Int. J. Production Economics* 128 (2010), 427-433.

Tybout, J.R. (1990) "Making Noisy Data Sing A Micro Approach to Measuring Industrial Efficiency". Country Economics Dept., World Bank.

Tziogkidis, P. (2012) '' Bootstrap DEA and Hypothesis Testing''. *Working Paper in Cardiff Economics Working Papers*. No. E2012/18.

Van De Walle, N. (1989) "Privatization in Developing Countries: A Review of the Issues" *World Development*. Vol. 17, No. 5, pp. 601-615, 1989. Printed in Great Britain.

Vencappa, D.; Fenn, P.; and Diacon, S., (2008) "Parametric decomposition of total factor productivity growth in the European insurance industry: evidence from life and non-life companies". Working paper, Nottingham University.

Vogt, W. P. (1993) Dictionary of statistics and methodology: A non-technical guide for the social sciences. Thousand Oaks, California: Sage Publications.

Wadud, A. and White, B. (2000) "Farm household efficiency in Bangladesh: a comparison of stochastic frontier and DEA methods''*. Applied Economics*. 200, 32: 1665-1673.

Williams, A. (2003) "How to … Write and analyse a questionnaire". *Journal of Orthodontics.* Vol. 30, 245–252.

Wilson, P.; Hadley, D.; and Asby, C. (2001) "The Influence of Management Characteristics on the TE of Wheat Farmers in Eastern England". *Agricultural Economics* 24 (2001), pp. 329-338.

Wilson, P.; Hadley, D.; Ramsden, S.; and Kaltsas, I. (1998) "Measuring and Explaining TE in UK Potato Production", *Journal of Agricultural Economics*, Vol. 49(3), pp 294-305.

Winsten, C. B. (1957) "Discussion on Mr. Farrel's paper". *Journal of the Royal Statistical Society* 120, 282—284.

Xue, M. and Harker, P. T. (1999) "Overcoming the Inherent Dependency of DEA Efficiency Scores: A Bootstrap Approach*", Center for Financial Institutions*

Working Papers 99-17, Wharton School Center for Financial Institutions, University of Pennsylvania.

Zhang, B.; Wang, J.; Liu, C.; and Zhao, Y. (2012) "Evaluating the TE of Chinese airport airside activities". *Journal of Air Transport Management.* 20 (2012) 23-27.

Zhou, Y. (2014) "FDI and Technical Efficiency in Manufacturing Firms: A Stochastic Frontier Approach". *Master's Theses.* Paper 95.

Zhu, J. (2003) *Quantitative Models for Performance Evaluation and Benchmarking*. Springer's International Series, USA.

9. Appendices

Appendix 1: Machine productivity in the GSFMO branches (1988-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1988	10.3	11.79	9.82	12.36	14.23				
1989	10.3	11.79	9.82	12.36	14.23				
1990	10.15	11.53	9.46	11.91	13.82				
1991	9.98	11.4	9.51	12.09	13.72				
1992	10.4	11.29	9.52	11.99	13.71				
1993	10.46	11.38	10.44	12.42	14.43				
1994	11.06	11.57	11.24	12.56	14.29				
1995	11.1	11.73	11.16	12.53	13.79				
1996	11.98	12.43	11.04	12.63	16.45				
1997	12.44	12.52	11.23	12.58	15.71				
1998	12.26	12.61	11.03	12.75	15.6	18.83			
1999	12.27	12.71	10.91	12.6	14.39	19.14			
2000	12.23	12.76	10.68	12.42	14.43	19.1			
2001	12.36	12.7	10.88	12.73	17.01	19.22			
2002	12.45	12.71	10.85	12.23	16.35	19.26			
2003	13.28	12.73	11.58	12.69	17.29	19.94			
2004	14.66	12.59	11.46	13.68	17.48	20.01			
2005	15.82	12.45	11.35	14.69	17.67	20.07			
2006	15.99	12.57	11.32	14	17.58	20.14			
2007	15.92	12.97	11.28	13.43	17.26	20.14			
2008	15.91	12.36	10.9	13.45	15.2	20.03	31.86	21.16	20.35
2009	16.54	12.93	11.07	13.82	16.81	19.97	21.5	19.98	20.31
2010	16.87	13.36	12.59	14.71	17.83	20.1	20.84	20.04	20.21
2011	17.04	13.4	14.94	14.75	17.87	20.06	20.78	20.16	20.34
Mean	12.99	12.35	11	12.97	15.71	19.71	23.74	20.34	20.3
Max	17.04	13.4	14.94	14.75	17.87	20.14	31.86	21.16	20.35
Min	9.98	11.29	9.46	11.91	13.71	18.83	20.78	19.98	20.21
Std. Dev.	2.44	0.63	1.12	0.87	1.55	0.48	5.42	0.56	0.06
Rate of change %	118.1	112.3	100	117.9	142.8	179.2	215.8	184.9	184.5

Source: Collected and calculated using: GSFMO, Annual reports (1988-2011).

Appendix 2: Human productivity in the GSFMO branches (1988-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1988	1238.7	1162.5	932.5	708.3	1277				
1989	1233.4	1163.8	936.7	709.9	1280.4				
1990	1237.2	1162.9	933	707.5	1281.5				
1991	1151.4	1061.4	936.6	690.6	960.3				
1992	1375.4	1265.9	1003.1	776	1534.1				
1993	1216.7	1222.1	1099.9	780.7	1498				
1994	1350.4	1202.6	1062	741.3	1287.5				
1995	1197.5	1174.6	920.3	729.8	1321.6				
1996	1321.7	1344.3	971.3	771.1	1325.1				
1997	1333.1	1084.1	938.1	690	1513.4				
1998	1128.3	1076.3	844.3	641.6	1401.5	1359.7			
1999	716.9	1208.8	895.5	1068.8	1169.3	1895.2			
2000	716.9	1317.6	949	1088	1110	1436.2			
2001	774	1303.1	942.5	1116	1217.4	1519.7			
2002	824.7	1388.8	1035.6	1148.8	1536.7	1483.2			
2003	1344.3	1396.7	1128.2	818.3	1767.4	952.4			
2004	1866.4	1367.9	1140.5	883.1	1809.2	1064.1			
2005	1993.6	1136.3	1101.4	922.6	1810.5	1032.9			
2006	1292.5	1124.2	1065.3	811.3	1548.7	1044.6			
2007	1360.5	1503.2	1140.6	803.9	1708.2	1191.9			
2008	1310.7	1159.4	1011.4	656.5	1171	899.3	736.3	387.6	27.8
2009	1335.1	1055.1	937.8	538.5	1120.5	703.4	861.1	635.6	556
2010	1359	1085.7	577.3	571.4	932.1	666.2	744.7	674.4	606.4
2011	1336.8	1000.1	862.9	571.7	948.5	696.6	765.5	702	724
Mean	1250.6	1206.9	973.6	789.4	1355.4	1165.5	776.9	599.9	478.6
Max	1993.6	1503.2	1140.6	1148.8	1810.5	1895.2	861.1	702	724
Min	716.9	1000.1	577.3	538.5	932.1	666.2	736.3	387.6	27.8
Std. Dev.	296.9	128.8	121.5	171.2	262.5	363.5	57.5	144.1	308.6
Rate of chane %	261.3	252.2	203.4	164.9	283.2	243.5	162.3	125.3	100

Source: Collected and calculated using: GSFMO, Annual reports (1988-2011).

Appendix 3: Manufacturing yield for GSFMO mills (1988-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1988	0.79	0.85	0.8	0.85	0.79				
1989	0.79	0.85	0.8	0.85	0.79				
1990	0.79	0.84	0.8	0.8	0.77				
1191	0.78	0.84	0.79	0.81	0.77				
1992	0.79	0.84	0.79	0.83	0.78				
1993	0.79	0.84	0.81	0.84	0.79				
1994	0.79	0.84	0.81	0.83	0.79				
1995	0.81	0.84	0.79	0.83	0.76				
1996	0.8	0.83	0.79	0.85	0.76				
1997	0.81	0.84	0.8	0.85	0.77				
1998	0.8	0.84	0.78	0.85	0.76	0.8			
1999	0.8	0.84	0.78	0.84	0.74	0.81			
2000	0.8	0.84	0.77	0.82	0.72	0.82			
2001	0.81	0.84	0.78	0.83	0.71	0.82			
2002	0.81	0.84	0.78	0.84	0.74	0.83			
2003	0.84	0.84	0.82	0.85	0.78	0.86			
2004	0.83	0.84	0.82	0.83	0.79	0.86			
2005	0.83	0.84	0.81	0.82	0.8	0.86			
2006	0.83	0.83	0.83	0.83	0.83	0.83			
2007	0.8	0.81	0.81	0.76	0.78	0.86			
2008	0.78	0.77	0.77	0.71	0.75	0.8	0.81	0.8	0.81
2009	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
2010	0.79	0.8	0.78	0.78	0.78	0.8	0.82	0.79	0.79
2011	0.8	0.8	0.79	0.79	0.78	0.8	0.82	0.8	0.8
Mean	0.8	0.83	0.8	0.82	0.77	0.83	0.82	0.81	0.81
Max	0.84	0.85	0.83	0.85	0.83	0.86	0.83	0.83	0.83
Min	0.78	0.77	0.77	0.71	0.71	0.8	0.81	0.79	0.79
Std. Dev.	0.06	0.08	0.06	0.14	0.12	0.06	0.02	0.04	0.04
Rate of change %	104.4	108.1	103.6	106.7	100	108.1	107	104.8	105.2

Source: Collected and calculated using: GSFMO, Annual reports (1988-2011).

Appendix 4: Mean salaries and wage costs per worker in each branch

(1990-2011) (Thousand riyal)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1990	94.20	23.40	51.60	51.00	36.00				
1991	76.20	21.00	42.60	46.20	23.40				
1992	70.20	18.60	42.60	34.80	26.40				
1993	70.20	24.00	48.60	45.00	32.40				
1994	64.20	27.00	48.60	35.40	30.00				
1995	46.80	29.40	40.20	36.60	26.40				
1996	53.40	36.60	39.00	42.00	29.40				
1997	67.20	31.20	47.40	40.20	38.40				
1998	65.40	34.20	43.80	45.60	48.60	67.80			
1999	68.40	33.60	45.00	45.60	50.40	67.80			
2000	68.40	33.00	48.00	48.60	53.40	50.40			
2001	64.80	33.60	45.60	46.20	42.60	46.20			
2002	40.20	40.80	50.40	74.40	38.40	51.00			
2003	57.00	39.00	44.40	47.40	39.00	29.40			
2004	70.80	43.80	50.40	51.60	43.20	37.80			
2005	45.00	45.00	52.80	77.40	43.20	39.00			
2006	70.20	50.40	55.80	58.20	49.20	45.00			
2007	86.40	55.20	62.40	65.40	54.00	57.60			
2008	86.40	49.80	63.60	66.60	57.00	54.60	24.00	40.80	21.60
2009	67.80	54.60	67.80	74.40	64.80	54.60	34.20	51.00	36.00
2010	87.60	75.60	84.60	101.40	90.60	65.40	40.20	60.00	46.20
2011	94.80	82.80	100.20	109.80	86.40	76.20	52.20	72.60	58.20
Mean	68.89	40.12	53.43	56.54	45.60	53.06	37.65	56.10	40.50
Max	94.80	82.80	100.20	109.80	90.60	76.20	52.20	72.60	58.20
Min	40.20	18.60	39.00	34.80	23.40	29.40	24.00	40.80	21.60
Std. Dev.	14.89	16.44	14.82	20.34	17.64	13.19	11.78	13.51	15.53

Source: Collected and calculated using: GSFMO, Annual reports (1990-2011).

Appendix 5: Average salaries (Saudi riyal) and wage costs per tonne of flour in GSFMO branches (1990-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1990	57.60	17.40	43.20	52.80	23.40				
1991	58.80	19.20	40.20	56.40	26.40				
1992	54.60	16.20	42.00	46.20	23.40				
1993	57.60	19.80	44.40	57.60	21.60				
1994	47.40	22.20	45.60	47.40	23.40				
1995	39.00	25.20	43.80	49.80	19.80				
1996	40.20	27.00	40.20	54.60	22.20				
1997	50.40	28.80	50.40	58.20	25.20				
1998	51.60	29.40	50.40	64.80	27.60	49.80			
1999	49.80	29.40	50.40	62.40	30.00	36.00			
2000	53.40	30.60	53.40	71.40	34.80	34.80			
2001	49.80	28.20	49.80	61.80	29.40	30.60			
2002	49.20	29.40	48.60	64.80	25.20	34.20			
2003	42.60	27.60	39.60	57.60	22.20	30.60			
2004	37.80	31.80	43.80	58.20	24.00	35.40			
2005	33.60	34.80	46.20	56.40	24.60	37.80			
2006	39.00	39.00	50.40	69.00	30.60	43.20			
2007	41.40	35.40	55.80	85.20	33.00	48.00			
2008	42.60	43.20	63.60	99.60	38.40	61.20	32.40	106.20	766.80
2009	43.20	47.40	69.60	129.00	45.00	77.40	39.60	79.80	64.80
2010	51.60	55.80	108.00	133.20	61.80	97.80	54.00	88.80	76.80
2011	61.80	71.40	85.20	156.00	75.00	109.20	67.80	103.80	80.40
Mean	47.86	32.24	52.94	72.38	31.23	51.86	48.45	94.65	247.20
Max	61.80	71.40	108.00	156.00	75.00	109.20	67.80	106.20	766.80
Min	33.60	16.20	39.60	46.20	19.80	30.60	32.40	79.80	64.80
St.D	7.75	13.02	16.30	30.09	13.61	25.51	15.72	12.54	346.46

Source: Collected and calculated using: GSFMO, Annual reports (1990-2011).

Appendix 6: Average operating costs per tonne of flour in GSFMO branches (1990-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1990	6.54	5.88	8.28	6.48	7.32				
1991	6.72	5.94	8.28	6.60	7.20				
1992	6.60	5.94	8.46	6.48	7.14				
1993	6.66	5.94	8.40	6.66	7.26				
1994	6.66	5.88	8.52	6.72	7.26				
1995	6.60	5.82	8.34	6.54	7.32				
1996	6.66	5.88	8.34	6.66	7.08				
1997	6.60	5.88	8.28	6.54	7.20				
1998	5.22	4.98	6.54	5.70	3.72	11.40			
1999	3.78	3.24	5.58	3.54	3.18	3.60			
2000	5.94	8.76	7.50	5.22	5.46	4.80			
2001	6.24	5.04	8.10	6.54	6.54	5.88			
2002	6.24	4.98	8.88	7.26	4.86	6.06			
2003	8.16	6.18	8.82	6.30	4.86	5.82			
2004	6.00	40.08	11.04	6.72	4.80	5.76			
2005	4.74	16.32	9.78	5.82	4.98	5.76			
2006	5.16	16.62	10.50	7.20	5.70	6.78			
2007	7.74	18.66	15.06	15.18	6.42	7.14			
2008	11.58	21.72	19.02	17.52	9.84	9.96	15.18	28.62	145.44
2009	9.00	21.24	20.34	19.14	10.56	10.38	11.52	13.62	16.92
2010	14.34	21.72	29.28	17.04	11.46	13.80	14.52	15.54	21.90
2011	11.10	25.08	24.24	25.20	14.52	16.14	16.08	16.02	18.42
Mean	7.19	11.90	11.44	9.14	7.03	8.09	14.33	18.45	50.67
Max	14.34	40.08	29.28	25.20	14.52	16.14	16.08	28.62	145.44
Min	3.78	3.24	5.58	3.54	3.18	3.60	11.52	13.62	16.92
St.D	2.42	9.47	6.21	5.68	2.63	3.68	1.98	6.86	63.21

Source: Collected and calculated using: GSFMO, Annual reports (1990-2011).

Appendix 7: Average maintenance and hygiene contracts costs per tonne of flour in the GSFMO branches (1990-2011)

Year	Riyadh	Jeddah	Dammam	Qassim	Khamis Mushyat	Tabuk	Almadinah	Hail	Aljouf
1990	40.86	60.06	65.88	35.94	50.34				
1991	40.86	60.00	66.00	35.88	50.58				
1992	40.86	60.00	66.06	35.88	50.46				
1993	40.68	59.94	66.06	36.06	50.40				
1994	40.86	59.94	66.12	36.00	50.52				
1995	40.86	59.94	66.06	36.00	50.40				
1996	40.68	59.94	66.06	36.06	50.40				
1997	40.92	60.00	66.12	36.12	50.46				
1998	29.70	133.26	105.42	25.08	30.96	18.48			
1999	31.38	32.88	32.94	24.18	35.10	22.98			
2000	29.46	30.30	36.60	30.00	33.18	20.64			
2001	36.42	57.90	56.34	35.82	30.96	34.92			
2002	46.08	35.64	56.94	41.46	39.90	30.42			
2003	45.00	39.66	58.68	35.34	41.52	29.34			
2004	54.78	54.18	59.88	38.46	50.04	37.20			
2005	42.90	47.52	60.48	41.52	39.30	40.80			
2006	52.38	57.06	56.34	44.22	55.80	38.88			
2007	49.50	49.74	44.52	52.68	38.76	33.54			
2008	53.34	65.70	71.52	74.22	52.68	46.80	40.98	42.06	52.86
2009	50.34	65.46	68.40	65.88	50.70	52.26	41.22	53.52	28.26
2010	65.58	83.40	140.46	47.70	44.10	40.86	45.96	55.26	55.20
2011	38.40	75.78	74.34	84.18	79.26	39.18	62.70	63.72	44.76
Mean	43.27	59.47	65.96	42.21	46.63	34.74	47.72	53.64	45.27
Max	65.58	133.26	140.46	84.18	79.26	52.26	62.70	63.72	55.20
Min	29.46	30.30	32.94	24.18	30.96	18.48	40.98	42.06	28.26
St.D	8.59	20.88	21.84	14.91	10.53	9.69	10.25	8.91	12.19

Source: Collected and calculated using: GSFMO, Annual reports (1990-2011).

Appendix 8: Output and inputs for the Riyadh and Jeddah branches (1988-2011)

DMU	Amount of flour	Amount of wheat	Machine hour	Man hour
Riyadh1988	159,794.0	201,633.0	15,517.0	47,085.0
Riyadh1989	187,482.0	236,566.0	18,206.0	55,480.0
Riyadh1990	211,555.0	269,185.0	20,833.0	62,415.0
Riyadh1991	196,894.0	251,350.0	19,732.0	62,415.0
Riyadh1992	218,687.0	276,349.0	21,033.0	58,035.0
Riyadh1993	215,349.0	272,852.0	20,597.0	64,605.0
Riyadh1994	234,962.0	295,587.0	21,244.0	63,510.0
Riyadh1995	227,527.0	281,566.0	20,501.0	69,350.0
Riyadh1996	243,197.0	302,899.0	20,304.0	67,160.0
Riyadh1997	262,618.0	325,543.0	21,111.0	71,905.0
Riyadh1998	240,318.0	301,715.0	19,598.0	77,745.0
Riyadh1999	252,351.0	316,274.0	20,561.0	128,480.0
Riyadh2000	252,351.0	313,747.0	20,628.0	128,480.0
Riyadh2001	278,622.0	343,227.0	22,550.0	131,400.0
Riyadh2002	296,879.0	365,017.0	23,849.0	131,400.0
Riyadh2003	338,775.0	403,159.0	25,506.0	91,980.0
Riyadh2004	410,618.0	492,936.0	28,004.0	80,300.0
Riyadh2005	482,461.0	582,712.0	30,501.0	88,330.0
Riyadh2006	452,368.0	542,842.0	28,290.0	127,750.0
Riyadh2007	457,131.3	571,774.0	28,706.8	122,640.0
Riyadh2008	491,503.2	633,058.2	30,891.5	136,875.0
Riyadh2009	552,720.0	663,264.0	33,421.5	151,110.0
Riyadh2010	573,495.5	726,021.8	33,999.5	154,030.0
Riyadh2011	573,501.2	719,942.7	33,647.1	156,585.0
Jeddah1988	342,932.0	403,899.0	29,096.0	107,675.0
Jeddah1989	379,382.0	446,829.0	32,189.0	118,990.0
Jeddah1990	397,727.0	471,838.0	34,483.0	124,830.0
Jeddah1991	363,000.0	431,473.0	31,832.0	124,830.0
Jeddah1992	394,952.0	472,628.0	34,986.0	113,880.0
Jeddah1993	415,499.0	494,226.0	36,520.0	124,100.0
Jeddah1994	429,331.0	508,482.0	37,099.0	130,305.0
Jeddah1995	433,441.0	516,299.0	36,966.0	134,685.0
Jeddah1996	501,410.0	600,932.0	40,342.0	136,145.0
Jeddah1997	467,224.0	558,395.0	37,321.0	157,315.0
Jeddah1998	432,679.0	516,725.0	34,300.0	146,730.0
Jeddah1999	426,722.0	510,177.0	33,582.0	128,845.0
Jeddah2000	465,115.0	552,290.0	36,464.0	128,845.0
Jeddah2001	475,641.0	566,570.0	37,445.0	133,225.0
Jeddah2002	506,905.0	605,353.0	39,895.0	133,225.0
Jeddah2003	512,602.0	609,620.0	40,272.0	133,955.0
Jeddah2004	493,796.0	588,720.0	39,206.0	131,765.0
Jeddah2005	474,990.0	567,819.0	38,140.0	152,570.0
Jeddah2006	469,915.0	563,898.0	37,384.0	152,570.0
Jeddah2007	562,179.7	690,413.6	43,357.7	136,510.0
Jeddah2008	477,672.3	618,837.1	38,662.1	150,380.0
Jeddah2009	480,081.0	576,097.0	37,131.0	166,075.0
Jeddah2010	508,095.1	636,566.2	38,034.7	170,820.0
Jeddah2011	478,039.6	601,184.4	35,680.7	174,470.0

Appendix 9: Output and inputs for the Dammam and Qassim branches

(1988-2011)

DMU	Amount of flour	Amount of wheat	Machine hour	Man hour
Dammam1988	118,423.0	148,169.0	12,060.0	46,355.0
Dammam1989	135,815.0	169,929.0	13,831.0	52,925.0
Dammam1990	152,075.0	191,262.0	16,069.0	59,495.0
Dammam1991	152,672.0	192,496.0	16,052.0	59,495.0
Dammam1992	163,507.0	206,602.0	17,173.0	59,495.0
Dammam1993	192,478.0	236,581.0	18,436.0	63,875.0
Dammam1994	218,763.0	271,052.0	19,471.0	75,190.0
Dammam1995	215,354.0	272,679.0	19,292.0	85,410.0
Dammam1996	223,394.0	282,355.0	20,229.0	83,950.0
Dammam1997	224,203.0	281,629.0	19,962.0	87,235.0
Dammam1998	202,637.0	259,034.0	18,364.0	87,600.0
Dammam1999	204,170.0	262,002.0	18,722.0	83,220.0
Dammam2000	216,362.0	279,313.0	20,267.0	83,220.0
Dammam2001	221,480.0	283,666.0	20,364.0	85,775.0
Dammam2002	243,365.0	311,918.0	22,425.0	85,775.0
Dammam2003	273,022.0	333,146.0	23,586.0	88,330.0
Dammam2004	271,431.0	332,394.0	23,678.0	86,870.0
Dammam2005	269,840.0	331,642.0	23,769.0	89,425.0
Dammam2006	268,451.0	322,141.0	23,714.0	91,980.0
Dammam2007	266,895.8	330,989.5	23,653.9	85,410.0
Dammam2008	245,778.6	318,850.7	22,541.9	88,695.0
Dammam2009	244,770.0	293,724.0	22,119.3	95,265.0
Dammam2010	182,432.7	232,665.6	14,493.1	115,340.0
Dammam2011	287,348.1	362,452.8	19,236.1	121,545.0
Qassim1988	94,912.0	112,167.0	7,678.0	48,910.0
Qassim1989	109,328.0	129,204.0	8,844.0	56,210.0
Qassim1990	130,188.0	162,006.0	10,935.0	67,160.0
Qassim1991	127,065.0	156,872.0	10,514.0	67,160.0
Qassim1992	138,895.0	168,096.0	11,587.0	65,335.0
Qassim1993	153,022.0	182,148.0	12,324.0	71,540.0
Qassim1994	160,124.0	193,683.0	12,751.0	78,840.0
Qassim1995	164,937.0	199,174.0	13,160.0	82,490.0
Qassim1996	179,676.0	212,199.0	14,226.0	85,045.0
Qassim1997	174,562.0	206,337.0	13,878.0	92,345.0
Qassim1998	157,839.0	184,999.0	12,381.0	89,790.0
Qassim1999	168,862.0	200,449.0	13,403.0	57,670.0
Qassim2000	171,896.0	208,720.0	13,845.0	57,670.0
Qassim2001	184,134.0	221,086.0	14,465.0	60,225.0
Qassim2002	189,555.0	226,239.0	15,501.0	60,225.0
Qassim2003	200,474.0	235,515.0	15,795.0	89,425.0
Qassim2004	213,716.0	256,335.0	15,621.0	88,330.0
Qassim2005	226,957.0	277,154.0	15,447.0	89,790.0
Qassim2006	207,679.0	249,215.0	14,834.0	93,440.0
Qassim2007	185,704.9	244,506.7	13,828.5	84,315.0
Qassim2008	164,132.9	229,768.2	12,202.5	91,250.0
Qassim2009	147,534.0	177,041.0	10,674.0	100,010.0
Qassim2010	176,003.8	224,667.9	11,965.3	112,420.0
Qassim2011	176,074.4	224,217.9	11,938.5	112,420.0

Appendix 10: Output and inputs for the Khamis (1988-2011)and Tabuk branches (1998-2011)

DMU	Amount of flour	Amount of wheat	Machine hour	Man hour
Khamis1988	154,514.0	194,591.0	10,859.0	44,165.0
Khamis1989	201,025.0	253,166.0	14,128.0	57,305.0
Khamis1990	188,373.0	245,488.0	13,628.0	53,655.0
Khamis1991	141,168.0	183,075.0	10,290.0	53,655.0
Khamis1992	168,753.0	216,833.0	12,305.0	40,150.0
Khamis1993	197,734.0	248,967.0	13,706.0	48,180.0
Khamis1994	198,271.0	251,385.0	13,876.0	56,210.0
Khamis1995	204,850.0	270,133.0	14,851.0	56,575.0
Khamis1996	212,015.0	279,831.0	12,888.0	58,400.0
Khamis1997	249,716.0	325,513.0	15,894.0	60,225.0
Khamis1998	273,285.0	357,463.0	17,520.0	71,175.0
Khamis1999	266,603.0	362,468.0	18,533.0	83,220.0
Khamis2000	253,077.0	350,284.0	17,540.0	83,220.0
Khamis2001	284,864.0	398,960.0	16,745.0	85,410.0
Khamis2002	359,577.0	489,208.0	21,990.0	85,410.0
Khamis2003	395,901.0	510,243.0	22,899.0	81,760.0
Khamis2004	401,634.0	509,781.0	22,976.0	81,030.0
Khamis2005	407,366.0	509,318.0	23,053.0	82,125.0
Khamis2006	359,307.0	431,168.0	20,443.0	84,680.0
Khamis2007	365,554.5	471,527.0	21,178.0	78,110.0
Khamis2008	334,903.6	446,271.8	22,039.3	104,390.0
Khamis2009	336,158.0	403,390.0	19,995.7	109,500.0
Khamis2010	314,129.8	403,542.3	17,618.8	123,005.0
Khamis2011	330,066.1	422,321.9	18,467.7	127,020.0
Tabuk1998	84,299.0	105,404.0	4,476.0	22,630.0
Tabuk1999	117,504.0	144,419.0	6,139.0	22,630.0
Tabuk2000	124,947.0	152,202.0	6,542.0	31,755.0
Tabuk2001	132,217.0	161,963.0	6,879.0	31,755.0
Tabuk2002	137,934.0	166,102.0	7,163.0	33,945.0
Tabuk2003	165,712.0	192,080.0	8,309.0	63,510.0
Tabuk2004	166,001.0	192,247.0	8,297.0	56,940.0
Tabuk2005	166,289.0	192,414.0	8,285.0	58,765.0
Tabuk2006	168,182.0	201,818.0	8,352.0	58,765.0
Tabuk2007	168,054.5	195,203.3	8,344.9	51,465.0
Tabuk2008	144,792.1	180,836.8	7,228.4	58,765.0
Tabuk2009	121,682.0	146,018.0	6,093.6	63,145.0
Tabuk2010	121,913.8	151,732.5	6,066.8	66,795.0
Tabuk2011	130,254.9	162,390.4	6,493.5	68,255.0

Appendix 11: Output and inputs for the Almadinah, Hail and Aljouf branches (2008-2011)

DMU	Amount of flour	Amount of wheat	Machine hour	Man hour
Almadinah2008	118,545.7	145,541.3	3,721.0	58,765.0
Almadinah2009	155,857.0	187,028.0	7,250.5	66,065.0
Almadinah2010	152,669.7	185,672.2	7,326.0	74,825.0
Almadinah2011	156,921.2	190,423.9	7,553.0	74,825.0
Hail2008	71,314.2	88,679.2	3,369.7	67,160.0
Hail2009	127,757.0	153,308.0	6,393.9	73,365.0
Hail2010	138,930.3	175,042.2	6,932.0	75,190.0
Hail2011	146,012.8	183,640.6	7,242.0	75,920.0
Aljouf2008	4,537.9	5,579.9	223.0	59,495.0
Aljouf2009	106,196.0	127,435.0	5,227.5	69,715.0
Aljouf2010	120,679.2	152,164.4	5,970.0	72,635.0
Aljouf2011	143,345.1	179,245.7	7,049.0	72,270.0

Appendix 12

Questionnaire for some managers in the Grain Silos and Flour Mills Organisation (GSFMO)

These data are confidential and will only be used for scientific research purposes.

	SECTION A: General Information									
1	Name of Manager(optional)									
2	Title of Manager									
3	Age									
4	Educational level									
5	How long have you been on your current position?									
	1 year		2-4 years		4-6 years		6-10 years		More than 10 years	
	SECTION B:Training and Skill acquisition									
1	Have you received any training in the milling industry?	Yes		No						
2	If yes, what courses have you attended since the start of your employment in the organisation?									
3	Have you received any training after becoming a manager?	Yes		No						
4	If yes, how many courses achieved since your appointment as a manager?									
5	Please specify the type of training courses you have successfully achieved.									
6	Please specify where you have achieved these training courses.	Internal in Saudi		External in overseas		Both				
7	Where do branch managers obtain their information about the milling industry?	Internal expertise		Attracting external consultant		Both				
8	How would you describe typical interaction between branch managers and the organisation's headquarters?	Visit		email		phone		all		
9	How often do headquarters visit the GSFMO's branches?	Once a week		Once a month		Once a year		never		
10	Of all branches, which of the branches do you think interacts most with the headquarters?									
11	Is there any interaction between the different branch managers to gain experience or exchange skills?	Yes		No						
12	If yes, please state which branches interact.									

13	If no, can you please provide the reasons for lack of interaction?	- - -

	SECTION C: Mills operation						
1	Are there any issues or opportunities in the milling industry as a result of resorting to imported wheat to replace locally produced wheat?	Yes(problem)		No			
		Yes(opportunities)		No			
2	If yes, what are the issues or opportunities that have arisen as a result of using imported wheat to substitute locally produced wheat?	- - -					
3	Is there a difference in terms of manufacturing efficiency between using locally produced wheat and imported wheat?	Yes		No			
4	If yes, what are, in your opinion, the reasons for such a difference between using locally produced wheat and imported wheat?	- - -					
5	Do you think labour is sufficient in the branch(es)?	Yes		No			
6	If no, what is approximately the number of workers required to fill the shortage gap? Please specify which branch(es).						
7	If the branch has too much labour, please indicate how many people needs to lose.						
8	How often are maintenance and improvements to mills carried out?	Monthly		Every six months		Annual	
9	What sort of machinery is used in the milling industry?	Mostly new		Mostly average		Mostly old	
10	How do you describe facilities; for example, roads and services, in the branches?	Excellent		Average		Poor	
	SECTION D: Profits gained and losses incurred in the mills						
1	In your opinion, do mills yield profits or incur losses?	Make profits		Incur losses			

2	If mills incur losses, what do you think the reasons for these losses are?	- - -
3	Can you think of any suggestions to help reduce the losses?	- - - -

	SECTION E: Problems faced by the milling industry	
1	In your point of view, what are the major problems faced by the milling industry in the branches?	- - - - -
2	In your opinion, how can these issues be resolved?	- - - - - -

Appendix 13: TE of Riyadh branch under CRS and VRS (1988-2011)

DMUs	Technical Efficiency(TE) CRS-input orientated	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Riyadh1988	92.95	93.38	93.24
Riyadh1989	92.93	93.04	92.93
Riyadh1990	92.23	92.28	92.40
Riyadh1991	91.44	91.56	91.71
Riyadh1992	93.53	93.68	93.59
Riyadh1993	92.48	92.61	92.73
Riyadh1994	93.80	93.81	93.90
Riyadh1995	94.39	94.73	94.83
Riyadh1996	94.54	94.68	94.76
Riyadh1997	95.01	95.25	95.32
Riyadh1998	92.70	93.32	93.43
Riyadh1999	92.32	93.33	93.45
Riyadh2000	93.07	94.08	94.19
Riyadh2001	93.93	95.14	95.22
Riyadh2002	94.11	95.45	95.59
Riyadh2003	98.73	99.40	99.40
Riyadh2004	100.00	100.00	100.00
Riyadh2005	100.00	100.00	100.00
Riyadh2006	97.69	99.54	99.55
Riyadh2007	94.36	95.83	95.91
Riyadh2008	91.60	94.16	94.55
Riyadh2009	97.92	100.00	100.00
Riyadh2010	93.46	100.00	100.00
Riyadh2011	94.01	100.00	100.00

Appendix 14: TE of Jeddah branch under CRS and VRS (1988-2011)

DMUs	Technical Efficiency (TE) CRS- input and output oriented	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Jeddah1988	98.59	99.88	99.88
Jeddah1989	98.60	100.00	100.00
Jeddah1990	97.90	99.45	99.47
Jeddah1991	97.49	99.03	99.04
Jeddah1992	97.78	98.83	98.84
Jeddah1993	98.05	99.34	99.36
Jeddah1994	98.31	99.88	99.88
Jeddah1995	97.60	99.34	99.36
Jeddah1996	98.09	99.17	99.19
Jeddah1997	97.03	99.28	99.30
Jeddah1998	97.08	99.21	99.23
Jeddah1999	97.50	99.10	99.12
Jeddah2000	98.79	99.96	99.96
Jeddah2001	98.42	99.69	99.69
Jeddah2002	98.65	99.57	99.58
Jeddah2003	99.07	100.00	100.00
Jeddah2004	98.69	99.66	99.66
Jeddah2005	97.12	99.28	99.29
Jeddah2006	96.73	98.92	98.94
Jeddah2007	96.63	100.00	100.00
Jeddah2008	90.26	91.83	91.98
Jeddah2009	96.58	99.05	99.07
Jeddah2010	92.67	95.20	95.37
Jeddah2011	92.14	94.74	94.84

Appendix 15: TE of Dammam branch under CRS and VRS (1988-2011)

DMUs	Technical Efficiency(TE) CRS-input and output orientated	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Dammam1988	93.90	94.42	93.90
Dammam1989	92.48	93.35	92.84
Dammam1990	92.00	92.23	92.00
Dammam1991	91.77	92.00	91.77
Dammam1992	91.72	91.78	91.87
Dammam1993	94.45	94.76	94.86
Dammam1994	93.63	94.19	94.30
Dammam1995	91.38	92.05	92.22
Dammam1996	91.62	92.29	92.46
Dammam1997	92.12	92.87	93.02
Dammam1998	90.52	91.03	91.24
Dammam1999	90.17	90.70	90.91
Dammam2000	89.69	90.29	90.50
Dammam2001	90.37	91.06	91.25
Dammam2002	90.53	91.25	91.39
Dammam2003	95.18	96.11	96.17
Dammam2004	94.92	95.81	95.88
Dammam2005	94.46	95.37	95.44
Dammam2006	96.60	97.59	97.64
Dammam2007	93.83	94.63	94.71
Dammam2008	89.42	90.15	90.30
Dammam2009	96.43	97.41	97.46
Dammam2010	90.73	90.98	91.22
Dammam2011	91.73	93.52	93.71

Appendix 16: TE of Qassim branch under CRS and VRS (1988-2011)

DMUs	Technical Efficiency(TE) CRS- Input and output orientated	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Qassim1988	97.91	99.66	99.62
Qassim1989	97.91	98.30	98.21
Qassim1990	92.99	93.03	93.02
Qassim1991	93.72	93.78	93.76
Qassim1992	95.61	95.64	95.63
Qassim1993	97.21	97.22	97.22
Qassim1994	95.66	95.67	95.68
Qassim1995	95.82	95.82	95.92
Qassim1996	97.98	98.21	98.26
Qassim1997	97.89	98.04	98.10
Qassim1998	98.72	98.73	98.73
Qassim1999	97.64	97.66	97.72
Qassim2000	95.55	95.61	95.72
Qassim2001	96.66	96.88	96.95
Qassim2002	97.30	97.58	97.63
Qassim2003	98.49	99.03	99.05
Qassim2004	96.47	97.15	97.22
Qassim2005	94.75	95.62	95.79
Qassim2006	96.43	97.04	97.11
Qassim2007	87.88	88.18	88.46
Qassim2008	82.66	82.66	83.07
Qassim2009	96.43	96.45	96.44
Qassim2010	90.65	90.81	91.05
Qassim2011	90.87	91.03	91.26

Appendix 17: TE of Khamis branch under CRS and VRS (1988-2011)

DMUs	Technical Efficiency(TE) CRS-input and output orientated	Technical Efficiency(TE)	
		VRS- Input orientated	VRS- Output orientated
Khamis1988	93.33	93.9	93.77
Khamis1989	93.35	93.45	93.36
Khamis1990	90.44	90.72	90.57
Khamis1991	89.32	90.13	89.49
Khamis1992	92.74	93.6	93.48
Khamis1993	94.38	94.88	94.79
Khamis1994	92.81	92.96	92.84
Khamis1995	89.65	89.89	89.74
Khamis1996	89.94	90.05	90.24
Khamis1997	91.69	91.76	91.69
Khamis1998	90.78	90.83	91.07
Khamis1999	86.38	86.89	87.21
Khamis2000	84.63	85.18	85.56
Khamis2001	85.52	88.75	90.57
Khamis2002	89.03	91.16	91.78
Khamis2003	94.72	97.71	97.78
Khamis2004	96.2	99.43	99.44
Khamis2005	97.51	100	100
Khamis2006	99.29	100	100
Khamis2007	94.36	96.76	96.82
Khamis2008	88.01	89.22	89.44
Khamis2009	96.73	98.95	98.98
Khamis2010	90.08	95.58	96.09
Khamis2011	90.47	96.51	96.89

Appendix 18: TE of Tabuk, Almadinah, Hail and Aljouf branches under CRS and VRS (1988-2011)

DMUs	Technical Efficiency(TE) CRS-Input and output orientated	Technical Efficiency(TE)	
		VRS- Input	VRS- Output
Tabuk1998	95.42	100.00	100.00
Tabuk1999	100.00	100.00	100.00
Tabuk2000	98.06	98.91	98.81
Tabuk2001	98.32	98.33	98.43
Tabuk2002	99.38	99.46	99.44
Tabuk2003	99.83	99.83	99.83
Tabuk2004	100.00	100.00	100.00
Tabuk2005	100.00	100.00	100.00
Tabuk2006	97.11	97.54	97.78
Tabuk2007	100.00	100.00	100.00
Tabuk2008	93.60	93.77	93.60
Tabuk2009	96.85	96.90	96.89
Tabuk2010	93.92	93.96	93.95
Tabuk2011	93.76	93.79	93.78
Almadinah2008	100.00	100.00	100.00
Almadinah2009	97.81	98.12	98.33
Almadinah2010	96.28	96.29	96.59
Almadinah2011	96.43	96.60	96.96
Hail2008	94.63	94.79	94.78
Hail2009	96.86	96.89	96.89
Hail2010	92.89	92.91	92.90
Hail2011	93.11	93.12	93.30
Aljouf2008	95.07	100.00	100.00
Aljouf2009	97.08	97.15	97.14
Aljouf2010	92.94	92.98	92.96
Aljouf2011	93.69	93.70	93.69

Appendix 19: TE of all branches using SFA Cobb-Douglas under exponential distribution JMLS estimator (1988-2011)

	Riyadh	Jeddah	Dammam	Qassim	Khamis	Tabuk	Almadinah	Hail	Aljouf
1988	97.27	98.96	97.56	98.97	97.43				
1989	97.17	98.94	97.49	98.95	97.27				
1990	96.59	98.82	97.15	97.47	94.96				
1991	96.33	98.77	97.01	97.81	95.12				
1992	97.12	98.70	96.93	98.49	96.44				
1993	96.82	98.79	98.16	98.81	97.47				
1994	97.29	98.85	97.79	98.44	96.92				
1995	97.92	98.74	96.48	98.46	93.92				
1996	97.72	98.64	96.64	98.90	93.80				
1997	97.88	98.62	96.97	98.85	94.97				
1998	97.18	98.65	95.71	98.97	94.44	98.072			
1999	96.66	98.68	95.50	98.94	90.64	98.63			
2000	97.13	98.82	95.06	98.53	89.00	98.67			
2001	97.62	98.76	95.66	98.75	88.02	98.57			
2002	97.73	98.72	95.68	98.86	90.80	98.87			
2003	98.85	98.80	98.28	98.97	95.72	99.18			
2004	98.79	98.75	98.18	98.64	96.80	99.21			
2005	98.67	98.63	98.03	98.18	97.59	99.21			
2006	98.62	98.54	98.66	98.60	98.75	98.76			
2007	97.19	97.99	97.72	93.18	95.67	99.20			
2008	95.04	94.34	94.64	87.45	92.21	97.49	98.10	97.20	96.34
2009	98.58	98.50	98.62	98.48	98.63	98.66	98.69	98.61	98.59
2010	96.29	96.74	95.33	95.27	95.07	97.44	98.31	96.69	96.60
2011	98.81	96.42	96.41	95.47	95.38	97.37	98.38	96.82	97.20

Appendix 20: TE of all branches using SFA Cobb-Douglas under exponential distribution BC estimator (1988-2011)

	Riyadh	Jeddah	Dammam	Qassim	Khamis	Tabuk	Almadinah	Hail	Aljouf
1988	97.29	98.96	97.57	98.97	97.44				
1989	97.19	98.94	97.50	98.95	97.29				
1990	96.62	98.83	97.17	97.49	94.99				
1991	96.35	98.78	97.03	97.82	95.15				
1992	97.14	98.71	96.95	98.50	96.46				
1993	96.84	98.79	98.17	98.81	97.48				
1994	97.31	98.85	97.80	98.44	96.93				
1995	97.93	98.74	96.50	98.47	93.94				
1996	97.73	98.65	96.66	98.90	93.83				
1997	97.90	98.62	96.99	98.86	95.00				
1998	97.20	98.65	95.73	98.97	94.47	98.08			
1999	96.68	98.69	95.53	98.94	90.67	98.64			
2000	97.15	98.83	95.09	98.54	89.03	98.68			
2001	97.63	98.76	95.69	98.76	88.05	98.57			
2002	97.74	98.73	95.71	98.87	90.83	98.87			
2003	98.86	98.80	98.29	98.98	95.74	99.18			
2004	98.80	98.76	98.19	98.65	96.82	99.21			
2005	98.67	98.64	98.04	98.19	97.60	99.21			
2006	98.63	98.55	98.67	98.60	98.76	98.76			
2007	97.21	98.01	97.73	93.21	95.69	99.21			
2008	95.07	94.37	94.67	87.48	92.24	97.51	98.11	97.22	96.36
2009	98.59	98.51	98.63	98.49	98.64	98.67	98.70	98.61	98.60
2010	96.31	96.76	95.35	95.30	95.10	97.46	98.32	96.71	96.62
2011	96.83	96.45	96.43	95.49	95.41	97.38	98.38	96.84	97.21

Appendix 21: TE of all branches using SFA Cobb-Douglas under Half-Normal distribution JMLS estimator (1988-2011)

	Riyadh	Jeddah	Dammam	Qassim	Khamis	Tabuk	Almadinah	Hail	Aljouf
1988	94.27	99.06	94.70	98.86	94.51				
1989	94.18	99.04	94.64	98.82	94.38				
1990	933.87	98.74	94.12	94.68	91.41				
1991	93.02	98.59	93.90	95.37	91.51				
1992	94.16	98.36	93.79	97.29	92.99				
1993	93.73	98.65	96.34	98.46	94.67				
1994	94.49	98.83	95.49	97.19	93.80				
1995	95.78	98.52	93.33	97.30	90.41				
1996	95.33	98.26	93.55	98.80	90.32				
1997	95.74	98.20	94.04	98.67	91.52				
1998	94.36	98.27	92.38	98.99	91.06	95.56			
1999	93.74	98.34	92.13	98.86	89.53	97.46			
2000	94.45	98.77	91.68	97.44	86.00	97.74			
2001	95.36	98.60	92.35	98.28	85.14	97.34			
2002	95.61	98.50	92.39	98.64	87.75	98.51			
2003	98.76	98.72	96.85	99.02	92.54	99.43			
2004	98.58	98.59	96.56	98.00	93.92	99.47			
2005	98.24	98.24	96.18	96.54	95.26	99.48			
2006	98.16	97.97	98.12	97.86	98.45	98.27			
2007	94.69	96.40	95.43	89.80	92.45	99.46			
2008	92.00	91.31	91.30	84.50	89.10	94.70	96.01	97.20	96.34
2009	98.13	97.87	97.99	97.40	98.10	97.88	98.05	98.61	98.59
2010	93.50	94.11	92.02	91.94	91.90	94.60	96.75	96.69	96.60
2011	94.22	93.67	93.41	92.15	92.25	94.49	96.98	96.82	97.20

Appendix 22: TE of all branches using SFA Cobb-Douglas under half-normal distribution BC estimator for all branches (1988-2011)

	Riyadh	Jeddah	Dammam	Qassim	Khamis	Tabuk	Almadinah	Hail	Aljouf
1988	94.275	99.059	94.709	98.859	94.516				
1989	94.191	99.042	94.649	98.828	94.389				
1990	93.394	98.746	94.124	94.689	91.42				
1991	93.024	98.592	93.905	95.372	91.517				
1992	94.163	98.369	93.793	97.294	92.996				
1993	93.733	98.651	96.343	98.464	94.678				
1994	94.497	98.828	95.497	97.201	93.807				
1995	95.789	98.526	93.333	97.303	90.414				
1996	95.342	98.262	93.561	98.803	90.326				
1997	95.744	98.209	94.05	98.675	91.529				
1998	94.367	98.277	92.385	98.996	91.066	95.569			
1999	93.748	98.347	92.141	98.859	87.532	97.469			
2000	94.461	98.769	91.687	97.445	86.011	97.744			
2001	95.367	98.601	92.353	98.28	85.142	97.35			
2002	95.614	98.508	92.398	98.642	87.758	98.515			
2003	98.767	98.723	96.86	99.026	92.545	99.43			
2004	98.586	98.59	96.563	98.001	93.923	99.472			
2005	98.249	98.244	96.183	96.549	95.264	99.476			
2006	98.168	97.973	98.122	97.861	98.458	98.27			
2007	94.693	96.404	95.435	89.806	92.455	99.459			
2008	92.01	91.322	91.303	84.504	89.105	94.709	96.017	94.055	92.085
2009	98.134	97.878	97.992	97.408	98.101	97.886	98.058	97.722	97.606
2010	93.507	94.119	92.023	91.946	91.903	94.608	96.758	93.475	93.302
2011	94.227	93.678	93.422	92.155	92.256	94.497	96.982	93.673	94.247

Appendix 23: TE of Riyadh branch using DEA and SFA (1988-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Riyadh1988	94.28	92.95	93.38	93.24
Riyadh1989	94.19	92.93	93.04	92.93
Riyadh1990	93.39	92.23	92.28	92.4
Riyadh1991	93.02	91.44	91.56	91.71
Riyadh1992	94.16	93.53	93.68	93.59
Riyadh1993	93.73	92.48	92.61	92.73
Riyadh1994	94.50	93.8	93.81	93.9
Riyadh1995	95.79	94.39	94.73	94.83
Riyadh1996	95.34	94.54	94.68	94.76
Riyadh1997	95.74	95.01	95.25	95.32
Riyadh1998	94.37	92.7	93.32	93.43
Riyadh1999	93.75	92.32	93.33	93.45
Riyadh2000	94.46	93.07	94.08	94.19
Riyadh2001	95.37	93.93	95.14	95.22
Riyadh2002	95.61	94.11	95.45	95.59
Riyadh2003	98.77	98.73	99.4	99.4
Riyadh2004	98.59	100	100	100
Riyadh2005	98.25	100	100	100
Riyadh2006	98.17	97.69	99.54	99.55
Riyadh2007	94.69	94.36	95.83	95.91
Riyadh2008	92.01	91.6	94.16	94.55
Riyadh2009	98.13	97.92	100	100
Riyadh2010	93.51	93.46	100	100
Riyadh2011	94.23	94.01	100	100
Mean	95.17	94.47	95.64	95.70
Max	98.77	100.00	100.00	100.00
Min	92.01	91.44	91.56	91.71

Appendix 24: TE of Jeddah branch using DEA and SFA (1988-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Jeddah1988	99.06	98.59	99.88	99.88
Jeddah1989	99.04	98.6	100	100
Jeddah1990	98.75	97.9	99.45	99.47
Jeddah1991	98.59	97.49	99.03	99.04
Jeddah1992	98.37	97.78	98.83	98.84
Jeddah1993	98.65	98.05	99.34	99.36
Jeddah1994	98.83	98.31	99.88	99.88
Jeddah1995	98.53	97.6	99.34	99.36
Jeddah1996	98.26	98.09	99.17	99.19
Jeddah1997	98.21	97.03	99.28	99.3
Jeddah1998	98.28	97.08	99.21	99.23
Jeddah1999	98.35	97.5	99.1	99.12
Jeddah2000	98.77	98.79	99.96	99.96
Jeddah2001	98.60	98.42	99.69	99.69
Jeddah2002	98.51	98.65	99.57	99.58
Jeddah2003	98.72	99.07	100	100
Jeddah2004	98.59	98.69	99.66	99.66
Jeddah2005	98.24	97.12	99.28	99.29
Jeddah2006	97.97	96.73	98.92	98.94
Jeddah2007	96.40	96.63	100	100
Jeddah2008	91.32	90.26	91.83	91.98
Jeddah2009	97.88	96.58	99.05	99.07
Jeddah2010	94.12	92.67	95.2	95.37
Jeddah2011	93.68	92.14	94.74	94.84
Mean	97.74	97.07	98.77	98.79
Max	99.06	99.07	100.00	100.00
Min	91.32	90.26	91.83	91.98

Appendix 25: TE of Dammam branch using DEA and SFA (1988-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Dammam1988	94.71	93.9	94.42	93.9
Dammam1989	94.65	92.48	93.35	92.84
Dammam1990	94.12	92	92.23	92
Dammam1991	93.91	91.77	92	91.77
Dammam1992	93.79	91.72	91.78	91.87
Dammam1993	96.34	94.45	94.76	94.86
Dammam1994	95.50	93.63	94.19	94.3
Dammam1995	93.33	91.38	92.05	92.22
Dammam1996	93.56	91.62	92.29	92.46
Dammam1997	94.05	92.12	92.87	93.02
Dammam1998	92.39	90.52	91.03	91.24
Dammam1999	92.14	90.17	90.7	90.91
Dammam2000	91.69	89.69	90.29	90.5
Dammam2001	92.35	90.37	91.06	91.25
Dammam2002	92.40	90.53	91.25	91.39
Dammam2003	96.86	95.18	96.11	96.17
Dammam2004	96.56	94.92	95.81	95.88
Dammam2005	96.18	94.46	95.37	95.44
Dammam2006	98.12	96.6	97.59	97.64
Dammam2007	95.44	93.83	94.63	94.71
Dammam2008	91.30	89.42	90.15	90.3
Dammam2009	97.99	96.43	97.41	97.46
Dammam2010	92.02	90.73	90.98	91.22
Dammam2011	93.42	91.73	93.52	93.71
Mean	94.28	92.49	93.16	93.21
Max	98.12	96.60	97.59	97.64
Min	91.30	89.42	90.15	90.30

Appendix 26: TE of Qassim branch using DEA and SFA (1988-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Qassim1988	98.86	97.91	99.66	99.62
Qassim1989	98.83	97.91	98.3	98.21
Qassim1990	94.69	92.99	93.03	93.02
Qassim1991	95.37	93.72	93.78	93.76
Qassim1992	97.29	95.61	95.64	95.63
Qassim1993	98.46	97.21	97.22	97.22
Qassim1994	97.20	95.66	95.67	95.68
Qassim1995	97.30	95.82	95.82	95.92
Qassim1996	98.80	97.98	98.21	98.26
Qassim1997	98.68	97.89	98.04	98.1
Qassim1998	99.00	98.72	98.73	98.73
Qassim1999	98.86	97.64	97.66	97.72
Qassim2000	97.45	95.55	95.61	95.72
Qassim2001	98.28	96.66	96.88	96.95
Qassim2002	98.64	97.3	97.58	97.63
Qassim2003	99.03	98.49	99.03	99.05
Qassim2004	98.00	96.47	97.15	97.22
Qassim2005	96.55	94.75	95.62	95.79
Qassim2006	97.86	96.43	97.04	97.11
Qassim2007	89.81	87.88	88.18	88.46
Qassim2008	84.50	82.66	82.66	83.07
Qassim2009	97.41	96.43	96.45	96.44
Qassim2010	91.95	90.65	90.81	91.05
Qassim2011	92.16	90.87	91.03	91.26
Mean	96.46	95.13	95.41	95.48
Max	99.03	98.72	99.66	99.62
Min	84.50	82.66	82.66	83.07

Appendix 27: TE of Khamis branch using DEA and SFA (1988-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Khamis1988	94.52	93.33	93.9	93.77
Khamis1989	94.39	93.35	93.45	93.36
Khamis1990	91.42	90.44	90.72	90.57
Khamis1991	91.52	89.32	90.13	89.49
Khamis1992	93.00	92.74	93.6	93.48
Khamis1993	94.68	94.38	94.88	94.79
Khamis1994	93.81	92.81	92.96	92.84
Khamis1995	90.41	89.65	89.89	89.74
Khamis1996	90.33	89.94	90.05	90.24
Khamis1997	91.53	91.69	91.76	91.69
Khamis1998	91.07	90.78	90.83	91.07
Khamis1999	87.53	86.38	86.89	87.21
Khamis2000	86.01	84.63	85.18	85.56
Khamis2001	85.14	85.52	88.75	90.57
Khamis2002	87.76	89.03	91.16	91.78
Khamis2003	92.55	94.72	97.71	97.78
Khamis2004	93.92	96.2	99.43	99.44
Khamis2005	95.26	97.51	100	100
Khamis2006	98.46	99.29	100	100
Khamis2007	92.46	94.36	96.76	96.82
Khamis2008	89.11	88.01	89.22	89.44
Khamis2009	98.10	96.73	98.95	98.98
Khamis2010	91.90	90.08	95.58	96.09
Khamis2011	92.26	90.47	96.51	96.89
Mean	91.96	91.72	93.26	93.40
Max	98.46	99.29	100.00	100.00
Min	85.14	84.63	85.18	85.56

Appendix 28: TE of Tabuk branch using DEA and SFA (1998-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Tabuk1998	95.57	95.42	100	100
Tabuk1999	97.47	100	100	100
Tabuk2000	97.74	98.06	98.91	98.81
Tabuk2001	97.35	98.32	98.33	98.43
Tabuk2002	98.52	99.38	99.46	99.44
Tabuk2003	99.43	99.83	99.83	99.83
Tabuk2004	99.47	100	100	100
Tabuk2005	99.48	100	100	100
Tabuk2006	98.27	97.11	97.54	97.78
Tabuk2007	99.46	100	100	100
Tabuk2008	94.71	93.6	93.77	93.6
Tabuk2009	97.89	96.85	96.9	96.89
Tabuk2010	94.61	93.92	93.96	93.95
Tabuk2011	94.50	93.76	93.79	93.78
Mean	97.46	97.59	98.04	98.04
Max	99.48	100.00	100.00	100.00
Min	94.50	93.60	93.77	93.60

Appendix 29: TE of Almadinah, Hail and Aljouf branches using DEA and SFA (2008-2011)

Branch	TE using SFA	TE using DEA		
	Cobb-Douglas under Half-Normal Distribution-BC estimator	CRS-Input and output orientated	VRS-Input orientated	VRS-Output orientated
Almadinah2008	96.02	100	100	100
Almadinah2009	98.06	97.81	98.12	98.33
Almadinah2010	96.76	96.28	96.29	96.59
Almadinah2011	96.98	96.43	96.6	96.96
Hail2008	94.06	94.63	94.79	94.78
Hail2009	97.72	96.86	96.89	96.89
Hail2010	93.48	92.89	92.91	92.9
Hail2011	93.67	93.11	93.12	93.3
Aljouf2008	92.09	95.07	100	100
Aljouf2009	97.61	97.08	97.15	97.14
Aljouf2010	93.30	92.94	92.98	92.96
Aljouf2011	94.25	93.69	93.7	93.69
Mean Almadinah	96.95	97.63	97.75	97.97
Max Almadinah	98.06	100.00	100.00	100.00
Min Almadinah	96.02	96.28	96.29	96.59
Mean Hail	94.73	94.37	94.43	94.47
Max Hail	97.72	96.86	96.89	96.89
Min Hail	93.48	92.89	92.91	92.90
Mean Aljouf	94.31	94.70	95.96	95.95
Max	97.61	97.08	100.00	100.00
Min	92.09	92.94	92.98	92.96

Appendix 30: Riyadh and Jeddah branches target under CRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Riyadh1988	159794	159794	0	201633	187425.9	-7.05	15517	8800.56	-43.28	247680	230228.4	-7.05
Riyadh1989	187482	187482	0	236566	219830	-7.07	18206	10291.3	-43.47	291840	271193.6	-7.07
Riyadh1990	211555	211555	0	269185	248270.8	-7.77	20833	11714.8	-43.77	328320	302811.3	-7.77
Riyadh1991	196894	196894	0	251350	229835.7	-8.56	19732	10317.1	-47.71	328320	300217.4	-8.56
Riyadh1992	218687	218687	0	276349	258477.9	-6.47	21033	12985	-38.26	305280	285538	-6.47
Riyadh1993	215349	215349	0	272852	252320.3	-7.52	20597	11732.9	-43.04	339840	314267.6	-7.52
Riyadh1994	234962	234962	0	295587	277273.4	-6.2	21244	13741.4	-35.32	334080	313381.5	-6.2
Riyadh1995	227527	227527	0	281566	265767.3	-5.61	20501	12004.9	-41.44	364800	344331	-5.61
Riyadh1996	243197	243197	0	302899	286348.7	-5.46	20304	13916.8	-31.46	353280	333976.9	-5.46
Riyadh1997	262618	262618	0	325543	309301.1	-4.99	21111	15068.9	-28.62	378240	359369	-4.99
Riyadh1998	240318	240318	0	301715	279678.3	-7.3	19598	12189.3	-37.8	408960	379090.3	-7.3
Riyadh1999	252351	252351	0	316274	291996.9	-7.68	20561	12572.9	-38.85	675840	469103.4	-30.59
Riyadh2000	252351	252351	0	313747	291996.9	-6.93	20628	12572.9	-39.05	675840	469103.4	-30.59
Riyadh2001	278622	278622	0	343227	322395.2	-6.07	22550	13881.8	-38.44	691200	517939.5	-25.07
Riyadh2002	296879	296879	0	365017	343520.5	-5.89	23849	14791.4	-37.98	691200	551878	-20.16
Riyadh2003	338775	338775	0	403159	398051.3	-1.27	25506	18988.8	-25.55	483840	477710.1	-1.27
Riyadh2004	410618	410618	0	492936	492936	0	28004	28004	0	422400	422400	0
Riyadh2005	482461	482461	0	582712	582712	0	30501	30501	0	464640	464640	0
Riyadh2006	452368	452368	0	542842	530279.1	-2.31	28290	24764.7	-12.46	672000	656448	-2.31
Riyadh2007	457131	457131	0	571774	539515.7	-5.64	28707	26765.7	-6.76	645120	608723.7	-5.64
Riyadh2008	491503	491503	0	633058	579879.5	-8.4	30892	28296.5	-8.4	720000	659517.9	-8.4
Riyadh2009	552720	552720	0	663264	649498.5	-2.08	33422	31013	-7.21	794880	778383	-2.08
Riyadh2010	573496	573496	0	726022	678514.6	-6.54	34000	31774.7	-6.54	810240	757222	-6.54
Riyadh2011	573501	573501	0	719943	676812.3	-5.99	33647	31631.4	-5.99	823680	774334.8	-5.99
Jeddah1988	342932	342932	0	403899	398224.2	-1.41	29096	17032.7	-41.46	566400	558442.1	-1.41
Jeddah1989	379382	379382	0	446829	440562.9	-1.4	32189	18842.6	-41.46	625920	617142.4	-1.4
Jeddah1990	397727	397727	0	471838	461940.1	-2.1	34483	19751	-42.72	656640	642865.4	-2.1
Jeddah1991	363000	363000	0	431473	420649.5	-2.51	31832	18062.4	-43.26	656640	640168.2	-2.51
Jeddah1992	394952	394952	0	472628	462131.5	-2.22	34986	21220	-39.35	599040	585736.1	-2.22
Jeddah1993	415499	415499	0	494226	484579	-1.95	36520	21564.3	-40.95	652800	640057.7	-1.95
Jeddah1994	429331	429331	0	508482	499876.6	-1.69	37099	21884.9	-41.01	685440	673839.8	-1.69
Jeddah1995	433441	433441	0	516299	503913.5	-2.4	36966	21737.9	-41.2	708480	691484.3	-2.4
Jeddah1996	501410	501410	0	600932	589448.4	-1.91	40342	28250.2	-29.97	716160	702474.5	-1.91
Jeddah1997	467224	467224	0	558395	541802.6	-2.97	37321	23234.3	-37.74	827520	802930.7	-2.97
Jeddah1998	432679	432679	0	516725	501640.6	-2.92	34300	21520.3	-37.26	771840	749308.2	-2.92
Jeddah1999	426722	426722	0	510177	497434.8	-2.5	33582	22035.8	-34.38	677760	660832.2	-2.5
Jeddah2000	465115	465115	0	552290	545583.6	-1.21	36464	25635	-29.7	677760	669530	-1.21
Jeddah2001	475641	475641	0	566570	557595.3	-1.58	37445	26055.4	-30.42	700800	689699	-1.58
Jeddah2002	506905	506905	0	605353	597168.4	-1.35	39895	29160.1	-26.91	700800	691324.9	-1.35
Jeddah2003	512602	512602	0	609620	603947.5	-0.93	40272	29520.1	-26.7	704640	698083.3	-0.93
Jeddah2004	493796	493796	0	588720	581016.2	-1.31	39206	28068.3	-28.41	693120	684050	-1.31
Jeddah2005	474990	474990	0	567819	551467.7	-2.88	38140	23595.7	-38.13	802560	779448.9	-2.88
Jeddah2006	469915	469915	0	563898	545481.9	-3.27	37384	23347.1	-37.55	802560	776349.6	-3.27
Jeddah2007	562180	562180	0	690414	667154.4	-3.37	43358	34659.2	-20.06	718080	693888.8	-3.37
Jeddah2008	477672	477672	0	618837	558550.3	-9.74	38662	25487.2	-34.08	791040	713977.3	-9.74
Jeddah2009	480081	480081	0	576097	556377.5	-3.42	37131	23886.2	-35.67	873600	843697.1	-3.42
Jeddah2010	508095	508095	0	636566	589921.9	-7.33	38035	25239.5	-33.64	898560	832718.2	-7.33
Jeddah2011	478040	478040	0	601184	553913.4	-7.86	35681	23788.3	-33.33	917760	845596.7	-7.86

Appendix 31: Dammam and Qassim branches target under CRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Dammam1988	118423	118423	0	148169	137028	-7.52	12060	5900.18	-51.08	243840	220140.3	-9.72
Dammam1989	135815	135815	0	169929	157152.4	-7.52	13831	6766.7	-51.08	278400	252470.9	-9.31
Dammam1990	152075	152075	0	191262	175966.9	-8	16069	7576.82	-52.85	312960	282697.1	-9.67
Dammam1991	152672	152672	0	192496	176657.7	-8.23	16052	7606.56	-52.61	312960	283806.9	-9.32
Dammam1992	163507	163507	0	206602	189497.5	-8.28	17173	8135.02	-52.63	312960	287050.2	-8.28
Dammam1993	192478	192478	0	236581	223442.1	-5.55	18436	9562.57	-48.13	336000	317339.7	-5.55
Dammam1994	218763	218763	0	271052	253782.8	-6.37	19471	10874.9	-44.15	395520	370320.8	-6.37
Dammam1995	215354	215354	0	272679	249187.4	-8.62	19292	10729.6	-44.38	449280	400328.5	-10.9
Dammam1996	223394	223394	0	282355	258682.1	-8.38	20229	11122.9	-45.01	441600	404575.9	-8.38
Dammam1997	224203	224203	0	281629	259426.6	-7.88	19962	11170.4	-44.04	458880	416778.2	-9.17
Dammam1998	202637	202637	0	259034	234472.5	-9.48	18364	10096	-45.02	460800	376688.5	-18.25
Dammam1999	204170	204170	0	262002	236246.3	-9.83	18722	10172.3	-45.67	437760	379538.2	-13.3
Dammam2000	216362	216362	0	279313	250525	-10.31	20267	10773.4	-46.84	437760	392641.3	-10.31
Dammam2001	221480	221480	0	283666	256346.9	-9.63	20364	11032.1	-45.83	451200	407746.2	-9.63
Dammam2002	243365	243365	0	311918	282385.6	-9.47	22425	12095.6	-46.06	451200	408480.4	-9.47
Dammam2003	273022	273022	0	333146	317084.6	-4.82	23586	13558.8	-42.51	464640	442239.1	-4.82
Dammam2004	271431	271431	0	332394	315513.8	-5.08	23678	13589.5	-42.61	456960	433753.8	-5.08
Dammam2005	269840	269840	0	331642	313259.4	-5.54	23769	13405.6	-43.6	470400	444326.2	-5.54
Dammam2006	268451	268451	0	322141	311192.8	-3.4	23714	13353.7	-43.69	483840	467396.3	-3.4
Dammam2007	266896	266896	0	330990	310572.3	-6.17	23654	13519.8	-42.84	449280	421566	-6.17
Dammam2008	245779	245779	0	318851	285103	-10.58	22542	12218.7	-45.8	466560	417178.4	-10.58
Dammam2009	244770	244770	0	293724	283224.8	-3.57	22119	12195.2	-44.87	501120	455010.9	-9.2
Dammam2010	182433	182433	0	232666	211094	-9.27	14493	9089.33	-37.29	606720	339130.1	-44.1
Dammam2011	287348	287348	0	362453	332492.2	-8.27	19236	14316.5	-25.57	639360	534160.7	-16.45
Qassim1988	94912	94912	0	112167	109823.2	-2.09	7678	4728.79	-38.41	257280	176435	-31.42
Qassim1989	109328	109328	0	129204	126504.1	-2.09	8844	5447.04	-38.41	295680	203233.4	-31.27
Qassim1990	130188	130188	0	162006	150641.3	-7.01	10935	6486.34	-40.68	353280	242010.7	-31.5
Qassim1991	127065	127065	0	156872	147027.7	-6.28	10514	6330.75	-39.79	353280	236205.2	-33.14
Qassim1992	138895	138895	0	168096	160716.2	-4.39	11587	6920.15	-40.28	343680	258196.4	-24.87
Qassim1993	153022	153022	0	182148	177062.7	-2.79	12324	7624	-38.14	376320	284457.5	-24.41
Qassim1994	160124	160124	0	193683	185280.4	-4.34	12751	7977.84	-37.43	414720	297659.7	-28.23
Qassim1995	164937	164937	0	199174	190849.6	-4.18	13160	8217.64	-37.56	433920	306606.7	-29.34
Qassim1996	179676	179676	0	212199	207904.2	-2.02	14226	8951.98	-37.07	447360	334005.5	-25.34
Qassim1997	174562	174562	0	206337	201986.7	-2.11	13878	8697.18	-37.33	485760	324499	-33.2
Qassim1998	157839	157839	0	184999	182636.5	-1.28	12381	7864	-36.48	472320	293412	-37.88
Qassim1999	168862	168862	0	200449	195708.5	-2.36	13403	8401.27	-37.32	303360	296185.7	-2.36
Qassim2000	171896	171896	0	208720	199433.4	-4.45	13845	8544.37	-38.29	303360	289862.6	-4.45
Qassim2001	184134	184134	0	221086	213708.4	-3.34	14465	9149.81	-36.75	316800	306228.4	-3.34
Qassim2002	189555	189555	0	226239	220125.5	-2.7	15501	9414.47	-39.27	316800	308239.3	-2.7
Qassim2003	200474	200474	0	235515	231969.7	-1.51	15795	9988.2	-36.76	470400	372667.6	-20.78
Qassim2004	213716	213716	0	256335	247292.1	-3.53	15621	10648	-31.84	464640	397283.6	-14.5
Qassim2005	226957	226957	0	277154	262613.3	-5.25	15447	11307.7	-26.8	472320	421897.7	-10.68
Qassim2006	207679	207679	0	249215	240306.6	-3.57	14834	10347.2	-30.25	491520	386061.2	-21.46
Qassim2007	185705	185705	0	244507	214880.3	-12.12	13829	9252.36	-33.09	443520	345212.8	-22.17
Qassim2008	164133	164133	0	229768	189919.2	-17.34	12203	8177.58	-32.98	480000	305112	-36.44
Qassim2009	147534	147534	0	177041	170712.5	-3.57	10674	7350.57	-31.14	526080	274255.7	-47.87
Qassim2010	176004	176004	0	224668	203655.1	-9.35	11965	8769.02	-26.71	591360	327179.2	-44.67
Qassim2011	176074	176074	0	224218	203736.8	-9.13	11939	8772.54	-26.52	591360	327310.4	-44.65

Appendix 32: Khamis and Tabuk branches target under CRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Khamis1988	154514	154514	0	194591	181619.8	-6.67	10859	8694.1	-19.94	232320	216833.8	-6.67
Khamis1989	201025	201025	0	253166	236336.9	-6.65	14128	11333.5	-19.78	301440	281402	-6.65
Khamis1990	188373	188373	0	245488	222025.8	-9.56	13628	10888.6	-20.1	282240	255265.3	-9.56
Khamis1991	141168	141168	0	183075	163531	-10.68	10290	7026.46	-31.72	282240	252109.7	-10.68
Khamis1992	168753	168753	0	216833	201094.2	-7.26	12305	10799.4	-12.24	211200	195870.1	-7.26
Khamis1993	197734	197734	0	248967	234981.2	-5.62	13706	12345.3	-9.93	253440	239202.9	-5.62
Khamis1994	198271	198271	0	251385	233308.4	-7.19	13876	11277.9	-18.72	295680	274418.2	-7.19
Khamis1995	204850	204850	0	270133	242168.6	-10.35	14851	12185	-17.95	297600	266792.2	-10.35
Khamis1996	212015	212015	0	279831	251678.8	-10.06	12888	11591.4	-10.06	307200	276294.4	-10.06
Khamis1997	249716	249716	0	325513	298456.9	-8.31	15894	14572.9	-8.31	316800	290468.1	-8.31
Khamis1998	273285	273285	0	357463	324500.8	-9.22	17520	15904.5	-9.22	374400	339876	-9.22
Khamis1999	266603	266603	0	362468	313103.9	-13.62	18533	14873.3	-19.75	437760	378142	-13.62
Khamis2000	253077	253077	0	350284	296448.3	-15.37	17540	13751.7	-21.6	437760	370480	-15.37
Khamis2001	284864	284864	0	398960	341203.7	-14.48	16745	14320.9	-14.48	449280	384239	-14.48
Khamis2002	359577	359577	0	489208	435540.3	-10.97	21990	19577.6	-10.97	449280	399992.5	-10.97
Khamis2003	395901	395901	0	510243	483291	-5.28	22899	21689.4	-5.28	430080	407362.4	-5.28
Khamis2004	401634	401634	0	509781	490433.8	-3.8	22976	22104	-3.8	426240	410063.4	-3.8
Khamis2005	407366	407366	0	509318	496627	-2.49	23053	22478.6	-2.49	432000	421235.6	-2.49
Khamis2006	359307	359307	0	431168	428105	-0.71	20443	20297.8	-0.71	445440	442275.6	-0.71
Khamis2007	365555	365555	0	471527	444924.5	-5.64	21178	19983.2	-5.64	410880	387699	-5.64
Khamis2008	334904	334904	0	446272	392765	-11.99	22039	18420.5	-16.42	549120	483282	-11.99
Khamis2009	336158	336158	0	403390	390183.7	-3.27	19996	16702.8	-16.47	576000	557142.8	-3.27
Khamis2010	314130	314130	0	403542	363501.3	-9.92	17619	15650.1	-11.17	647040	582838.3	-9.92
Khamis2011	330066	330066	0	422322	382083.9	-9.53	18468	16438.7	-10.99	668160	604499.1	-9.53
Tabuk1998	84299	84299	0	105404	100571.5	-4.58	4476	4270.79	-4.58	119040	113582.4	-4.58
Tabuk1999	117504	117504	0	144419	144419	0	6139	6139	0	119040	119040	0
Tabuk2000	124947	124947	0	152202	149244.2	-1.94	6542	6414.86	-1.94	167040	163793.8	-1.94
Tabuk2001	132217	132217	0	161963	159246.3	-1.68	6879	6763.61	-1.68	167040	164238.2	-1.68
Tabuk2002	137934	137934	0	166102	165079	-0.62	7163	7118.88	-0.62	178560	177460.3	-0.62
Tabuk2003	165712	165712	0	192080	191746.4	-0.17	8309	8256.25	-0.63	334080	308047.4	-7.79
Tabuk2004	166001	166001	0	192247	192243.2	0	8297	8264.54	-0.39	299520	299514.1	0
Tabuk2005	166289	166289	0	192414	192414	0	8285	8285	0	309120	309120	0
Tabuk2006	168182	168182	0	201818	195982.8	-2.89	8352	8110.52	-2.89	309120	300182.4	-2.89
Tabuk2007	168055	168055	0	195203	195203.3	0	8344.9	8344.9	0	270720	270720	0
Tabuk2008	144792	144792	0	180837	169257.6	-6.4	7228.4	6765.55	-6.4	309120	287370	-7.04
Tabuk2009	121682	121682	0	146018	141415.8	-3.15	6093.6	5901.54	-3.15	332160	232737.7	-29.93
Tabuk2010	121914	121914	0	151733	142508	-6.08	6066.8	5697.97	-6.08	351360	241905.1	-31.15
Tabuk2011	130255	130255	0	162390	152256.4	-6.24	6493.5	6088.27	-6.24	359040	258437.3	-28.02

Appendix 33: Almadinah, Hail and Aljouf branches target under CRS-input orientated (2008-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Almadinah2008	118546	118546	0	145541	145541.3	0	3721	3721	0	309120	309120	0
Almadinah2009	155857	155857	0	187028	182924.4	-2.19	7250.5	7091.41	-2.19	347520	317094.1	-8.76
Almadinah2010	152670	152670	0	185672	178772.3	-3.72	7326	7053.75	-3.72	393600	306249.3	-22.19
Almadinah2011	156921	156921	0	190424	183623.9	-3.57	7553	7283.28	-3.57	393600	313433.4	-20.37
Hail2008	71314.2	71314.2	0	88679.2	83914.19	-5.37	3369.7	3188.64	-5.37	353280	147369.5	-58.29
Hail2009	127757	127757	0	153308	148488.5	-3.14	6393.9	6192.9	-3.14	385920	244490.3	-36.65
Hail2010	138930	138930	0	175042	162605.2	-7.11	6932	6439.47	-7.11	395520	277855.4	-29.75
Hail2011	146013	146013	0	183641	170989.1	-6.89	7242	6743.08	-6.89	399360	293022	-26.63
Aljouf2008	4537.9	4537.9	0	5579.9	5304.79	-4.93	223	212.01	-4.93	312960	9007.73	-97.12
Aljouf2009	106196	106196	0	127435	123708.8	-2.92	5227.5	5074.65	-2.92	366720	206197.6	-43.77
Aljouf2010	120679	120679	0	152164	141417.1	-7.06	5970	5548.34	-7.06	382080	243189	-36.35
Aljouf2011	143345	143345	0	179246	167926.5	-6.31	7049	6603.86	-6.31	380160	288319	-24.16

Appendix 34: Riyadh and Jeddah branches target under CRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Riyadh1988	159794	171907	7.58	201633	201633	0	15517	9467.7	-38.99	247680	247680	0
Riyadh1989	187482	201755	7.61	236566	236566	0	18206	11075	-39.17	291840	291840	0
Riyadh1990	211555	229376	8.42	269185	269185	0	20833	12702	-39.03	328320	328320	0
Riyadh1991	196894	215325	9.36	251350	251350	0	19732	11283	-42.82	328320	328320	0
Riyadh1992	218687	233807	6.91	276349	276349	0	21033	13883	-34	305280	305280	0
Riyadh1993	215349	232872	8.14	272852	272852	0	20597	12688	-38.4	339840	339840	0
Riyadh1994	234962	250481	6.6	295587	295587	0	21244	14649	-31.04	334080	334080	0
Riyadh1995	227527	241053	5.94	281566	281566	0	20501	12719	-37.96	364800	364800	0
Riyadh1996	243197	257253	5.78	302899	302899	0	20304	14721	-27.5	353280	353280	0
Riyadh1997	262618	276408	5.25	325543	325543	0	21111	15860	-24.87	378240	378240	0
Riyadh1998	240318	259253	7.88	301715	301715	0	19598	13150	-32.9	408960	408960	0
Riyadh1999	252351	273332	8.31	316274	316274	0	20561	13618	-33.77	675840	508106	-24.82
Riyadh2000	252351	271148	7.45	313747	313747	0	20628	13509	-34.51	675840	504046	-25.42
Riyadh2001	278622	296625	6.46	343227	343227	0	22550	14779	-34.46	691200	551407	-20.22
Riyadh2002	296879	315457	6.26	365017	365017	0	23849	15717	-34.1	691200	586413	-15.16
Riyadh2003	338775	343122	1.28	403159	403159	0	25506	19232	-24.6	483840	483840	0
Riyadh2004	410618	410618	0	492936	492936	0	28004	28004	0	422400	422400	0
Riyadh2005	482461	482461	0	582712	582712	0	30501	30501	0	464640	464640	0
Riyadh2006	452368	463085	2.37	542842	542842	0	28290	25351	-10.39	672000	672000	0
Riyadh2007	457131	484464	5.98	571774	571774	0	28707	28366	-1.19	645120	645120	0
Riyadh2008	491503	536577	9.17	633058	633058	0	30892	30892	0	720000	720000	0
Riyadh2009	552720	564434	2.12	663264	663264	0	33422	31670	-5.24	794880	794880	0
Riyadh2010	573496	613650	7	726022	726022	0	34000	34000	0	810240	810240	0
Riyadh2011	573501	610048	6.37	719943	719943	0	33647	33647	0	823680	823680	0
Jeddah1988	342932	347819	1.43	403899	403899	0	29096	17275	-40.63	566400	566400	0
Jeddah1989	379382	384778	1.42	446829	446829	0	32189	19111	-40.63	625920	625920	0
Jeddah1990	397727	406249	2.14	471838	471838	0	34483	20174	-41.5	656640	656640	0
Jeddah1991	363000	372340	2.57	431473	431473	0	31832	18527	-41.8	656640	656640	0
Jeddah1992	394952	403923	2.27	472628	472628	0	34986	21702	-37.97	599040	599040	0
Jeddah1993	415499	423771	1.99	494226	494226	0	36520	21994	-39.78	652800	652800	0
Jeddah1994	429331	436722	1.72	508482	508482	0	37099	22262	-39.99	685440	685440	0
Jeddah1995	433441	444094	2.46	516299	516299	0	36966	22272	-39.75	708480	708480	0
Jeddah1996	501410	511178	1.95	600932	600932	0	40342	28801	-28.61	716160	716160	0
Jeddah1997	467224	481533	3.06	558395	558395	0	37321	23946	-35.84	827520	827520	0
Jeddah1998	432679	445690	3.01	516725	516725	0	34300	22167	-35.37	771840	771840	0
Jeddah1999	426722	437653	2.56	510177	510177	0	33582	22600	-32.7	677760	677760	0
Jeddah2000	465115	470832	1.23	552290	552290	0	36464	25950	-28.83	677760	677760	0
Jeddah2001	475641	483297	1.61	566570	566570	0	37445	26475	-29.3	700800	700800	0
Jeddah2002	506905	513852	1.37	605353	605353	0	39895	29560	-25.91	700800	700800	0
Jeddah2003	512602	517417	0.94	609620	609620	0	40272	29797	-26.01	704640	704640	0
Jeddah2004	493796	500343	1.33	588720	588720	0	39206	28440	-27.46	693120	693120	0
Jeddah2005	474990	489074	2.97	567819	567819	0	38140	24295	-36.3	802560	802560	0
Jeddah2006	469915	485780	3.38	563898	563898	0	37384	24135	-35.44	802560	802560	0
Jeddah2007	562180	581779	3.49	690414	690414	0	43358	35868	-17.28	718080	718080	0
Jeddah2008	477672	529230	10.79	618837	618837	0	38662	28238	-26.96	791040	791040	0
Jeddah2009	480081	497096	3.54	576097	576097	0	37131	24733	-33.39	873600	873600	0
Jeddah2010	508095	548269	7.91	636566	636566	0	38035	27235	-28.39	898560	898560	0
Jeddah2011	478040	518836	8.53	601184	601184	0	35681	25818	-27.64	917760	917760	0

Appendix 35: Dammam and Qassim branches target under CRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Dammam1988	118423	128051	8.13	148169	148169	0	12060	6379.9	-47.1	243840	238039	-2.38
Dammam1989	135815	146857	8.13	169929	169929	0	13831	7316.8	-47.1	278400	272997	-1.94
Dammam1990	152075	165293	8.69	191262	191262	0	16069	8235.4	-48.75	312960	307269	-1.82
Dammam1991	152672	166360	8.97	192496	192496	0	16052	8288.5	-48.36	312960	309252	-1.18
Dammam1992	163507	178266	9.03	206602	206602	0	17173	8869.3	-48.35	312960	312960	0
Dammam1993	192478	203796	5.88	236581	236581	0	18436	10125	-45.08	336000	336000	0
Dammam1994	218763	233649	6.8	271052	271052	0	19471	11615	-40.35	395520	395520	0
Dammam1995	215354	235656	9.43	272679	272679	0	19292	11741	-39.14	449280	438069	-2.5
Dammam1996	223394	243838	9.15	282355	282355	0	20229	12141	-39.98	441600	441600	0
Dammam1997	224203	243391	8.56	281629	281629	0	19962	12126	-39.25	458880	452447	-1.4
Dammam1998	202637	223864	10.48	259034	259034	0	18364	11154	-39.26	460800	416147	-9.69
Dammam1999	204170	226429	10.9	262002	262002	0	18722	11281	-39.74	437760	420916	-3.85
Dammam2000	216362	241224	11.49	279313	279313	0	20267	12011	-40.73	437760	437760	0
Dammam2001	221480	245083	10.66	283666	283666	0	20364	12208	-40.05	451200	451200	0
Dammam2002	243365	268817	10.46	311918	311918	0	22425	13361	-40.42	451200	451200	0
Dammam2003	273022	286851	5.07	333146	333146	0	23586	14246	-39.6	464640	464640	0
Dammam2004	271431	285953	5.35	332394	332394	0	23678	14317	-39.54	456960	456960	0
Dammam2005	269840	285675	5.87	331642	331642	0	23769	14192	-40.29	470400	470400	0
Dammam2006	268451	277895	3.52	322141	322141	0	23714	13824	-41.71	483840	483840	0
Dammam2007	266896	284442	6.57	330990	330990	0	23654	14409	-39.09	449280	449280	0
Dammam2008	245779	274872	11.84	318851	318851	0	22542	13665	-39.38	466560	466560	0
Dammam2009	244770	253844	3.71	293724	293724	0	22119	12647	-42.82	501120	471878	-5.84
Dammam2010	182433	201075	10.22	232666	232666	0	14493	10018	-30.88	606720	373786	-38.39
Dammam2011	287348	313241	9.01	362453	362453	0	19236	15607	-18.87	639360	582293	-8.93
Qassim1988	94912	96938	2.13	112167	112167	0	7678	4829.7	-37.1	257280	180200	-29.96
Qassim1989	109328	111661	2.13	129204	129204	0	8844	5563.3	-37.1	295680	207571	-29.8
Qassim1990	130188	140010	7.54	162006	162006	0	10935	6975.7	-36.21	353280	260268	-26.33
Qassim1991	127065	135573	6.7	156872	156872	0	10514	6754.6	-35.76	353280	252021	-28.66
Qassim1992	138895	145273	4.59	168096	168096	0	11587	7237.9	-37.53	343680	270052	-21.42
Qassim1993	153022	157417	2.87	182148	182148	0	12324	7843	-36.36	376320	292627	-22.24
Qassim1994	160124	167386	4.54	193683	193683	0	12751	8339.6	-34.6	414720	311159	-24.97
Qassim1995	164937	172131	4.36	199174	199174	0	13160	8576.1	-34.83	433920	319980	-26.26
Qassim1996	179676	183388	2.07	212199	212199	0	14226	9136.9	-35.77	447360	340905	-23.8
Qassim1997	174562	178322	2.15	206337	206337	0	13878	8884.5	-35.98	485760	331488	-31.76
Qassim1998	157839	159881	1.29	184999	184999	0	12381	7965.7	-35.66	472320	297208	-37.07
Qassim1999	168862	172952	2.42	200449	200449	0	13403	8604.8	-35.8	303360	303360	0
Qassim2000	171896	179900	4.66	208720	208720	0	13845	8942.2	-35.41	303360	303360	0
Qassim2001	184134	190491	3.45	221086	221086	0	14465	9465.7	-34.56	316800	316800	0
Qassim2002	189555	194819	2.78	226239	226239	0	15501	9675.9	-37.58	316800	316800	0
Qassim2003	200474	203538	1.53	235515	235515	0	15795	10141	-35.8	470400	378363	-19.57
Qassim2004	213716	221531	3.66	256335	256335	0	15621	11037	-29.34	464640	411811	-11.37
Qassim2005	226957	239523	5.54	277154	277154	0	15447	11934	-22.74	472320	445258	-5.73
Qassim2006	207679	215378	3.71	249215	249215	0	14834	10731	-27.66	491520	400373	-18.54
Qassim2007	185705	211309	13.79	244507	244507	0	13829	10528	-23.87	443520	392809	-11.43
Qassim2008	164133	198571	20.98	229768	229768	0	12203	9893.4	-18.92	480000	369131	-23.1
Qassim2009	147534	153003	3.71	177041	177041	0	10674	7623.1	-28.58	526080	284423	-45.94
Qassim2010	176004	194164	10.32	224668	224668	0	11965	9673.8	-19.15	591360	360937	-38.96
Qassim2011	176074	193775	10.05	224218	224218	0	11939	9654.4	-19.13	591360	360214	-39.09

Appendix 36: Khamis and Tabuk branches target under CRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Khamis1988	154514	165549	7.14	194591	194591	0	10859	9315	-14.22	232320	232320	0
Khamis1989	201025	215340	7.12	253166	253166	0	14128	12141	-14.07	301440	301440	0
Khamis1990	188373	208279	10.57	245488	245488	0	13628	12039	-11.66	282240	282240	0
Khamis1991	141168	158039	11.95	183075	183075	0	10290	7866.2	-23.55	282240	282240	0
Khamis1992	168753	181961	7.83	216833	216833	0	12305	11645	-5.37	211200	211200	0
Khamis1993	197734	209503	5.95	248967	248967	0	13706	13080	-4.57	253440	253440	0
Khamis1994	198271	213633	7.75	251385	251385	0	13876	12152	-12.43	295680	295680	0
Khamis1995	204850	228505	11.55	270133	270133	0	14851	13592	-8.48	297600	297600	0
Khamis1996	212015	235730	11.19	279831	279831	0	12888	12888	0	307200	307200	0
Khamis1997	249716	272354	9.07	325513	325513	0	15894	15894	0	316800	316800	0
Khamis1998	273285	301045	10.16	357463	357463	0	17520	17520	0	374400	374400	0
Khamis1999	266603	308636	15.77	362468	362468	0	18533	17218	-7.09	437760	437760	0
Khamis2000	253077	299036	18.16	350284	350284	0	17540	16249	-7.36	437760	437760	0
Khamis2001	284864	333084	16.93	398960	398960	0	16745	16745	0	449280	449280	0
Khamis2002	359577	403884	12.32	489208	489208	0	21990	21990	0	449280	449280	0
Khamis2003	395901	417979	5.58	510243	510243	0	22899	22899	0	430080	430080	0
Khamis2004	401634	417478	3.94	509781	509781	0	22976	22976	0	426240	426240	0
Khamis2005	407366	417776	2.56	509318	509318	0	23053	23053	0	432000	432000	0
Khamis2006	359307	361878	0.72	431168	431168	0	20443	20443	0	445440	445440	0
Khamis2007	365555	387411	5.98	471527	471527	0	21178	21178	0	410880	410880	0
Khamis2008	334904	380528	13.62	446272	446272	0	22039	20930	-5.03	549120	549120	0
Khamis2009	336158	347536	3.38	403390	403390	0	19996	17268	-13.64	576000	576000	0
Khamis2010	314130	348732	11.02	403542	403542	0	17619	17374	-1.39	647040	647040	0
Khamis2011	330066	364826	10.53	422322	422322	0	18468	18170	-1.61	668160	668160	0
Tabuk1998	84299	88350	4.81	105404	105404	0	4476	4476	0	119040	119040	0
Tabuk1999	117504	117504	0	144419	144419	0	6139	6139	0	119040	119040	0
Tabuk2000	124947	127423	1.98	152202	152202	0	6542	6542	0	167040	167040	0
Tabuk2001	132217	134473	1.71	161963	161963	0	6879	6879	0	167040	167040	0
Tabuk2002	137934	138789	0.62	166102	166102	0	7163	7163	0	178560	178560	0
Tabuk2003	165712	166000	0.17	192080	192080	0	8309	8270.6	-0.46	334080	308583	-7.63
Tabuk2004	166001	166004	0	192247	192247	0	8297	8264.7	-0.39	299520	299520	0
Tabuk2005	166289	166289	0	192414	192414	0	8285	8285	0	309120	309120	0
Tabuk2006	168182	173189	2.98	201818	201818	0	8352	8352	0	309120	309120	0
Tabuk2007	168055	168055	0	195203	195203	0	8344.9	8344.9	0	270720	270720	0
Tabuk2008	144792	154698	6.84	180837	180837	0	7228.4	7228.4	0	309120	307030	-0.68
Tabuk2009	121682	125642	3.25	146018	146018	0	6093.6	6093.6	0	332160	240312	-27.65
Tabuk2010	121914	129805	6.47	151733	151733	0	6066.8	6066.8	0	351360	257564	-26.7
Tabuk2011	130255	138924	6.66	162390	162390	0	6493.5	6493.5	0	359040	275639	-23.23

Appendix 37: Almadinah, Hail and Aljouf branches target under CRS-output orientated (2008-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Almadinah2008	118546	118546	0	145541	145541	0	3721	3721	0	309120	309120	0
Almadinah2009	155857	159353	2.24	187028	187028	0	7250.5	7250.5	0	347520	324208	-6.71
Almadinah2010	152670	158562	3.86	185672	185672	0	7326	7326	0	393600	318069	-19.19
Almadinah2011	156921	162732	3.7	190424	190424	0	7553	7553	0	393600	325041	-17.42
Hail2008	71314	75364	5.68	88679.2	88679.2	0	3369.7	3369.7	0	353280	155738	-55.92
Hail2009	127757	131904	3.25	153308	153308	0	6393.9	6393.9	0	385920	252426	-34.59
Hail2010	138930	149557	7.65	175042	175042	0	6932	6932	0	395520	299107	-24.38
Hail2011	146013	156816	7.4	183641	183641	0	7242	7242	0	399360	314703	-21.2
Aljouf2008	4537.9	4773.2	5.19	5579.9	5579.9	0	223	223	0	312960	9474.87	-96.97
Aljouf2009	106196	109395	3.01	127435	127435	0	5227.5	5227.5	0	366720	212408	-42.08
Aljouf2010	120679	129851	7.6	152164	152164	0	5970	5970	0	382080	261671	-31.51
Aljouf2011	143345	153007	6.74	179246	179246	0	7049	7049	0	380160	307753	-19.05

Appendix 38: Riyadh and Jeddah branches target under VRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Riyadh1988	159794	159794	0	201633	188280	-6.62	15517	8215.3	-47.06	247680	231277	-6.62
Riyadh1989	187482	187482	0	236566	220112	-6.96	18206	10098	-44.54	291840	271541	-6.96
Riyadh1990	211555	211555	0	269185	248401	-7.72	20833	11963	-42.58	328320	302971	-7.72
Riyadh1991	196894	196894	0	251350	230141	-8.44	19732	10900	-44.76	328320	300616	-8.44
Riyadh1992	218687	218687	0	276349	258889	-6.32	21033	12707	-39.59	305280	285992	-6.32
Riyadh1993	215349	215349	0	272852	252693	-7.39	20597	12443	-39.59	339840	314732	-7.39
Riyadh1994	234962	234962	0	295587	277295	-6.19	21244	13783	-35.12	334080	313406	-6.19
Riyadh1995	227527	227527	0	281566	266737	-5.27	20501	13855	-32.42	364800	345588	-5.27
Riyadh1996	243197	243197	0	302899	286784	-5.32	20304	14742	-27.39	353280	334485	-5.32
Riyadh1997	262618	262618	0	325543	310091	-4.75	21111	16567	-21.53	378240	360287	-4.75
Riyadh1998	240318	240318	0	301715	281550	-6.68	19598	15993	-18.39	408960	381627	-6.68
Riyadh1999	252351	252351	0	316274	295165	-6.67	20561	17939	-12.75	675840	437066	-35.33
Riyadh2000	252351	252351	0	313747	295165	-5.92	20628	17939	-13.04	675840	437066	-35.33
Riyadh2001	278622	278622	0	343227	326530	-4.86	22550	20886	-7.38	691200	476123	-31.12
Riyadh2002	296879	296879	0	365017	348416	-4.55	23849	22764	-4.55	691200	502438	-27.31
Riyadh2003	338775	338775	0	403159	400730	-0.6	25506	24077	-5.6	483840	480925	-0.6
Riyadh2004	410618	410618	0	492936	492936	0	28004	28004	0	422400	422400	0
Riyadh2005	482461	482461	0	582712	582712	0	30501	30501	0	464640	464640	0
Riyadh2006	452368	452368	0	542842	540342	-0.46	28290	28160	-0.46	672000	668905	-0.46
Riyadh2007	457131	457131	0	571774	547941	-4.17	28707	27510	-4.17	645120	618230	-4.17
Riyadh2008	491503	491503	0	633058	596103	-5.84	30892	29088	-5.84	720000	677970	-5.84
Riyadh2009	552720	552720	0	663264	663264	0	33422	33422	0	794880	794880	0
Riyadh2010	573496	573496	0	726022	726022	0	34000	34000	0	810240	810240	0
Riyadh2011	573501	573501	0	719943	719943	0	33647	33647	0	823680	823680	0
Jeddah1988	342932	342932	0	403899	403411	-0.12	29096	28080	-3.49	566400	565715	-0.12
Jeddah1989	379382	379382	0	446829	446829	0	32189	32189	0	625920	625920	0
Jeddah1990	397727	397727	0	471838	469246	-0.55	34483	33302	-3.42	656640	636760	-3.03
Jeddah1991	363000	363000	0	431473	427270	-0.97	31832	30351	-4.65	656640	601565	-8.39
Jeddah1992	394952	394952	0	472628	467092	-1.17	34986	31071	-11.19	599040	592023	-1.17
Jeddah1993	415499	415499	0	494226	490963	-0.66	36520	34380	-5.86	652800	647262	-0.85
Jeddah1994	429331	429331	0	508482	507865	-0.12	37099	35220	-5.07	685440	655435	-4.38
Jeddah1995	433441	433441	0	516299	512888	-0.66	36966	35469	-4.05	708480	657864	-7.14
Jeddah1996	501410	501410	0	600932	595944	-0.83	40342	39593	-1.86	716160	698027	-2.53
Jeddah1997	467224	467224	0	558395	554401	-0.72	37321	37054	-0.72	827520	681156	-17.69
Jeddah1998	432679	432679	0	516725	512650	-0.79	34300	34029	-0.79	771840	667397	-13.53
Jeddah1999	426722	426722	0	510177	505564	-0.9	33582	33278	-0.9	677760	666670	-1.64
Jeddah2000	465115	465115	0	552290	552072	-0.04	36464	36450	-0.04	677760	677492	-0.04
Jeddah2001	475641	475641	0	566570	564804	-0.31	37445	37328	-0.31	700800	687824	-1.85
Jeddah2002	506905	506905	0	605353	602773	-0.43	39895	39725	-0.43	700800	697814	-0.43
Jeddah2003	512602	512602	0	609620	609620	0	40272	40272	0	704640	704640	0
Jeddah2004	493796	493796	0	588720	586719	-0.34	39206	38999	-0.53	693120	690764	-0.34
Jeddah2005	474990	474990	0	567819	563722	-0.72	38140	37865	-0.72	802560	683312	-14.86
Jeddah2006	469915	469915	0	563898	557807	-1.08	37384	36980	-1.08	802560	684445	-14.72
Jeddah2007	562180	562180	0	690414	690414	0	43358	43358	0	718080	718080	0
Jeddah2008	477672	477672	0	618837	568256	-8.17	38662	35502	-8.17	791040	702995	-11.13
Jeddah2009	480081	480081	0	576097	570637	-0.95	37131	36779	-0.95	873600	696314	-20.29
Jeddah2010	508095	508095	0	636566	605999	-4.8	38035	36208	-4.8	898560	729138	-18.85
Jeddah2011	478040	478040	0	601184	569561	-5.26	35681	33804	-5.26	917760	715541	-22.03

Appendix 39: Dammam and Qassim branches target under VRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Dammam1988	118423	118423	0	148169	139902	-5.58	12060	5969.3	-50.5	243840	230235	-5.58
Dammam1989	135815	135815	0	169929	158627	-6.65	13831	6775.8	-51.01	278400	259883	-6.65
Dammam1990	152075	152075	0	191262	176392	-7.77	16069	7577.6	-52.84	312960	288629	-7.77
Dammam1991	152672	152672	0	192496	177096	-8	16052	7606.2	-52.62	312960	287922	-8
Dammam1992	163507	163507	0	206602	189618	-8.22	17173	8148.4	-52.55	312960	287232	-8.22
Dammam1993	192478	192478	0	236581	224174	-5.24	18436	11123	-39.67	336000	318380	-5.24
Dammam1994	218763	218763	0	271052	255306	-5.81	19471	14122	-27.47	395520	372543	-5.81
Dammam1995	215354	215354	0	272679	250993	-7.95	19292	13789	-28.53	449280	382064	-14.96
Dammam1996	223394	223394	0	282355	260593	-7.71	20229	14691	-27.38	441600	394017	-10.78
Dammam1997	224203	224203	0	281629	261558	-7.13	19962	14782	-25.95	458880	395219	-13.87
Dammam1998	202637	202637	0	259034	235810	-8.97	18364	12362	-32.68	460800	363158	-21.19
Dammam1999	204170	204170	0	262002	237641	-9.3	18722	12534	-33.05	437760	365437	-16.52
Dammam2000	216362	216362	0	279313	252197	-9.71	20267	13902	-31.41	437760	383562	-12.38
Dammam2001	221480	221480	0	283666	258307	-8.94	20364	14476	-28.91	451200	391171	-13.3
Dammam2002	243365	243365	0	311918	284635	-8.75	22425	16891	-24.68	451200	411734	-8.75
Dammam2003	273022	273022	0	333146	320203	-3.89	23586	20162	-14.52	464640	446589	-3.89
Dammam2004	271431	271431	0	332394	318483	-4.19	23678	19691	-16.84	456960	437836	-4.19
Dammam2005	269840	269840	0	331642	316285	-4.63	23769	19852	-16.48	470400	448618	-4.63
Dammam2006	268451	268451	0	322141	314387	-2.41	23714	19745	-16.74	483840	461002	-4.72
Dammam2007	266896	266896	0	330990	313228	-5.37	23654	18938	-19.94	449280	425171	-5.37
Dammam2008	245779	245779	0	318851	287429	-9.85	22542	17179	-23.79	466560	420583	-9.85
Dammam2009	244770	244770	0	293724	286114	-2.59	22119	17089	-22.74	501120	425796	-15.03
Dammam2010	182433	182433	0	232666	211688	-9.02	14493	10096	-30.34	606720	333120	-45.09
Dammam2011	287348	287348	0	362453	338966	-6.48	19236	17990	-6.48	639360	470213	-26.46
Qassim1988	94912	94912	0	112167	111787	-0.34	7678	4767.7	-37.9	257280	256409	-0.34
Qassim1989	109328	109328	0	129204	127004	-1.7	8844	5437	-38.52	295680	290645	-1.7
Qassim1990	130188	130188	0	162006	150715	-6.97	10935	6485.7	-40.69	353280	309977	-12.26
Qassim1991	127065	127065	0	156872	147107	-6.22	10514	6330	-39.79	353280	310051	-12.24
Qassim1992	138895	138895	0	168096	160772	-4.36	11587	6919.6	-40.28	343680	309770	-9.87
Qassim1993	153022	153022	0	182148	177090	-2.78	12324	7623.8	-38.14	376320	309435	-17.77
Qassim1994	160124	160124	0	193683	185293	-4.33	12751	7977.7	-37.43	414720	309266	-25.43
Qassim1995	164937	164937	0	199174	190852	-4.18	13160	8217.6	-37.56	433920	309152	-28.75
Qassim1996	179676	179676	0	212199	208397	-1.79	14226	9786.7	-31.21	447360	329022	-26.45
Qassim1997	174562	174562	0	206337	202291	-1.96	13878	9213	-33.61	485760	321419	-33.83
Qassim1998	157839	157839	0	184999	182654	-1.27	12381	7863.8	-36.48	472320	309321	-34.51
Qassim1999	168862	168862	0	200449	195763	-2.34	13403	8517.5	-36.45	303360	296268	-2.34
Qassim2000	171896	171896	0	208720	199563	-4.39	13845	8821.7	-36.28	303360	290052	-4.39
Qassim2001	184134	184134	0	221086	214197	-3.12	14465	10190	-29.55	316800	306928	-3.12
Qassim2002	189555	189555	0	226239	220766	-2.42	15501	10778	-30.47	316800	309136	-2.42
Qassim2003	200474	200474	0	235515	233228	-0.97	15795	12120	-23.27	470400	359942	-23.48
Qassim2004	213716	213716	0	256335	249038	-2.85	15621	13605	-12.9	464640	379629	-18.3
Qassim2005	226957	226957	0	277154	265013	-4.38	15447	14770	-4.38	472320	397754	-15.79
Qassim2006	207679	207679	0	249215	241830	-2.96	14834	12928	-12.85	491520	370653	-24.59
Qassim2007	185705	185705	0	244507	215595	-11.82	13829	10463	-24.34	443520	337985	-23.79
Qassim2008	164133	164133	0	229768	189924	-17.34	12203	8177.5	-32.98	480000	309171	-35.59
Qassim2009	147534	147534	0	177041	170751	-3.55	10674	7350.2	-31.14	526080	309565	-41.16
Qassim2010	176004	176004	0	224668	204013	-9.19	11965	9374.8	-21.65	591360	323563	-45.28
Qassim2011	176074	176074	0	224218	204097	-8.97	11939	9382.7	-21.41	591360	323668	-45.27

Appendix 40: Khamis and Tabuk branches target under VRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Khamis1988	154514	154514	0	194591	182721	-6.1	10859	7942.1	-26.86	232320	218148	-6.1
Khamis1989	201025	201025	0	253166	236578	-6.55	14128	11169	-20.94	301440	281689	-6.55
Khamis1990	188373	188373	0	245488	222711	-9.28	13628	10423	-23.52	282240	256053	-9.28
Khamis1991	141168	141168	0	183075	165008	-9.87	10290	7048.6	-31.5	282240	254387	-9.87
Khamis1992	168753	168753	0	216833	202953	-6.4	12305	9558.7	-22.32	211200	197681	-6.4
Khamis1993	197734	197734	0	248967	236213	-5.12	13706	11519	-15.95	253440	240457	-5.12
Khamis1994	198271	198271	0	251385	233677	-7.04	13876	11026	-20.54	295680	274852	-7.04
Khamis1995	204850	204850	0	270133	242827	-10.11	14851	11740	-20.95	297600	267517	-10.11
Khamis1996	212015	212015	0	279831	251990	-9.95	12888	11606	-9.95	307200	276636	-9.95
Khamis1997	249716	249716	0	325513	298699	-8.24	15894	14585	-8.24	316800	290704	-8.24
Khamis1998	273285	273285	0	357463	324695	-9.17	17520	15914	-9.17	374400	340079	-9.17
Khamis1999	266603	266603	0	362468	314935	-13.11	18533	16103	-13.11	437760	380353	-13.11
Khamis2000	253077	253077	0	350284	298368	-14.82	17540	14940	-14.82	437760	372880	-14.82
Khamis2001	284864	284864	0	398960	354072	-11.25	16745	14861	-11.25	449280	398730	-11.25
Khamis2002	359577	359577	0	489208	445984	-8.84	21990	20047	-8.84	449280	409584	-8.84
Khamis2003	395901	395901	0	510243	494884	-3.01	22899	22376	-2.29	430080	420252	-2.29
Khamis2004	401634	401634	0	509781	501229	-1.68	22976	22845	-0.57	426240	423812	-0.57
Khamis2005	407366	407366	0	509318	509318	0	23053	23053	0	432000	432000	0
Khamis2006	359307	359307	0	431168	431168	0	20443	20443	0	445440	445440	0
Khamis2007	365555	365555	0	471527	456234	-3.24	21178	20491	-3.24	410880	397554	-3.24
Khamis2008	334904	334904	0	446272	398164	-10.78	22039	19664	-10.78	549120	489926	-10.78
Khamis2009	336158	336158	0	403390	399157	-1.05	19996	19786	-1.05	576000	524851	-8.88
Khamis2010	314130	314130	0	403542	385704	-4.42	17619	16840	-4.42	647040	529150	-18.22
Khamis2011	330066	330066	0	422322	407572	-3.49	18468	17823	-3.49	668160	547478	-18.06
Tabuk1998	84299	84299	0	105404	105404	0	4476	4476	0	119040	119040	0
Tabuk1999	117504	117504	0	144419	144419	0	6139	6139	0	119040	119040	0
Tabuk2000	124947	124947	0	152202	150543	-1.09	6542	6412.6	-1.98	167040	165219	-1.09
Tabuk2001	132217	132217	0	161963	159263	-1.67	6879	6764.3	-1.67	167040	164256	-1.67
Tabuk2002	137934	137934	0	166102	165201	-0.54	7163	7073.8	-1.24	178560	177592	-0.54
Tabuk2003	165712	165712	0	192080	191748	-0.17	8309	8256.2	-0.63	334080	309134	-7.47
Tabuk2004	166001	166001	0	192247	192247	0	8297	8297	0	299520	299520	0
Tabuk2005	166289	166289	0	192414	192414	0	8285	8285	0	309120	309120	0
Tabuk2006	168182	168182	0	201818	196847	-2.46	8352	8146.3	-2.46	309120	301506	-2.46
Tabuk2007	168055	168055	0	195203	195203	0	8344.9	8344.9	0	270720	270720	0
Tabuk2008	144792	144792	0	180837	169563	-6.23	7228.4	6777.8	-6.23	309120	289848	-6.23
Tabuk2009	121682	121682	0	146018	141485	-3.1	6093.6	5904.5	-3.1	332160	310097	-6.64
Tabuk2010	121914	121914	0	151733	142570	-6.04	6066.8	5700.4	-6.04	351360	309980	-11.78
Tabuk2011	130255	130255	0	162390	152303	-6.21	6493.5	6090.1	-6.21	359040	309769	-13.72

Appendix 41: Almadinah, Hail and Aljouf branches target under VRS-input orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Almadinah2008	118546	118546	0	145541	145541	0	3721	3721	0	309120	309120	0
Almadinah2009	155857	155857	0	187028	183516	-1.88	7250.5	7114.4	-1.88	347520	316256	-9
Almadinah2010	152670	152670	0	185672	178775	-3.71	7326	7053.9	-3.71	393600	309157	-21.45
Almadinah2011	156921	156921	0	190424	183942	-3.4	7553	7295.9	-3.4	393600	312971	-20.48
Hail2008	71314	71314	0	88679.2	84063.4	-5.21	3369.7	3194.3	-5.21	353280	311190	-11.91
Hail2009	127757	127757	0	153308	148547	-3.11	6393.9	6195.4	-3.11	385920	309947	-19.69
Hail2010	138930	138930	0	175042	162634	-7.09	6932	6440.6	-7.09	395520	309520	-21.74
Hail2011	146013	146013	0	183641	171004	-6.88	7242	6743.7	-6.88	399360	309326	-22.54
Aljouf2008	4537.9	4537.9	0	5579.9	5579.9	0	223	223	0	312960	312960	0
Aljouf2009	106196	106196	0	127435	123803	-2.85	5227.5	5078.5	-2.85	366720	310437	-15.35
Aljouf2010	120679	120679	0	152164	141478	-7.02	5970	5550.7	-7.02	382080	309964	-18.87
Aljouf2011	143345	143345	0	179246	167946	-6.3	7049	6604.6	-6.3	380160	309386	-18.62

Appendix 42: Riyadh and Jeddah branches target under VRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Riyadh1988	159794	171373	7.25	201633	201633	0	15517	9009.4	-41.94	247680	247680	0
Riyadh1989	187482	201754	7.61	236566	236566	0	18206	11077	-39.16	291840	291840	0
Riyadh1990	211555	228946	8.22	269185	269185	0	20833	13638	-34.54	328320	328320	0
Riyadh1991	196894	214698	9.04	251350	251350	0	19732	12646	-35.91	328320	328320	0
Riyadh1992	218687	233670	6.85	276349	276349	0	21033	13765	-34.56	305280	305280	0
Riyadh1993	215349	232233	7.84	272852	272852	0	20597	14078	-31.65	339840	339840	0
Riyadh1994	234962	250217	6.49	295587	295587	0	21244	15223	-28.34	334080	334080	0
Riyadh1995	227527	239941	5.46	281566	281566	0	20501	15176	-25.97	364800	364800	0
Riyadh1996	243197	256655	5.53	302899	302899	0	20304	16023	-21.08	353280	353280	0
Riyadh1997	262618	275520	4.91	325543	325543	0	21111	17793	-15.72	378240	378240	0
Riyadh1998	240318	257228	7.04	301715	301715	0	19598	17849	-8.92	408960	408960	0
Riyadh1999	252351	270032	7.01	316274	316274	0	20561	19922	-3.11	675840	463352	-31.44
Riyadh2000	252351	267915	6.17	313747	313747	0	20628	19685	-4.57	675840	460205	-31.91
Riyadh2001	278622	292607	5.02	343227	343227	0	22550	22455	-0.42	691200	496914	-28.11
Riyadh2002	296879	310586	4.62	365017	365017	0	23849	23849	0	691200	520609	-24.68
Riyadh2003	338775	340806	0.6	403159	403159	0	25506	24271	-4.84	483840	483840	0
Riyadh2004	410618	410618	0	492936	492936	0	28004	28004	0	422400	422400	0
Riyadh2005	482461	482461	0	582712	582712	0	30501	30501	0	464640	464640	0
Riyadh2006	452368	454420	0.45	542842	542842	0	28290	28290	0	672000	672000	0
Riyadh2007	457131	476635	4.27	571774	571774	0	28707	28707	0	645120	645120	0
Riyadh2008	491503	519823	5.76	633058	633058	0	30892	30892	0	720000	720000	0
Riyadh2009	552720	552720	0	663264	663264	0	33422	33422	0	794880	794880	0
Riyadh2010	573496	573496	0	726022	726022	0	34000	34000	0	810240	810240	0
Riyadh2011	573501	573501	0	719943	719943	0	33647	33647	0	823680	823680	0
Jeddah1988	342932	343342	0.12	403899	403899	0	29096	28126	-3.33	566400	566400	0
Jeddah1989	379382	379382	0	446829	446829	0	32189	32189	0	625920	625920	0
Jeddah1990	397727	399848	0.53	471838	471838	0	34483	33431	-3.05	656640	638013	-2.84
Jeddah1991	363000	366520	0.97	431473	431473	0	31832	30746	-3.41	656640	606799	-7.59
Jeddah1992	394952	399583	1.17	472628	472628	0	34986	31557	-9.8	599040	599040	0
Jeddah1993	415499	418169	0.64	494226	494226	0	36520	34542	-5.42	652800	648840	-0.61
Jeddah1994	429331	429836	0.12	508482	508482	0	37099	35250	-4.98	685440	655733	-4.33
Jeddah1995	433441	436233	0.64	516299	516299	0	36966	35638	-3.59	708480	659513	-6.91
Jeddah1996	501410	505492	0.81	600932	600932	0	40342	39841	-1.24	716160	700439	-2.2
Jeddah1997	467224	470520	0.71	558395	558395	0	37321	37321	0	827520	682624	-17.51
Jeddah1998	432679	436041	0.78	516725	516725	0	34300	34300	0	771840	668907	-13.34
Jeddah1999	426722	430526	0.89	510177	510177	0	33582	33582	0	677760	668396	-1.38
Jeddah2000	465115	465295	0.04	552290	552290	0	36464	36464	0	677760	677760	0
Jeddah2001	475641	477098	0.31	566570	566570	0	37445	37445	0	700800	688482	-1.76
Jeddah2002	506905	509040	0.42	605353	605353	0	39895	39895	0	700800	700800	0
Jeddah2003	512602	512602	0	609620	609620	0	40272	40272	0	704640	704640	0
Jeddah2004	493796	495466	0.34	588720	588720	0	39206	39166	-0.1	693120	693120	0
Jeddah2005	474990	478372	0.71	567819	567819	0	38140	38140	0	802560	684808	-14.67
Jeddah2006	469915	474940	1.07	563898	563898	0	37384	37384	0	802560	686706	-14.44
Jeddah2007	562180	562180	0	690414	690414	0	43358	43358	0	718080	718080	0
Jeddah2008	477672	519323	8.72	618837	618837	0	38662	38662	0	791040	723070	-8.59
Jeddah2009	480081	484582	0.94	576097	576097	0	37131	37131	0	873600	698408	-20.05
Jeddah2010	508095	532754	4.85	636566	636566	0	38035	36831	-3.17	898560	749969	-16.54
Jeddah2011	478040	504040	5.44	601184	601184	0	35681	35681	0	917760	728760	-20.59

Appendix 43: Dammam and Qassim branches target under VRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Dammam1988	118423	126121	6.5	148169	148169	0	12060	6325.4	-47.55	243840	243840	0
Dammam1989	135815	146296	7.72	169929	169929	0	13831	7268.1	-47.45	278400	278400	0
Dammam1990	152075	165292	8.69	191262	191262	0	16069	8235.3	-48.75	312960	309144	-1.22
Dammam1991	152672	166358	8.96	192496	192496	0	16052	8292.7	-48.34	312960	309222	-1.19
Dammam1992	163507	177984	8.85	206602	206602	0	17173	9551.3	-44.38	312960	312960	0
Dammam1993	192478	202899	5.41	236581	236581	0	18436	12299	-33.29	336000	336000	0
Dammam1994	218763	231998	6.05	271052	271052	0	19471	15618	-19.79	395520	395520	0
Dammam1995	215354	233517	8.43	272679	272679	0	19292	15826	-17.96	449280	409067	-8.95
Dammam1996	223394	241622	8.16	282355	282355	0	20229	16736	-17.27	441600	421115	-4.64
Dammam1997	224203	241014	7.5	281629	281629	0	19962	16667	-16.5	458880	420211	-8.43
Dammam1998	202637	222089	9.6	259034	259034	0	18364	14544	-20.8	460800	392076	-14.91
Dammam1999	204170	224575	9.99	262002	262002	0	18722	14823	-20.82	437760	395772	-9.59
Dammam2000	216362	239074	10.5	279313	279313	0	20267	16450	-18.83	437760	417327	-4.67
Dammam2001	221480	242720	9.59	283666	283666	0	20364	16859	-17.21	451200	422748	-6.31
Dammam2002	243365	266292	9.42	311918	311918	0	22425	19481	-13.13	451200	451200	0
Dammam2003	273022	283887	3.98	333146	333146	0	23586	21377	-9.36	464640	464640	0
Dammam2004	271431	283102	4.3	332394	332394	0	23678	20984	-11.38	456960	456960	0
Dammam2005	269840	282739	4.78	331642	331642	0	23769	21308	-10.35	470400	470400	0
Dammam2006	268451	274946	2.42	322141	322141	0	23714	20474	-13.66	483840	470657	-2.72
Dammam2007	266896	281790	5.58	330990	330990	0	23654	20574	-13.02	449280	449280	0
Dammam2008	245779	272190	10.75	318851	318851	0	22542	20165	-10.55	466560	466560	0
Dammam2009	244770	251144	2.6	293724	293724	0	22119	17804	-19.51	501120	435272	-13.14
Dammam2010	182433	200003	9.63	232666	232666	0	14493	12067	-16.74	606720	359242	-40.79
Dammam2011	287348	306621	6.71	362453	362453	0	19236	19236	0	639360	494404	-22.67
Qassim1988	94912	95275	0.38	112167	112167	0	7678	4784.1	-37.69	257280	257280	0
Qassim1989	109328	111323	1.82	129204	129204	0	8844	5546.7	-37.28	295680	295680	0
Qassim1990	130188	139963	7.51	162006	162006	0	10935	6972.9	-36.23	353280	309745	-12.32
Qassim1991	127065	135519	6.65	156872	156872	0	10514	6751.3	-35.79	353280	309850	-12.29
Qassim1992	138895	145236	4.57	168096	168096	0	11587	7235.7	-37.55	343680	309620	-9.91
Qassim1993	153022	157401	2.86	182148	182148	0	12324	7842	-36.37	376320	309331	-17.8
Qassim1994	160124	167352	4.51	193683	193683	0	12751	8404.2	-34.09	414720	310700	-25.08
Qassim1995	164937	171951	4.25	199174	199174	0	13160	8920.2	-32.22	433920	317538	-26.82
Qassim1996	179676	182861	1.77	212199	212199	0	14226	10144	-28.69	447360	333756	-25.39
Qassim1997	174562	177951	1.94	206337	206337	0	13878	9593.2	-30.88	485760	326457	-32.79
Qassim1998	157839	159869	1.29	184999	184999	0	12381	7965	-35.67	472320	309272	-34.52
Qassim1999	168862	172804	2.33	200449	200449	0	13403	8963.8	-33.12	303360	303360	0
Qassim2000	171896	179591	4.48	208720	208720	0	13845	9691.2	-30	303360	303360	0
Qassim2001	184134	189922	3.14	221086	221086	0	14465	10844	-25.04	316800	316800	0
Qassim2002	189555	194151	2.42	226239	226239	0	15501	11297	-27.12	316800	316800	0
Qassim2003	200474	202390	0.96	235515	235515	0	15795	12335	-21.91	470400	362790	-22.88
Qassim2004	213716	219828	2.86	256335	256335	0	15621	14291	-8.52	464640	388715	-16.34
Qassim2005	226957	236933	4.4	277154	277154	0	15447	15447	0	472320	410429	-13.1
Qassim2006	207679	213864	2.98	249215	249215	0	14834	13622	-8.17	491520	379849	-22.72
Qassim2007	185705	209921	13.04	244507	244507	0	13829	13179	-4.69	443520	373986	-15.68
Qassim2008	164133	197576	20.38	229768	229768	0	12203	11795	-3.34	480000	355634	-25.91
Qassim2009	147534	152980	3.69	177041	177041	0	10674	7621.7	-28.6	526080	309436	-41.18
Qassim2010	176004	193304	9.83	224668	224668	0	11965	11315	-5.43	591360	349283	-40.94
Qassim2011	176074	192927	9.57	224218	224218	0	11939	11273	-5.57	591360	348723	-41.03

Appendix 44: Khamis and Tabuk branches target under VRS-output orientated (1988-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Khamis1988	154514	164778	6.64	194591	194591	0	10859	8651.8	-20.33	232320	232320	0
Khamis1989	201025	215314	7.11	253166	253166	0	14128	12197	-13.67	301440	301440	0
Khamis1990	188373	207993	10.42	245488	245488	0	13628	11794	-13.46	282240	282240	0
Khamis1991	141168	157751	11.75	183075	183075	0	10290	7850.1	-23.71	282240	282240	0
Khamis1992	168753	180531	6.98	216833	216833	0	12305	10416	-15.35	211200	211200	0
Khamis1993	197734	208598	5.49	248967	248967	0	13706	12302	-10.24	253440	253440	0
Khamis1994	198271	213559	7.71	251385	251385	0	13876	12088	-12.89	295680	295680	0
Khamis1995	204850	228276	11.44	270133	270133	0	14851	13395	-9.8	297600	297600	0
Khamis1996	212015	234950	10.82	279831	279831	0	12888	12888	0	307200	307200	0
Khamis1997	249716	272337	9.06	325513	325513	0	15894	15894	0	316800	316800	0
Khamis1998	273285	300098	9.81	357463	357463	0	17520	17520	0	374400	374400	0
Khamis1999	266603	305695	14.66	362468	362468	0	18533	18533	0	437760	437760	0
Khamis2000	253077	295790	16.88	350284	350284	0	17540	17540	0	437760	437760	0
Khamis2001	284864	314515	10.41	398960	392612	-1.59	16745	16745	0	449280	449280	0
Khamis2002	359577	391761	8.95	489208	489208	0	21990	21990	0	449280	449280	0
Khamis2003	395901	404895	2.27	510243	506207	-0.79	22899	22899	0	430080	430080	0
Khamis2004	401634	403880	0.56	509781	504059	-1.12	22976	22976	0	426240	426240	0
Khamis2005	407366	407366	0	509318	509318	0	23053	23053	0	432000	432000	0
Khamis2006	359307	359307	0	431168	431168	0	20443	20443	0	445440	445440	0
Khamis2007	365555	377549	3.28	471527	471527	0	21178	21178	0	410880	410880	0
Khamis2008	334904	374450	11.81	446272	446272	0	22039	22039	0	549120	549120	0
Khamis2009	336158	339625	1.03	403390	403390	0	19996	19996	0	576000	529133	-8.14
Khamis2010	314130	326927	4.07	403542	403542	0	17619	17619	0	647040	543917	-15.94
Khamis2011	330066	340657	3.21	422322	422322	0	18468	18468	0	668160	559696	-16.23
Tabuk1998	84299	84299	0	105404	105404	0	4476	4476	0	119040	119040	0
Tabuk1999	117504	117504	0	144419	144419	0	6139	6139	0	119040	119040	0
Tabuk2000	124947	126447	1.2	152202	152202	0	6542	6483.8	-0.89	167040	167040	0
Tabuk2001	132217	134327	1.6	161963	161963	0	6879	6879	0	167040	167040	0
Tabuk2002	137934	138705	0.56	166102	166102	0	7163	7128.6	-0.48	178560	178560	0
Tabuk2003	165712	166000	0.17	192080	192080	0	8309	8270.6	-0.46	334080	309127	-7.47
Tabuk2004	166001	166001	0	192247	192247	0	8297	8297	0	299520	299520	0
Tabuk2005	166289	166289	0	192414	192414	0	8285	8285	0	309120	309120	0
Tabuk2006	168182	171998	2.27	201818	201818	0	8352	8352	0	309120	309120	0
Tabuk2007	168055	168055	0	195203	195203	0	8344.9	8344.9	0	270720	270720	0
Tabuk2008	144792	154696	6.84	180837	180837	0	7228.4	7228.4	0	309120	309120	0
Tabuk2009	121682	125588	3.21	146018	146018	0	6093.6	6093.6	0	332160	310002	-6.67
Tabuk2010	121914	129765	6.44	151733	151733	0	6066.8	6066.8	0	351360	309781	-11.83
Tabuk2011	130255	138898	6.64	162390	162390	0	6493.5	6493.5	0	359040	309549	-13.78

Appendix 45: Almadinah, Hail and Aljouf branches target under VRS-output orientated (2008-2011)

DMUs	Amount of flour (Value)	Amount of flour (Target)	Amount of flour (Gain%)	Amount of wheat (Value)	Amount of Wheat (Target)	Amount of wheat (Gain%)	Machine hour (Value)	Machine hour (Target)	Machine hour (Gain%)	ManHours (Value)	ManHours (Target)	ManHours (Gain%)
Almadinah2008	118546	118546	0	145541	145541	0	3721	3721	0	309120	309120	0
Almadinah2009	155857	158508	1.7	187028	187028	0	7250.5	7250.5	0	347520	321084	-7.61
Almadinah2010	152670	158061	3.53	185672	185672	0	7326	7326	0	393600	316216	-19.66
Almadinah2011	156921	161841	3.14	190424	190424	0	7553	7553	0	393600	321744	-18.26
Hail2008	71314	75243	5.51	88679.2	88679.2	0	3369.7	3369.7	0	353280	311086	-11.94
Hail2009	127757	131859	3.21	153308	153308	0	6393.9	6393.9	0	385920	309847	-19.71
Hail2010	138930	149549	7.64	175042	175042	0	6932	6932	0	395520	309248	-21.81
Hail2011	146013	156504	7.18	183641	183641	0	7242	7242	0	399360	313547	-21.49
Aljouf2008	4537.9	4537.9	0	5579.9	5579.9	0	223	223	0	312960	312960	0
Aljouf2009	106196	109319	2.94	127435	127435	0	5227.5	5227.5	0	366720	310359	-15.37
Aljouf2010	120679	129813	7.57	152164	152164	0	5970	5970	0	382080	309728	-18.94
Aljouf2011	143345	153006	6.74	179246	179246	0	7049	7049	0	380160	309138	-18.68

Appendix 46: TE peers grope under DEA-CRS condition for the Riyadh and Jeddah branches.

Branch	Riyadh2004	Riyadh2005	Tabuk1999	Tabuk1999	Tabuk1999	Almadinah2008
Riyadh1988	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1989	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1990	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1991	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1992	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1993	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1994	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1995	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1996	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1997	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1998	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh1999	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Riyadh2000	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Riyadh2001	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Riyadh2002	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Riyadh2003	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh2004	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE
Riyadh2005	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
Riyadh2006	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh2007	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh2008	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE
Riyadh2009	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Riyadh2010	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Riyadh2011	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE
Jeddah1988	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1989	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1990	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1991	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1992	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah1993	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah1994	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah1995	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah1996	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah1997	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1998	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah1999	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2000	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2001	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2002	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2003	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2004	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2005	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah2006	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah2007	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2008	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Jeddah2009	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah2010	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Jeddah2011	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE

Appendix 47: TE peers grope under DEA-CRS condition for the Dammam and Qassim branches.

Branch	Riyadh2004	Riyadh2005	Tabuk1999	Tabuk1999	Tabuk1999	Almadinah2008
Dammam1988	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1989	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1990	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1991	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1992	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam1993	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam1994	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam1995	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1996	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam1997	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1998	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam1999	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam2000	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2001	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2002	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2003	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2004	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Dammam2005	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2006	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2007	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Dammam2008	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Dammam2009	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam2010	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Dammam2011	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1988	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1989	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1990	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1991	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1992	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1993	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1994	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1995	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1996	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1997	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1998	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim1999	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Qassim2000	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Qassim2001	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Qassim2002	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Qassim2003	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2004	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2005	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2006	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2007	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2008	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2009	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2010	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Qassim2011	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE

Appendix 48: TE peers grope under DEA-CRS condition for the Khamis, Tabuk, Almadinah, Hail and Aljouf branches.

Branch	Riyadh2004	Riyadh2005	Tabuk1999	Tabuk1999	Tabuk1999	Almadinah2008
Khamis1988	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1989	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1990	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1991	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Khamis1992	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1993	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1994	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1995	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis1996	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis1997	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis1998	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE
Khamis1999	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis2000	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis2001	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
Khamis2002	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2003	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2004	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2005	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2006	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2007	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Khamis2008	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE
Khamis2009	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Khamis2010	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Khamis2011	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Tabuk1998	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
Tabuk1999	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE
Tabuk2000	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Tabuk2001	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
Tabuk2002	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE
Tabuk2003	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Tabuk2004	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE
Tabuk2005	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE
Tabuk2006	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
Tabuk2007	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
Tabuk2008	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Tabuk2009	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Tabuk2010	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Tabuk2011	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Almadinah2008	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
Almadinah2009	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Almadinah2010	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Almadinah2011	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Hail2008	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Hail2009	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Hail2010	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Hail2011	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Aljouf2008	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Aljouf2009	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Aljouf2010	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE
Aljouf2011	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE