Essays on GCC Energy Economics and Saudi Arabia's Economic Growth

by

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Abstract

The first chapter analyzes the impact of energy subsidies on a select sample of nitrogen fertilizer producers in the Arabian Gulf Cooperation Council (GCC) region that disclose their financial statements. The paper estimates ammonia production costs per ton in the GCC region ranging from $53 to $116, and urea production costs ranging from $56.64 to $102.28 using Yara's method. Using Budidarm's method, the production cost for a ton of urea is estimated to range from $86.25 to $152.50. The differences in cost are attributed to differences in calculation methods. Subsidies for the selected sample were estimated using the price gap approach. Subsidy rates were on average well above 50% and subsidy size reaches billions of dollars. The paper then develops a translog multi-output, multi-input restricted profit function to evaluate the impact of the energy subsidy and international natural gas prices on inputs demand, outputs supply, and profit of the GCC producers. Results show that output supply, input demand, and profit are highly responsive to changes in urea prices. The results also show that international natural gas prices have an inelastic positive impact on the GCC firms' profit. The study concluded that despite the distorting effect of subsidies in output supply and input demand, subsidy policy in the GCC region has achieved one of its major goals by increasing demand for labor. Furthermore, the GCC corporate nitrogen fertilizer executives' concern that a reduction in the energy subsidy would have an adverse effect on their companies' profitability has been confirmed in this paper to be a valid concern.

The second chapter aims to accomplish two objectives. The first is to extend the existing method of total factor productivity growth decomposition by incorporating network

characteristics. The second objective is to empirically evaluate technical change and productivity of the Saudi electricity sector. The results show that the Saudi electricity sector operates under the presence of economies of output density, economies of customer density, and diseconomies of scale. The technology used in the Saudi electricity sector is a cost saving technology. It is characterized as fuel using, capital neutral, and energy saving technology. The estimated average technical change term is positive. It indicates a cost increase during the timeframe of this study. The estimated average total factor productivity growth is positive using both the proposed and existing method. Compared with the proposed method, the existing method overestimated total factor productivity growth of the Saudi electricity sector. Furthermore, the paper estimated an optimal scale of output to be almost 11 percent larger than the maximum output level generated by the Saudi Electricity Company. The paper concludes that the Saudi Electricity Company needs to expand its size to reach the optimal output level.

The third chapter investigates the impact of the overall financing activities on economic growth in Saudi Arabia. The study developed a financing index that takes into account the overall available credit in Saudi Arabia. The index was shown to be sensitive to economic and political shocks such as the Arab Spring. Using Johnson cointegration approach, the paper found an evidence of a long run relationship between real GDP per capita, financing, real interest rate, public labor force, and capital. Using a vector error correction model, the paper found a robust estimate that proves the positive impact of financing on economic growth in Saudi Arabia. Furthermore, the Granger-Causality Wald test indicates that financing influences economic growth in Saudi Arabia.

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List of Abbreviations

GCC	Gulf Cooperation Council
GMM	Generalized Method of Moment
SAFCO	Saudi Arabian Fertilizer Company
QAFCO	Qatar Fertilizer Company
GPIC	Gulf Petrochemicals Industries Company
PIC	Petrochemical Industries Company
SEC	Saudi Electricity Company
TFP	Total Factor Productivity
EOS	Economies of Scale
EOD	Economies of Output Density
ECD	Economies of Customer Density
SC	Scale Component
TC	Technical Change
SUR	Seemingly Unrelated Regression
SAMA	Saudi Arabia Monetary Agency
VECM	Vector Error Correction Model

Chapter 1

The Impact of Energy Subsidy on Nitrogen Fertilizer Producers in the GCC

1.1 Introduction

Nitrogen fertilizer consists of ammonia and urea. The main feedstock in the production of ammonia is natural gas, and ammonia is used as a feedstock in the production of urea. The excess ammonia production is usually sold domestically or exported. As reported by Huang (2007), natural gas accounts for 72–85% of ammonia production cost; hence, natural gas cost is a major variable cost in the production of nitrogen fertilizer.

The Gulf Cooperation Council (GCC) is composed of Saudi Arabia, United Arab Emirates, Oman, Kuwait, Qatar, and Bahrain. Governments of these countries support their petrochemical industries, including chemical fertilizer manufacturers, by providing them with natural gas prices that are below international gas prices. The definition of subsidy by De Moor and Calamari[1] (1997) fits the type of subsidy given by the GCC governments to their fertilizer producers, since the governmental support reduces the production costs. The purpose of this energy subsidy is economic development through the utilization of local natural resources in providing the required feedstock for mega industrial projects. This contributes to the national income diversification by reducing the reliance on oil revenue, increasing the GDP, and reducing unemployment rate by providing high quality employment opportunities for citizens. Another purpose of this energy subsidy is to help local chemical and petrochemical corporations compete with international firms, since the majority of the GCC petrochemicals and fertilizer production is exported to international

[1] A subsidy is any measure that keeps prices for consumers below the market level or keeps prices for producers above the market level, or that reduces costs for consumers and producers by giving direct or indirect support.

markets. Many corporate executives and energy subsidy advocates in the GCC region claim that any increase in local subsidized natural gas prices will hinder their ability to compete in the international market and will adversely impact their profit. They argue that other international producers, such as Chinese producers, have a competitive advantage because they pay low wages.

The GCC nitrogen fertilizer capacity in 2011 reached almost 10% of the world total production capacity (Markey, 2011). The GCC total nitrogen fertilizer production capacity in 2012 reached 26.7 million tons (GPCA, 2013). Figure 1.1 shows that Qatar and Saudi Arabia are among ten of the largest urea producers in 2010. Three GCC countries (Saudi Arabia, Qatar, and Oman) were among the 10 largest urea exporters in 2009, as shown in Figure 1.2. As for the largest urea importers in 2009, India was first and the U.S. was second.

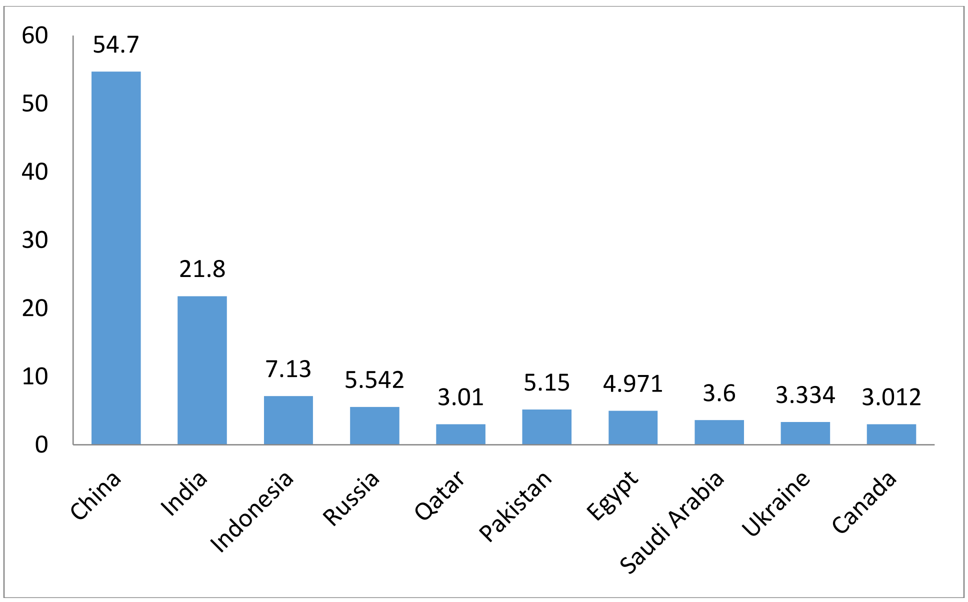

Figure. 1.1 Ten Largest Urea Producers in 2010- million metric ton
Source: QAFCO.com, Qafco Long Term Strategy and its increasing role in the world Fertilizer Supply Chain.

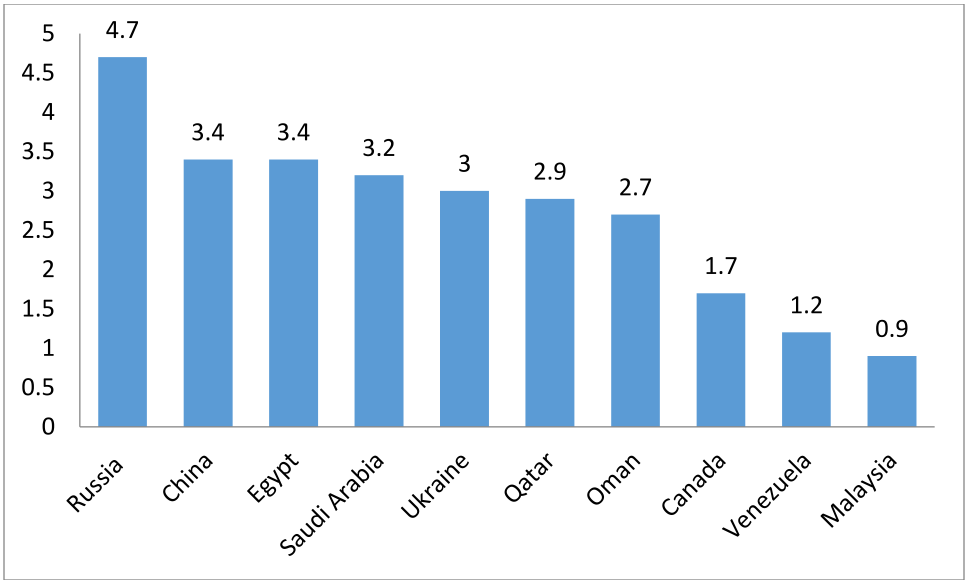

Figure. 1.2 Ten Largest Urea Exporters in 2009-million metric ton
Source: QAFCO.com, Source: QAFCO.com, Qafco Long Term Strategy and its increasing role in the world Fertilizer Supply Chain.

The main purpose of this paper is to discover the impact of energy subsidies and international natural gas prices on output supply (ammonia supply and urea supply), input demand (natural gas and labor), and profits of nitrogen fertilizer producers in the GCC region. The other purpose of this study is to conduct qualitative analysis to reveal the impact of energy subsidies on the production cost of both ammonia and urea.

1.2 Literature Review

To my knowledge, there is no study that evaluates the impact of energy subsidies and international natural gas prices on output supply, input demand, and profit of an exporting fertilizer firm. The existing literature on fertilizer subsidies focuses on subsidies that intend to increase the farmers' output, fertilizer application rate, or reduce fertilizer prices in the local market. Cui et al. (2011) investigated the impact of the U.S. energy policy on the economy. They found that a fuel tax of $0.96 per gasoline energy-equivalent gallon and $1.02/gallon ethanol subsidy would increase ethanol consumption by 44% and decrease gasoline consumption by 7.5%. Manzoor et al. (2012) studied the impact of removing the energy subsidy in Iran using a computable general equilibrium model suggesting that removing or eliminating energy subsidies that are part of production will increase the cost of production for the overall economy. Hansen (2004) estimated the Danish demand elasticity for nitrogen fertilizer using a generalized translog profit specification to be -0.45. Fulginiti and Perrin (1990) analyzed the impact of Argentinean price and tax policies on agricultural output growth rate using the translog profit function specification. The demand elasticity was found to be elastic with respect to capital and almost unitary for labor and other inputs. Bezlepkina et al. (2004) studied the impact of Russian dairy farming subsidies on profit and input-output allocation. Despite the distorting effect of subsidies, the study concludes that subsidies relive credit constrains and allow dairy farms to improve their allocative efficiency; hence, the subsidies have an important positive influence on farms' profits. Castro and Teixeira (2011) studied the credit impact of total expenditure on the demand for agricultural input and output supply in Brazil using the translog multi-output, multi-input restricted profit function. By using production credit as a proxy of total expenditure, the study concluded that government credit programs may increase agricultural supply. Wang and Lin (2014) stated that the nitrogen fertilizer industry in China gained a cost advantage due to subsidized natural gas prices, which resulted in overcapacity and a large amount of fertilizer exports. Gardner (2012) indicated that ethanol subsidies are unlikely to generate social gains, and corn producers would typically gain more from a corn deficiency payment subsidy than from an ethanol subsidy.

Bayes et al. (1985) evaluated a combined policy of output subsidy and fertilizer subsidy (input subsidy) in Bangladesh. Net producer benefits are greater under a single price support policy and lower under a single fertilizer subsidy policy. Hong et al. (2013) showed that natural gas consumption would decrease by 3.64 million tce (ton of coal equivalent) if energy subsidy was removed. Nwachukwu et al. (2013) found that fuel subsidy accounted for 79% of fuel prices in Nigeria, suggesting the removal of fuel subsidies would increase fuel prices significantly. Fattouh and El-Katiri (2012) studied energy subsidies in the Arab world. They stated that reducing or removing energy subsidies without compensatory programs would lead to a decline in household welfare and erode the competitiveness of some industries. Lin and Jiang (2011) concluded that reducing or removing energy subsidies in China would increase energy prices, and the assumption that subsidy removal would have negative impact on competitiveness is false. Hedly and Tabor (1989) estimated the fertilizer financial subsidies in Indonesia in 1986 to be Rp. 571 billion. Cho et al. (2004) found a complementary relationship between energy and labor in Korea.

What makes this paper a good contribution to the current literature is the analysis of energy subsidies in the GCC region. It is different from fertilizer subsidies given by governments worldwide because the only beneficiaries of this subsidy are the producers and local governments, since they own shares in these fertilizer firms. However, local farmers or consumers do not benefit from this subsidy. Fertilizer prices in local markets are linked to international markets, except that producers exempt local farmers from paying storage costs in formulating local market prices; hence, local market prices are slightly less than international market prices (Alriyadh, 2006). Furthermore, to my knowledge this paper is the first paper that studies the impact of energy subsidies on nitrogen fertilizer producers in the GCC.

1.3 Data

International natural gas prices from 1995 to 2013 came from the British Petroleum statistical review of world energy (2014). On the other hand, Table 1.1 shows natural gas prices in the GCC countries from 1995 to 2013.

Table 1.1 Natural Gas Prices in the GCC Region

Year	Saudi Arabia	Qatar	Bahrain	Oman	UAE	Kuwait
1995	0.75	0.75-1	1.5	0.77	1	0.37
1996	0.75	0.75-1	1.5	0.77	1	0.41
1997	0.75	0.75-1	1.5	0.77	1	0.42
1998	0.75	0.75-1	1.5	0.77	1	0.3
1999	0.75	0.75-1	1.5	0.77	1	0.42
2000	0.75	0.75-1	1.5	0.77	1	0.65
2001	0.75	0.75-1	1.5	0.77	1	0.57
2002	0.75	0.75-1	1.5	0.77	1	0.64
2003	0.75	0.75-1	1.5	0.77	1	0.67
2004	0.75	0.75-1	1.5	0.77	1	0.84
2005	0.75	0.75-1	1.5	0.77	1	1.3
2006	0.75	0.75-1	1.5	0.77	1	1.4
2007	0.75	0.75-1	1.5	0.77	1	1.47
2008	0.75	0.75-1	1.5	0.77	1	1.78
2009	0.75	0.75-1	1.5	0.77	1	1.75*-2.5**
2010	0.75	0.75-1	1.5	0.77	1	1.75*-2.5**
2011	0.75	0.75-1	1.5	0.77	1	1.75*-2.5**
2012	0.75	0.75-1	2.25	1.5	1	1.75*-2.5**
2013	0.75	0.75-1	2.25	2	1	1.75*-2.5**

*Indicates lowest ceiling price and ** indicates highest ceiling price

The natural gas price in Saudi Arabia has been confirmed to be $0.75 per MMBTU by local Saudi newspapers, reports such as Kuwait and Middle East Financial Investment Company "KMEFIC" (2009) and journal articles such as Hussein Razavi (2009). This pricing rate was valid until 2015. In 2016, Saudi government increased natural gas price to $1.25/MMBTU. Gas prices in Qatar and the UAE have been reported to be $1 per MMBTU by Hakim Darbouche (2012). PPIAF (2013) reported the price of natural gas in Qatar to vary from $0.75 to $1/MMBTU. Natural gas prices in Bahrain reported by Reuters (2011) were $1.50 until 2011, and the accuracy has been confirmed by local newspapers. In 2012, the Bahraini government increased the price to $2.25 per MMBTU. Oman's natural gas prices were reported by local and international newspapers, such as Business Standard (2011). Gas prices in Oman are sold to Oman Indian Fertilizer Company (OMIFCO) at those specific prices because Oman had a contract to sell natural gas to OMIFCO at $0.77 per MMBTU until 2011. However, the pricing has been changed to $1.50/MMBTU starting from 2012 and to increase later at an annual increase rate of $0.50 until it ultimately reaches $3 per MMBTU in 2015. Natural gas prices in Kuwait from 1995 to 2008 came from the Kuwait state official paper presented at the Arabian Energy Conference, and the prices from 2009 until 2014 have been taken from Alanba (2014). Kuwait implemented a new pricing formula in 2005 to link gas prices with other international oil prices. Readers should be careful in interpreting gas prices in Kuwait because the reported prices in Table 1.1 are the prices sold to Petrochemical Industries Company (PIC), and they will vary from as low as $1.75/MMBTU to as high as $2.50/MMBTU. PIC is charged different prices than other manufacturers in Kuwait or the electricity company. For instance, the electricity company is charged $26 per MMTBU (Alrai Media group, 2013).

By comparing natural gas prices in the GCC region to those of international prices, we observe a large gap between international natural gas prices and local prices in the GCC region. Almost all producers in the GCC region are paying prices with a ceiling that is unaffected by changes in international prices.

Table 1.A1 in Appendix A provides an overview of all nitrogen fertilizer firms in the GCC region. Since not all firms in the GCC region disclose their financial statements, the sample of this study will be Saudi Arabia Fertilizer Company (SAFCO), Qatar Fertilizer Company (QAFCO), PIC, and Gulf Petrochemical Industries Company (GPIC) because they are the only companies in the GCC region that fully or partially disclose their financial statements. Data for SAFCO and QAFCO come from their annual and sustainability reports. Data for PIC comes from their annual report and from the Kuwait state official paper presented at the Arabic Energy Conference. SAFCO and QAFCO data are available from 2000–2013 and GPIC from 2001–2013. PIC data are available

from 1996–2013.The international average nitrogen fertilizer selling prices in the GCC region are reported by QAFCO from 2000–2013. These prices are not available from 1995 to 1999. Thus, for PIC from 1995–1999, I use the nitrogen fertilizer price index as reported by the USDA as a proxy for ammonia price. For urea, I use international urea prices as reported by the World Bank. Besides ammonia and urea, GPIC sells methanol as well. As the focus of this paper is on nitrogen fertilizer, GPIC's production of methanol will be excluded from the analysis.

1.4 Economics of Fertilizers Production

In order to show the impact of natural gas subsidies on producers' production cost, it is important to demonstrate how much it costs a producer to produce one ton of ammonia and urea using different feedstock prices. Tables 1.2 and 1.3 show production costs for ammonia and urea, respectively, using Yara's Industry Fertilizer Handbook (2012) method. Gas consumption in the tables represent the required natural gas for ammonia production (36 MMBTU natural gas/tonne ammonia). Yara's handbook indicates that the other production costs represent fixed costs that are subject to scale advantage. These other production costs ($26) reflect a new and an efficient plant. However, the handbook indicates the corresponding costs for old and poorly maintained plants will be in the mid-forties. Urea production as shown in table 1.3 requires 0.58 ammonia for each tonne of urea. Also, urea production requires additional process gas (5.2 MMBTU).

Table 1.2 Ammonia Production Cost (US$/Ton)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Gas price	0.75	1	1.5	2	2.5
Gas Consumption	36	36	36	36	36
= Gas Cost	27	36	54	72	90
+ Other Production Cost	26	26	26	26	26
Total Cash Cost	53	62	80	98	116
Gas cost as % of Total Cost	51%	58%	68%	73%	78%

- Calculation method is based on Yara Fertilizer Industry Handbook (2012)

Table 1.3 Urea Production Cost (US$/Ton)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Ammonia Cost	53	62	80	98	116
× Ammonia Use	0.58	0.58	0.58	0.58	0.58
= Ammonia Cost	30.74	35.96	46.4	56.84	67.28
Additional Process Gas Consumption	5.2	5.2	5.2	5.2	5.2
+ Process Gas Cost	3.9	5.2	7.8	10.4	13
+ Other Production Cost	22	22	22	22	22
Total Cash Cost	56.64	63.16	76.2	89.24	102.28
Gas cost as % of Total Cost	35%	41%	51%	58%	64%

- Calculation method is based on Yara Fertilizer Industry Handbook (2012)

I have calculated the production costs using five different scenarios that reflect the prevalent natural gas costs in the GCC region prior to the energy pricing reforms that took place in late 2015 and early 2016 in most of GCC countries such as UAE, Qatar, and Saudi Arabia. Since the natural gas price in Saudi Arabia prior to the increase in early 2016 was $0.75/MMBTU, a typical fertilizer producer in Saudi Arabia would fall in scenario one and would incur a cost of $53 for ammonia and almost $57 for urea. It would cost a producer in the UAE or Qatar $62 for ammonia and $63.16 for urea, assuming that they were charged $1/MMBTU. Moreover, the Bahraini producer, GPIC, would produce ammonia for $80 and urea for $76.20 till 2011 because natural gas price in Bahrain until 2011 was $1.5/MMBTU. Since natural gas price in Oman starting in 2013 reached $2/MMBTU, it would cost OMAIFCO $98 for ammonia and $89.24 for urea. Assuming PIC was charged the highest natural gas price ($2.50/MMBTU) after the implementation of the new pricing formula, PIC would produce ammonia for $116 and urea for $102.28.

Table 1.4 shows urea production costs using Budidarmo's method (2007). He assumed operational expenditures (OPEX) cost $40/ton, capital expenditures (CAPEX) cost $50/ton for new technology plants, and $20/ton for old technology plants.

Table 1.4 Urea Production Cost (US$/Ton)

Gas Price	Old Technology	New Technology
0.75**	86.25	108.75
1**	95	115
1.5**	112.5	127.5
2	130	140
2.5**	147.5	152.5
3	165	165
4	200	190
5	235	215
6	270	240
7	305	265
8	340	290

- Urea production cost as calculated by Sutarto Budidarmo (2007). ** Production cost with double asterisk is based on the author calculation.

It can be inferred that the more gas prices increase, the more uneconomic it becomes to produce urea using old technology plants. From both Yara and Budidarmo's methods, it can be seen that producers in the GCC region have a cost advantage in producing ammonia and urea.

The main challenge for fertilizer producers in the GCC region in general, and in Kuwait in particular, is the availability of natural gas. Not only are prices regulated, quantities are regulated as well, since there are other competing users, such as petrochemical producers and electricity generation. Because Kuwait has recently become a net importer of natural gas, it has been reported by PIC (2008) that it had to partially shut down its fertilizer plants from June to August 2007 to save natural gas for electricity generation in order to ensure uninterrupted electricity production during the hot summer months. Also, SABIC's CEO Mohammed Al-Mady has mentioned in a conference that his company expansion has been constrained by the availability of natural gas supply (Alriyadh, 2014). Another concern for the GCC producers is how long the governments in the GCC region can keep natural gas prices not only below the international market prices, but even below production costs, specifically in Saudi Arabia. The main reason Saudi Arabia kept the low natural gas price of $0.75/MMBTU until 2015 is that the petrochemical companies provide high quality employment opportunities for citizens, which helps reduce the unemployment rate. Another possible reason is that the Saudi government owns shares in many petrochemical companies either directly or indirectly, and hence a portion of their profits go to the Saudi government.

I estimate the subsidies' size using the price-gap method because I found that it is the most straightforward method to estimate governmental support for the fertilizer manufacturers in the GCC region as compared to international prices. The method was established by Corden (1957). The method has been used widely in the literature (Liu and Li, 2011; Wang and Lin, 2014; Hong et al., 2013; Lin and Jiang, 2011; Hua et al., 2012). However, most scholars used it to estimate subsidy size on a country level or a consumer level. In this paper, I show that this method can be used on a corporate/firm level. Subsidy size is estimated using the price gap method by first calculating the difference between end-user price and a reference price.

$$\text{PG} = P_r - P_s \tag{1}$$

PG is the price gap, P_r is the reference price, and P_s is the supported or subsidized price. One of the main criticisms of the price gap approach is the determination of the reference price. To avoid this criticism in this paper, I will incorporate all the international natural gas prices as reported by British petroleum (2014) in my analysis. P_s will be the natural gas prices for the GCC producers, as in Table 1.1. By combining the price gap and Yara's method for calculating fertilizer production cost, I calculate subsidy size as below:

Subsidy size = (PG× gas consumption ×Q_A) + (PG × additional process gas × Q_U) (2)

Where Q_A stands for quantity produced of ammonia and Q_U quantity produced of urea. Gas consumption is the required quantity of natural gas for ammonia production (36 MMBTU natural gas/tonne ammonia). Additional process gas represents the additional quantity of natural gas required for urea production (5.8 MMBTU).

The petrochemical industry in the GCC region in general and fertilizer manufacturers in specific are highly subsidized. The subsidy rate (PG/P_r) for SAFCO reached as low as 67% using Canada (Alberta) international price as a reference price in 2012 and as high as 96% using OECD as a reference price in 2011, 2012, 2013, and using Japan CIF as a reference price in 2012. For QAFCO, I assumed the maximum price, $1 MMBTU, and the subsidy rate is as low as 61% compared with Canada (Alberta) in 2002 and as high as 95% compared with OECD in 2011. For GPIC, the subsidy rate reached its lowest level compared with Canada (Alberta) when the Bahraini government increased natural gas prices to $2.25 MMBTU in 2012 and its highest level at 92% compared with OECD measure. I assume that PIC is charged at the gas ceiling price, $2.50 MMBTU, from 2009–2013, which resulted in no subsidy in 2012 compared with Canada's measure. However, if the price was lower than $2.27, which may be true, there would be a subsidy; but I prefer in this paper to follow the extreme case. However, the subsidy rate reached its peak point in 1998 compared with Japan CIF price at 90%. In general, the subsidy rate for the fertilizer industry within the timeframe of the study has been well above 50%, which reflects the large subsidies. Furthermore, subsidy sizes for these companies reached billions of dollars.

1.5 Model

Hypothesized effects of a per-unit input subsidy on output and profit of a competitive nitrogen fertilizer firm that uses the inputs (natural gas and labor) to produce an intermediate product (ammonia) that is used in the production of the final product (urea). The excess supply of ammonia is sold in a competitive market along with the final product (urea).

Let the firm's objective function be defined as:

$$\max(X)\ \pi = p_1 q_1 + p_2 q_2 - (g - s)X - wL - FC \tag{3}$$

where π is profit, p_1 is the price of ammonia, q_1 is the excess quantity of ammonia that is offered for sale, p_2 is the price of urea, q_2 is the quantity sold of urea, g is the price of subsidized natural gas input per MMBTU, X is the quantity of natural gas used in ammonia and urea production, s is the per-unit subsidy, w is the wage of labor, L is quantity of labor, and FC is fixed costs.

Let the firm's production functions for the intermediate (ammonia) and final products (urea) be defined as:

$$q_1 = q_1(X, L) \qquad \left(\frac{\partial q_1}{\partial X} > 0, \frac{\partial^2 q_1}{\partial X^2} < 0;\ \frac{\partial q_1}{\partial L} > 0, \frac{\partial^2 q_1}{\partial L^2} < 0\right) \tag{4}$$

$$q_2 = q_2(q_1(X, L)) \qquad \left(\frac{\partial q_2}{\partial q_1} > 0, \frac{\partial^2 q_2}{\partial {q_1}^2} < 0\right) \tag{5}$$

Production of both products is subject to diminishing marginal products.

Since the firm is assumed to be a perfect competitor in both the output and input markets, prices are exogenous. This is a reasonable assumption for the GCC producers because in 2011 the total ammonia production capacity of GCC producers reached 8% of world production capacity, and in terms of urea it represented 10% of the world's total production capacity (Markey, 2011). Thus, the GCC producers can not affect the prevailing international output prices. Moreover, the firms can not affect natural gas price because natural gas price is regulated by local authority. Hence, the model contains five endogenous variables (π, q_1, q_2, X, L) and six exogenous variables (p_1, p_2, w, g, s, FC). Since the quantity of ammonia and urea is a function of labor and natural gas, $Q(X, L)$, equation (3) can be written as:

$$\pi = PQ(X, L) + sX - gX - wL - FC \tag{6}$$

For the sake of simplicity, I use P to represent output price (either ammonia price or urea price).I then use comparative static derivatives to obtain the hypothesized impact of the exogenous variables (output price, wage, natural gas price, and subsidy) on the optimal values of the endogenous variables. The results of comparative static derivatives are as below (full derivation of the comparative static derivatives are available in Appendix B).

$$\frac{\partial \bar{X}}{\partial g} < 0 \tag{a}$$

In driving the above comparative static results, I assumed a strictly concave production function ($Q_{LL} < 0, Q_{XX} < 0, and\ Q_{XX}Q_{LL} > Q_{XL}Q_{LX}$) . The result (a) says that the increase in natural gas price reduces the quantity demanded of natural gas.

$$\frac{\partial \bar{L}}{\partial g} < 0 \tag{1b}$$

In order to sign the comparative static derivative (1b), it is important to know the sign of the cross partial Q_{LX}, which is the effect of change in natural gas on the marginal productivity of labor. Hypothetically, if I assume it is positive, an increase in the price of natural gas will decrease the demand for labor. Thus, (1b) indicates that natural gas and labor are complements. On the other hand, if I hypothetically assume the sign of Q_{LX} is negative, I obtain the following comparative static derivatives:

$$\frac{\partial \bar{L}}{\partial g} > 0 \tag{2b}$$

(2b) predicts that an increase in natural gas price increases the demand for labor. Therefore, (2b) indicates that natural gas and labor are substitutes.

$$\frac{\partial \bar{X}}{\partial w} < 0 \tag{1c}$$

Hypothetically, if I assume that the effect of a change in labor on the marginal productivity of natural gas to be positive, $Q_{XL} > 0$. Consequently, (1c) predicts that natural gas demand will decrease in response to an increase in labor wage. Thus, (1c) indicates that natural gas and labor are complements. However, if I assume the sign for Q_{XL} is negatives, I obtain the following comparative static hypothesis.

$$\frac{\partial \bar{X}}{\partial w} > 0 \tag{2c}$$

(2c) predicts that natural gas demand will decrease in response to an increase in labor wage. Hence, (2c) indicates that natural gas and labor are substitutes.

$$\frac{\partial \bar{L}}{\partial w} < 0 \tag{d}$$

Comparative static (d) says an increase in wage will reduce the quantity demanded of labor.

The impact of subsidy on the demand for labor and natural gas based on comparative statics results assuming Q_{LX} is positive is expressed as follow:

$$\frac{\partial \bar{X}}{\partial s} > 0 \tag{e}$$

$$\frac{\partial \bar{L}}{\partial s} > 0 \tag{f}$$

Comparative static (e) predicts that an increase in subsidy increases natural gas demand. Also, (f) indicates that an increase in subsidy increases the demand for labor. Thus, comparative static derivative (f) satisfies one goal of the energy subsidy in the GCC region, which is to create more employment opportunities.

The impact of a change in output price (either ammonia price or urea price) on the demand of natural gas and labor assuming the sign of $Q_{LX}\ and\ Q_{XL}$ is positive can be expressed as below:

$$\frac{\partial \bar{X}}{\partial P} > 0 \tag{g}$$

$$\frac{\partial \bar{L}}{\partial P} > 0 \tag{h}$$

Comparative static (g) indicates that an increase in output price (either urea or ammonia) increases the demand for natural gas. Moreover, (h) predicts that an increase in output price (either urea or ammonia) will increase demand for labor.

In order to evaluate the above comparative static hypotheses empirically, I use a translog specification. The translog specification is a flexible functional form that gives a local second-order approximation to any arbitrary functional form. The local subsidized natural gas prices are unaffected by international natural gas prices and international natural gas prices are an important factor in the nitrogen fertilizer industry. Therefore, I include international natural gas prices in the model to reveal its impact on local ammonia and urea supply, demand for local natural gas and labor, and profit of the GCC firms.

$$\ln \pi = a_0 + \sum_{i=1}^{2} a_i \ln p_i + \sum_{j=1}^{2} \beta_j \ln w_j + c_z \ln z + d_s \ln s + e_h \ln h + 0.5 \sum_{i=1}^{2}\sum_{u=1}^{2} a_{iu} \ln p_i \ln p_u + 0.5 \sum_{j=1}^{2}\sum_{l=1}^{2} \beta_{jl} \ln w_j \ln w_l + \sum_{i=1}^{2}\sum_{j=1}^{2} \gamma_{ij} \ln p_i \ln w_j + \sum_{i=1}^{2} a_{iz} \ln p_i \ln z + \sum_{j=1}^{2} \beta_{jz} \ln w_j \ln z + \sum_{i=1}^{2} a_{is} \ln p_i \ln s + \sum_{j=1}^{2} \beta_{js} \ln w_j \ln s + \sum_{i=1}^{2} a_{ih} \ln p_i \ln h + \sum_{j=1}^{2} \beta_{jh} \ln w_j \ln h \quad (7)$$

Where p_i and p_u ($i = u = 1 \, and \, 2$) are output prices (ammonia and urea), w_i and w_l ($i = l = 1 \, and \, 2$) are input prices (natural gas and labor wage), Z is the fixed factor, s is the subsidy, h is the international natural gas price.

First order differentiation of the profit function with respect to output prices yields the output share equation:

$$S_i = a_i + a_{iu} \ln p_u + \gamma_{ij} \ln w_j + a_{iz} \ln z + a_{is} \ln s + a_{ih} \ln h \quad (8)$$

By differentiating equation (5) with respect to input prices, it results in the unrestricted input share equation:

$$S_j = \beta_j + \beta_{jl} \ln w_l + \gamma_{ij} \ln p_i + \beta_{jz} \ln z + \beta_{js} \ln s + \beta_{jh} \ln h \quad (9)$$

1.6 Estimation and Results

Since local natural gas prices are almost fixed and do not vary across years for most of the observations, I use the real natural gas prices instead of the nominal natural gas prices to allow some variation in the data. The real natural gas prices are calculated using the U.S. CPI since the local natural gas prices are valued using dollars. Another issue is the selection of subsidy measure. Because the total value of the subsidy can be calculated using six different international natural gas prices as discussed earlier in the paper, I have selected the subsidy calculated using Japan CIF as the sample of the study due to the fact that these nitrogen fertilizer firms operate in Asia. The Asian market is the largest market for the GCC fertilizer producers as reported by SAFCO and QAFCO annual reports. As for international natural gas impact, I chose the U.S. Henry Hub price as the sample of this study to evaluate its effect on the GCC nitrogen fertilizer industry output supply, input demand, and profit. I selected Henry Hub as the sample in this paper for three reasons. First, to avoid possible multicollinearity associated with using the same international gas price (since I used Japan CIF in subsidy calculation), I needed to use another price than that used in subsidy calculation. Second, the U.S. market is the second largest market for the GCC nitrogen fertilizer products and the largest market for GPIC’s urea products, in particular as reported by GPIC’s annual reports. Third, Henry Hub has a strong reputation to be the most influential international natural gas price worldwide.

To test for possible endogeneity of international natural gas price and ammonia price, I use the Hausman specification test since it allows to test whether it is necessary to use instrumental variable methods instead of a more efficient OLS estimator. The null hypothesis of the test is that OLS is efficient, hence there is no measurement error. The alternative hypothesis is that the two stage Least Squares (2SLS) is consistent. The test was performed using SAS software (Proc

Model). Results show that I reject the null hypothesis of no measurement error. Thus, an instrumental variable estimator is used in estimating the system of output-input shares and profit function equations. I estimate the model using generalized method of moments (GMM). I implement the GMM method by using the Proc Model procedure in SAS software. The Hansen's J test statistics indicates that the instruments are uncorrelated with the disturbance.

Furthermore, since the data is panel data, I added three dummy variables to account for the fact that the data is a panel data consisting of four firms. For the fixed input, I consider the accounting value of plant and equipment as the fixed input in this study. For GPIC, I use capital expenditure on assets as a proxy for the fixed input variable. There were few missing observations for QAFCO's fixed input. These missing observations were recovered using a linear trend method following (Coelli, Rahman, & Thirtle, 2003). Labor price is payments to labor divided by number of labors. Missing observations for labor price for GPIC, QAFCO, and PIC were recovered using wage and labor survey and statistics that closely matches fertilizer industry. Table 1.5 shows descriptive statistics for the key variables of the model.

Table 1.5 Descriptive Statistics of the Model Key Variables

Variables	Observations	Mean	Std Dev	Minimum	Maximum
Ammonia Price	59	284.11	135.52	95.00	515.00
Urea Price	59	254.55	120.74	66.00	475.00
Real Natural Gas Price	59	1.33	0.58	0.43	2.71
Wage	59	22458.63	21968.31	1335.91	94263.49
Plant & Equipment	59	493476396.00	584516794.00	5035000.00	3500285294.00
Ammonia Share (S1)	59	0.30	0.37	-1.37	1.84
Urea Share (S2)	59	0.96	2.80	-17.03	11.83
Natural Gas Share (S3)	59	-0.20	0.72	-2.34	4.49
Labor Share (S4)	59	-0.06	2.41	-10.34	14.91
Profit	59	539801852	615750768	-3127161.46	2147469879

*All values in US$

In estimating the model, I dropped the urea share equation to avoid singularity in the variance-covariance matrix. The instruments I used are chemicals and related product price index, mineral and fuel price index, and OPEC basket price as reported by Saudi Arabian Monterey Agency (the central bank of Saudi Arabia). Other instruments include third lag prices of both ammonia and Canada (Albarta) natural gas. The homogeneity and symmetry restrictions were imposed in the estimation process. Table 1.6 shows the estimated parameters of the model based on GMM estimator before standard error correction. Table 1.7 shows the parameters estimate after standard error correction using the Newey-West standard error correction method. Generally, standard error correction has improved the parameters' t-ratio. However, the sign of the parameters has not changed. The Shapiro-Wilk normality test shows that the assumption of normal distribution hold for the case of the profit function. Also, the R^2 shows that the model explains 80% of the variation in the profit function of the selected GCC firms.

Table 1.6 Parameter Estimates Based on GMM Estimator

Dependent Variable	Intercept	Ammonia Price	Urea Price	N Gas Price	Wage	Fixed Input	Subsidy	Int N Gas	Dummy Variable
Ammonia	0.103 (0.064)	0.049 (0.129)	0.161 (0.120)	-0.219*** (0.072)	0.009 (0.013)	0.067*** (0.021)	-0.188*** (0.032)	-0.083* (0.045)	-
Urea	6.577 (0.076)		-0.562*** (0.153)	0.313*** (0.101)	0.088*** (0.031)	0.103** (0.044)	0.494*** (0.174)	0.462 (0.411)	-
N Gas	-0.046 (0.105)			-0.157* (0.087)	0.064*** (0.017)	-0.019 (0.019)	0.144*** (0.047)	0.101 (0.074)	-
Labor	-0.074 (0.122)				-0.161*** (0.035)	-0.150*** (0.049)	0.278*** (0.047)	0.510*** (0.105)	-
Profit	6.594*** (2.010)	-	-	-	-	-	-	-	3.027*** (0.294) 0.002 (0.654) 0.0001 (0.466)
R^2	0.80								

Note: N Gas is local natural gas and Int N Gas is international natural gas price.

- Standard errors are in parenthesis

***Significant at 1%, **significant at 5%, and * significant at 10%.

Table 1.7 Parameter Estimates Based on GMM Estimator after Standard Error Correction

Dependent Variable	Intercept	Ammonia Price	Urea Price	N Gas Price	Wage	Fixed Input	Subsidy	Int N Gas	Dummy Variable
Ammonia	0.253*** (0.010)	0.053 (0.056)	0.206*** (0.055)	-0.271*** (0.018)	0.019** (0.005)	-0.069*** (0.010)	-0.211*** (0.013)	-0.161*** (0.026)	-
Urea	1.536*** (0.012)		-0.561* (0.561)	0.297* (0.159)	0.059*** (0.013)	0.191*** (0.040)	0.377** (0.166)	0.481** (0.180)	-
N Gas	-0.112*** (0.021)			-0.150*** (0.031)	0.124*** (0.015)	-0.020 (0.019)	0.228*** (0.026)	0.298*** (0.061)	-
Labor	-0.375*** (0.122)				-0.194*** (0.016)	-0.241*** (0.030)	0.338*** (0.033)	0.665*** (0.073)	-
Profit	-0.302 (0.257)	-	-	-	-	-	-	-	-0.302*** (0.000) -0.302 (1.038) -0.302 (1.038)
R^2	0.82								

Note: N Gas is local natural gas and Int N Gas is international natural gas price.

- Standard errors are in parenthesis

***Significant at 1%, **significant at 5%, and * significant at 10%.

I then calculated the elasticities using the formulas in Table 1.8. The estimated elasticities along with their significance level are reported in Table 1.9 and table 1.10 based on the GMM estimator before and after standard error correction, respectively. It is important to note that standard error correction has not altered the estimated elasticities sign. However, it has indeed improved the t-ratio for the estimated elasticities.

Table 1.8 Elasticity Formula

Elasticity	Expression
Output Own Price Supply Elasticity	$\frac{a_{ii+s_i}}{S_i + 1}$
Cross Output Price Supply Elasticity	$\frac{a_{iu}}{S_i} + S_u$
Supply Elasticity wrt Input Price	$\frac{-\beta_{il}}{S_i} - S_l$
Supply Elasticity wrt Fixed Factor	$c_z + a_{iz}\ln p_i + a_{uz}\ln p_u + \beta_{jz}\ln w_j + \beta_{lz}\ln w_l + \left[\frac{a_{iz}}{s_i}\right]$
Supply Elasticity wrt Subsidy	$d_s + a_{is}\ln p_i + a_{us}\ln p_u + \beta_{js}\ln w_j + \beta_{ls}\ln w_l + \left[\frac{a_{is}}{s_i}\right]$
Supply Elasticity wrt Subsidy Int NG	$e_h + a_{ih}\ln p_i + a_{uh}\ln p_u + \beta_{jh}\ln w_j + \beta_{lh}\ln w_l + \left[\frac{a_{ih}}{s_i}\right]$
Input Own Price Demand Elasticity	$\frac{-\beta_{jj}}{S_j} - S_j - 1$
Cross Price Elasticity of Demand for Input	$\frac{-\beta_{jl}}{S_j} - S_l$
Elasticity of demand for Input wrt output price	$\frac{-\gamma_{ji}}{S_j} + S_i$
Elasticity of Demand for Input wrt Fixed Factor	$c_z + a_{iz}\ln p_i + a_{uz}\ln p_u + \beta_{jz}\ln w_j + \beta_{lz}\ln w_l - \left[\frac{\beta_{jz}}{s_j}\right]$
Elasticity of Demand for Input wrt Subsidy	$d_s + a_{is}\ln p_i + a_{us}\ln p_u + \beta_{js}\ln w_j + \beta_{ls}\ln w_l - \left[\frac{\beta_{js}}{s_j}\right]$
Elasticity of Demand for Input wrt Int NG	$e_h + a_{ih}\ln p_i + a_{uh}\ln p_u + \beta_{jh}\ln w_j + \beta_{lh}\ln w_l - \left[\frac{\beta_{jh}}{s_j}\right]$

Table 1.9 Estimated Elasticities Evaluated at the Mean Data Points Based on GMM

	Ammonia Price	Urea Price	N Gas Price	Wage	Fixed Input	Subsidy	Int N Gas
Ammonia	0.269***	1.498***	0.931***	0.029	0.426***	-0.017	0.022
	(0.099)	(0.398)	(0.242)	(0.044)	(0.107)	(0.158)	(0.260)
Urea	0.468***	1.356***	-0.125	-0.034	0.311***	1.123***	0.780*
	(0.125)	(0.153)	(0.105)	(0.032)	(0.087)	(0.198)	(0.404)
N Gas	-0.790**	2.515***	-1.582***	0.377***	0.107	1.325***	0.802*
	(0.202)	(0.502)	(0.436)	(0.084)	(0.116)	(0.305)	(0.424)
Labor	0.453*	2.472***	1.294***	-3.700***	-2.374***	5.368***	9.026***
	(0.227)	(0.526)	(0.287)	(0.590)	(0.821)	(0.829)	(1.719)
Profit	-0.264	1.329***	0.133	-0.198***	0.135**	0.825***	0.657***
	(0.457)	(0.436)	(0.239)	(0.064)	(0.057)	(0.139)	(0.140)

***Significant at 1%, **significant at 5%, and * significant at 10%.

Table 1.10 Estimated Elasticities Evaluated at the Mean Data Points after Standard Error Correction

	Ammonia Price	Urea Price	N Gas Price	Wage	Fixed Input	Subsidy	Int N Gas
Ammonia	0.272***	1.644***	1.103***	0.019	0.463***	-0.041	-0.175
	(0.043)	(0.184)	(0.061)	(0.016)	(0.058)	(0.059)	(0.137)
Urea	0.515***	1.358***	-0.108	-0.003	0.433***	1.055***	0.861***
	(0.090)	(0.276)	(0.165)	(0.014)	(0.062)	(0.195)	(0.159)
N Gas	-1.047***	2.435***	-1.546***	0.677***	0.134**	1.796***	1.843***
	(0.202)	(0.149)	(0.155)	(0.076)	(0.054)	(0.139)	(0.295)
Labor	0.504***	1.960***	2.326***	-4.270***	-3.885***	6.436***	11.728***
	(0.080)	(0220)	(0.260)	(0.277)	(0.488)	(0.549)	(1.217)
Profit	-0.172	1.300***	0.076	-0.204***	0.123**	0.904***	0.819***
	(0.161)	(0.131)	(0.073)	(0.022)	(0.021)	(0.053)	(0.059)

***Significant at 1%, **significant at 5%, and * significant at 10%.

Before discussing the estimated elasticities, it is important to note that beside the symmetry and homogeneity that were imposed in the estimation, monotonicity and convexity are additional properties of a profit function that cannot be satisfied globally with the translog function. However, they may hold at specific data points used in estimating the function (Fulginiti and Perrin, 1990). Monotonicity is violated if the estimated output shares are negative or the estimated input shares are positive. Thus, monotonicity is satisfied in this study at the average data point. On the other hand, convexity is violated if own output price elasticity has a negative sign or own input price elasticity has a positive sign. The estimated elasticities in table 1.9 and table 1.10 show that all the own input and output price elasticities have the correct sign at the average data point, and hence convexity is not violated. The cross supply elasticities are positive, indicating a complementary relationship between ammonia and urea. Before standard error correction, the elasticity of ammonia supply in response to a general increase in ammonia and urea prices is 1.767. Similarly, the elasticity of urea supply in response to a general increase in both ammonia and urea prices is almost 1.824. After standard error correction these elasticities are 1.916 and 1.873, respectively. This indicates that a general increase in output prices, holding the impact of input prices constant, would cause an elastic response of aggregate output. Ammonia supply elasticity, with respect to domestic natural gas price, is positive indicating that natural gas is inferior input in ammonia supply. This case is true due to both cheap local natural gas prices and because the GCC producers produce urea and the excess (unused) ammonia is offered for sale. Moreover, the results show that labor price does not affect ammonia and urea supply.

Own price input demand elasticity for local natural gas and labor are -1.582 and -3.700 (-1.546 and -4.270 after standard error correction). Thus, a one percent increase in local natural gas price decreases natural gas consumption approximately by 1.6 percent. As a result, I accept the result of comparative static hypothesis (a), which indicated that the increase in the price of natural gas decreases natural gas consumption. Also, a one percent increase in the wage of labor decreases the quantity demanded of labor by more than 3 percent. As a result, I accept the result of hypothesis (d) since it indicted that the increase in wage decreases the quantity demanded of labor. Furthermore, Castro and Teixeira (2011) stated that elastic demands are consistent with an oligopolized sector, which may be true for the GCC producers since there are few producers in the GCC region, as shown in Table 1.A1 in Appendix A. All input cross price elasticities are positive, meaning that natural gas and labor are substitutes. Thus, I accept hypotheses (2b) and (2c). Consequently, I reject hypotheses (1b) and (1c). The impact of natural gas demand to a general combined increase in domestic natural gas price and labor wages is -1.205, compared with -2.406 for labor demand (-0.869 and -1.944 after standard error correction). Holding the impact of output prices constant, an increase in input prices would impact natural gas consumption less than labor use.

The demand for inputs are elastic with respect to the urea price, revealing a higher degree of responsiveness of labor and natural gas to changes in urea price. Therefore, I accept hypotheses (g) and (h) for the case of urea price since an increase in urea price increases the demand for both natural gas and labor. The reason labor has a very high elastic response with respect to the urea price is because some wage observations are annual aggregate salaries and include bonuses. Bonuses according to the GCC firms are given at the end of the year after evaluating the prevailing macroeconomic conditions and end of the year's profit of the firm (or its mother company in case of SAFCO). Profit of the GCC nitrogen fertilizer firms are highly linked to changes in quantity sold of urea and urea prices; this is the reason that the average urea shares, as shown in Table 1.1, is 0.96. Moreover, SABIC, the owner of SAFCO, has given and demanded all its affiliates (including SAFCO) to give all the employees a bonus, equivalent to a 4 month salary, in 2007 and in 2011, and a 3 month salary in 2009, 2010, 2012, and 2013. Conversely, during the great recession in 2008, SABIC had suspended its employees' promotions and limited bonuses to a 2 month salary. In 2014, the company paid an equivalent to 2.85 month salary. The other companies in the sample of this study pay bonuses as well, but there is no precise information on the bonus disbursement policy.

The estimated elasticities predict that an increase in ammonia price has an adverse effect on natural gas demand. Thus, I reject hypothesis (g) for the case of ammonia price. This is because ammonia production requires less quantity of natural gas than urea and increases in ammonia price would encourage the GCC producers to offer more ammonia for sale. This will result in a reduction in the use of natural gas. Also, ammonia price has a positive inelastic effect on the demand for labor. Thus, I accept hypothesis (h) for the case of ammonia price since an increase in ammonia price increases the demand for labor. Additionally, the fixed factor has inelastic positive effect on ammonia supply, urea supply, and profit. After standard error correction, the results show that the fixed factor positively affects the demand for natural gas. However, the fixed factor has an elastic negative effect on labor demand. This has an important policy implication. This implies that the GCC producers are using advanced technology in their plants and equipment, which reduces the demand for labor.

The subsidy is statistically significant and it has a positive elastic effect on natural gas demand. Thus, I accept hypothesis (e) since an increase in subsidy increases natural gas demand. The results show that subsidy does not affect ammonia supply. This indicates that the subsidy is directed toward urea production, and the leftover ammonia is supplied to the market. Moreover, the subsidy has a positive inelastic and significant at the one percent level effect with respect to profit. This shows that a one percent decrease in subsidy decreases profit by 0.825 percent (0.904 percent after standard error correction). This result confirms the GCC nitrogen fertilizer executives’ claim that changes in subsidy would adversely affect the profitability of the nitrogen fertilizer producers. Also, a statistically significant positive impact of subsidy on labor demand shows that the subsidy program in the GCC region has achieved one of its governmental goals in terms of creating more employment opportunity. Therefore, a one percent increase in subsidy increases demand for labor by 5.368 percent (6.436 percent after standard error correction). Consequently, I accept hypothesis (f) since an increase in subsidy increases the demand for labor.

The impact of international natural gas prices, as measured using the U.S. Henry Hub international gas price, does not affect ammonia supply. Also, the international natural gas price has a positive statistically significant effect at the ten percent level on urea supply. The international natural gas price has a positive inelastic effect on domestic natural gas demand. After standard error correction, the results show that international natural gas price has a positive elastic effect on domestic natural gas demand. QAFCO, as shown in its financial statement, sells excess (unused) natural gas. Hence, the increase in international natural gas prices would cause QAFCO to demand more natural gas, and then sell it after it satisfies its needs to produce both ammonia and urea. SAFCO has the ability to sell its excess shares of subsidized natural gas to its other SABIC's affiliates; however, there is no information on SAFCO and the other firms, other than QAFCO in the sample of this study that they can sell the excess natural gas. In addition, the international natural gas price has a positive inelastic impact on the profitability of the GCC firms. Increases in international natural gas prices mean automatically that nitrogen fertilizer prices will increase, which would mean that the profit of the GCC firm will increase as a result. The largest impact of international natural gas price is observed on labor demand. Labor demand is highly elastic with respect to international natural gas price. Thus, a one percent increase in international natural gas price increases labor demand by 9.026 percent (11.728 percent after standard error correction). Urea Price is elastic with respect to profit indicating that the profitability of the GCC producers is highly responsive to changes in urea price. The results show that a one percent increase in urea price increases profit by aprroximatly1.3 percent.

1.7 Conclusion

This paper analyzed the impact of energy subsidies on nitrogen fertilizer producers in the GCC region, which export the majority of their output. I estimated ammonia production cost per ton using Yara's method and found the cost of production in Saudi Arabia to be $53, in Qatar and the UAE it is approximately $64, in Bahrain prior to the 2012 increase in natural gas is $80, in Oman after the 2013 increase in natural gas price is $98, and $116 assuming PIC was charged $2.50. Similarly, production cost for urea per ton is $57, $63.16, $76.20, 89.24, and $102.28 for the mentioned countries/firms respectively. In addition, I showed urea production cost per ton using Budidarmo's method is $86.25, $95, $112.50, $130, and $147.50 assuming the use of old technology plants and $108.75, $115, $127.50, $140,and $152.50 assuming the use of new technology plants. SAFCO, QAFCO, GPIC, and PIC were chosen as the focus of this study as they disclose their financial statements. Then, I estimated subsidy size using the price gap approach. The subsidy was estimated to vary from millions to billions of dollars compared with other international natural gas prices as reported by British Petroleum, except PIC in 2012. I then developed a multiple input-output translog model to evaluate the impact of energy subsidy and international gas prices on output supply, input demand, and profit of the GCC firms. The results based on the GMM estimator show that output supply, input demand, and profits are elastic and statistically significant at the one percent level with respect to urea price indicating a high degree of responsiveness to changes in urea selling prices. Also, the results show that local natural gas is an inferior input in ammonia production and a normal input in urea production. Moreover, the results show that ammonia and urea are complements. The fixed inputs, as measured by the value of plant and equipment, has a negative elastic effect on labor demand. This implies that the GCC producers are using a production technology that requires less labor. Also, the fixed input has a positive inelastic effect on ammonia supply, urea supply, and profit of the GCC fertilizer producers.

Energy subsidy has a positive inelastic influence on domestic natural gas demand due to the fact that the producers in the GCC region have a predetermined quantity of subsidized natural gas input. In addition, energy subsidy has an elastic positive effect on urea supply and labor demand. Moreover, despite the distorting impact of subsidies on output supply and input demand, the study shows that the GCC executives' claim that changes in energy subsidies would adversely impact their profit is a valid claim. The results show that subsidy has an inelastic significant positive effect on profit. Thus, a one percent decrease in subsidy decreases profit by 0.62 percent and vice versa. Therefore, the study concluded that the energy subsidies in the GCC region have achieved one of its governmental purposes in terms of creating more employment opportunities and increasing the competitiveness of the GCC firms in international marketplace by reducing their production costs and increasing their profitability. On the other hand, international natural gas prices as measured by the U.S. Henry Hub international natural gas price, as a sample for this paper, showed a positive inelastic impact on urea supply, local natural gas demand, and profit of the GCC firms. The study recommends for future research to conduct a cost benefit analysis for the GCC governments considering the opportunity cost of selling natural gas in international markets, instead of selling it at the local market, bearing in mind that the GCC governments receive part of the chemical and petrochemical corporates' profit.

Chapter2

Economies of Scale, Technical Change, and Total Factor Productivity Growth of the Saudi Electricity Sector.

2.1 Introduction

The electric sector in Saudi Arabia is fully regulated by the government. In 2000, the council of ministers issued a royal decree to restructure the electric sector that used to be fully owned and managed by the government. This resulted in the consolidation of unified electricity firms working in eastern, central, western, and southern regions in addition to ten companies working in the northern region into a vertically integrated utility company. Furthermore, the decree stipulated the listing of the company as Saudi Electricity Company (SEC) in the Saudi stock market. Currently, 74.3 percent of company stock is owned by the government, 6.92 percent is owned by the Saudi Arabian oil company (ARAMCO), and the remaining stocks are owned by the public. As stated in the company's website, the company supplies over 75 percent of the generation capacity and maintains a monopoly position in the transmission and distribution of electricity. The company purchases energy to cover the deficit in electricity generation from the water and electricity company, desalination plants, and other producers. Furthermore, since the establishment of the SEC, the company has enjoyed much governmental support and privileges such as interest free loans, loan payment deferral, and waiver of dividends on the government's shareholding.

The mission of the SEC is to optimize its resources in generating electricity to meet the increased demand for electricity from various users such as residential, industrial, and commercial. The company's aim is to reduce the cost of electricity production. Thus, it is very important to conduct an empirical examination of the company's mission and aim statement by examining how

SEC uses its input efficiently in delivering its output to the final users. To my knowledge, there has not been a study that examines economic productivity and efficiency in the Saudi electricity sector. Therefore, the purpose of this paper is to examine the presence of economies of scale, technical change, and total factor productivity growth. Also, the paper tries to extend the existing literature about the decomposition of total factor productivity growth (TFP) by deriving an equation that takes into account the impact of network characteristics in TFP decomposition. The other objective of the paper is to inform the decision makers in the SEC about the optimal scale of operation.

2.2 Literature Review

The studies that have analyzed the electricity industries can be generally classified into two groups with regard to their empirical methodology. The first group employs a non-parametric approach that usually uses the data envelopment analysis (DEA) and the second group employs a parametric approach mostly using a stochastic frontier approach, a cost function, a production function and a distance function.

(Huang et al., 2010) used a stochastic meta frontier approach to estimate the cost efficiency of Taiwan's electricity distribution units. Their results show that the high circuit density group is more efficient than low circuit density group due to the impact of network characteristics in determining the efficiency for the electricity distribution industry. Also, they find that the current scale of distribution is smaller than the optimal scale. Using an input distance function (Subal et al., 2015) analyzed Norwegian electricity distribution companies. They concluded that the smaller companies achieved economies of scale and some of them are technically efficient while they could not find evidence of economies of scale among larger firms. Also, the authors found that technical progress in the industry had no relationship between technical change and firm size. As for studies in the U.S. electric sector, (Christensen and Greene, 1976) found evidence of scale economics in the U.S. electric power generation in 1955, (Atkinson and Halvorsen , 1984) found the range of estimates of scale economies using total shadow cost in range of 54.0 percent to -1.7 percent, and (Okunade, 1993) found the average scale economies of 0.26 in a sample of privately regulated private steam-electric utilities in East-North-Central U.S.. (Gao et al., 2013) studied the US electric power industry and found that on average the industry had its highest TFP growth rate in 2005 and 2008 and negative TFP growth rate in 2002 and 2007. (Andrikopulos and Vlachou, 1995) found evidence of economies of scale and the average TFP growth rate is 0.017 percent in the Greek public electric power industry. (Efthymoglou and Vlachou, 1989) estimated that the TFP of the integrated Greek power system increase at an average annual growth rate of 1.76 percent. (Filippini, 1998) used a translog cost function approach on a sample of Swiss municipal utilities. He concluded that the Swiss utilities operate with economies of output density, economies of customer density, and economies of scale. (Roberts, 1986) used a tronslog cost function approach and rejected the hypothesis of no economies of output density and customer density at the one percent level. Additionally, he rejected the hypotheses of no economies of size at the five percent level. (Tovar et al., 2011) analyzed Brazilian electricity distribution industry using a stochastic translogarithmic distance function. The results show a positive TFP with an annual growth of 0.9 percent during 1998-2005 and the average technical change growth is estimated to be 4.9 percent. (Goto and Sueyoshi, 2009) found evidence of economies of scale, negative technical change (due to large investment cost), and a negative TFP growth in the Japanese electricity distribution industry. The study also indicated that the network characteristics (load factor, customer density, and underground ratio of lines) influence the cost of distribution. (See and Coelli, 2013) found the average TFP growth in the Malaysian electricity generation industry of 0.5 percent, 0.94 percent, and 2.34 percent using Malmquist method, Törnqvist method, and stochastic frontier analysis, respectively. The authors attributed the differences because different methods use different explicit or implicit cost and revenue share to weight inputs and output variables components. (Arcos and de Toledo, 2009) concluded that the Spanish electricity utility industry exhibit diseconomy of scale. (Akkemik, 2009) found that the technical change in the Turkish electricity generation sector is energy using and labor and capital saving. Also, the results showed presence of economies of scale and a general trend for technological progress to deteriorate. (Oh, 2015) analyzed Korean fossil-fuel generation companies and found evidence of economies of scale, technical deterioration, average scale component of 1.459 percent, and, on average, a negative TFP growth rate of -0.697 percent. (Burney, 1998) estimated a translog variable cost function using a time series data on Kuwait electricity generation sector. The author found evidence supporting the presence of diseconomy of scale in electricity generation in Kuwait. (Hisnanicka and Kymnb, 1999) stressed the importance of additional research to investigate the impact of scale economies on productive behavior.

Studies on the electric sector that used non-parametric approach are many. For example, (Lam and Shiu, 2004) China’s thermal power generation using a DEA approach. They found the average TFP growth rate is 2.1 percent. (Abbott, 2006) analyzed the Australian electricity supply industry using DEA approach and found an average technical progress growth rate of 1.8 percent, and a TFP average annual growth rate of 2.5 percent. (Çelen, 2013) estimated the mean TFP change of 1.033 percent in Turkish electricity distribution companies. See and Coelli (2014) use Törnqvist index to estimate TFP growth of Tenaga Nasional Berhad in Malaysia. The study found a TFP growth of 1.19 percent prior to the company’s corporatization, 5.73 percent after the company corporatization, and 0.36 for the full period of study.

To my knowledge, this is the first paper that analyzes economies of scale, technical change, and TFP growth of the Saudi electricity sector. Also, this is the first study that includes network characteristics in TFP growth decomposition.

2.3 Methodology and Data

2.3.1 Theoretical Model

The model that will be used in this paper is the same model derived by (Oh, 2015). However, this paper will improve Oh's model by incorporating network characteristic into the decomposition of TFP. Thus, the approach is a dual approach that uses a cost function. The model assumes that firms minimize costs and that factor markets are competitive. The cost function is represented as:

$$C= C(w, y, N, t) \qquad (1)$$

where C is the total cost, w represents input prices, y is firm's output, N is network characteristics such as customer density, length of transmission and distribution line, etc. and t is a time trend variable.

By taking the total differential, equation (1) becomes

$$dlnC = \sum_i \frac{\partial ln\ C}{\partial lnw_i} dlnw_i + \frac{\partial ln\ C}{\partial lny} dlny + \frac{\partial lnC}{\partial lnN} dlnN + \frac{\partial lnC}{\partial t} dt \qquad (2)$$

By applying Shephard's lemma, we obtain the following cost share equation:

$$\frac{\partial lnC}{\partial lnw_i} = \frac{w_i x_i}{C} = S_i \qquad (3)$$

S_i denotes input cost share. Inserting equation (3) into (2) yields the following

$$\frac{dlnC}{dt} = \sum_i S_i \frac{dlnw_i}{dt} + \frac{\partial lnC}{\partial lny}\frac{dlny}{dt} + \frac{\partial lnC}{\partial lnN}\frac{dlnN}{dt} + \frac{\partial lnC}{\partial t} \quad (4)$$

The above logarithmic time derivatives, which denote rate of change, can be expressed as:

$$\dot{C} = \sum_i S_i \dot{w_i} + \frac{\partial lnC}{\partial lny}\dot{y} + \frac{\partial lnC}{\partial lnN}\dot{N} + \frac{\partial lnC}{\partial t} \quad (5)$$

Since the logarithmic time derivatives of cost[2] and the Divisia index of total factor productivity growth($T\dot{F}P$) are expressed as:

$$\dot{C} = \sum_i S_i \dot{X_i} + \sum_i S_i \dot{w_i} \quad (6)$$

$$T\dot{F}P = \dot{y} - \sum_i S_i \dot{X_i} \quad (7)$$

By inserting equation (6) into (7), we obtain

$$T\dot{F}P = \dot{y} - (\dot{C} - \sum_i S_i \dot{w_i}) \quad (8)$$

where $\dot{y}$ is the growth rate of output. Then by inserting equation (5) into equation (8), we obtain the final decomposition of $T\dot{F}P$ growth that takes into account the impact of network charactaristics as below:

$$T\dot{F}P = \dot{y} - (\sum_i S_i \dot{w_i} + \frac{\partial lnC}{\partial lny}\dot{y} + \frac{\partial lnC}{\partial lnN}\dot{N} + \frac{\partial lnC}{\partial t} - \sum_i S_i \dot{w_i}) \quad (9)$$

$$T\dot{F}P = \left(1 - \frac{\partial lnC}{\partial lny}\right)\dot{y} + (-\frac{\partial lnC}{\partial lnN}\dot{N}) + (-\frac{\partial lnC}{\partial t}) \quad (10)$$

$$T\dot{F}P = SC + (-\varepsilon_N \dot{N}) + TC \quad (11)$$

[2] For further details regarding the derivation of the logarithmic time derivatives of cost equation (6), please refer to Oh (2015).

where SC denotes scale component. ε_N is the elasticity of total cost with respect to the network variable and $\dot{N}$ is the growth rate in the network variable. TC is the technical change.

Some authors who did not include network characteristics in their analysis, such as (Akkemik ,2009) and (Oh, 2015) have defined economies of scale as the elasticity of total cost with respect to output, $\frac{\partial lnC}{\partial lny}$. On the other hand, (Christensen and Greene, 1976) have defined economies of scale as unity minus the elasticity of total cost with respect to output. $1-\frac{\partial lnC}{\partial lny}$.

The scale components shows how a firm adjusts its size to approach or deviate from the optimal size. As mentioned by Oh, if a firm is operating under the economies of scale (or economies of output density for authors who include network characteristics) and increasing its size, then the scale component is positive. Also, a positive scale component can occur if a firm is operating under diseconomies of scale and decreasing its firm size. Conversely, a negative scale component indicates that the firm is deviating far from the optimal size.

The technical change term, which equals the negative of the elasticity of total cost with respect to time, shows the reduction in firm's cost over time.

Therefore, the proposed total factor productivity growth in this paper equals the summation of scale component, the negative of the elasticity of network variables times their growth, and technical change.

2.3.2 Econometric Model

This paper will use translog cost function approach since it has been widely used in the literature to estimate empirically the cost function in the electricity industry, for example (Akkemik, 2009) and (Filippini, 1998). The model is written as:

$$lnC = a_c + a_y lny + \frac{1}{2}\ a_{yy}(lny)^2 + a_t t + \frac{1}{2}\ a_{tt}t^2 + a_{yt}(\ln y)t + \sum_i \delta_i\ lnP_i +$$
$$\frac{1}{2}\sum_i \sum_j \gamma_{ij} lnP_i\ lnP_j + \sum_i \gamma_{iy} lnP_i\ lny + \sum_i \gamma_{it}\ lnP_i\ t + \varphi_i N_i \qquad (12)$$

Where C denotes total cost, y is output, t is a time trend variable, P_i and P_j is the price of the ith and jth input $(f = fuel, e = purchased\ energy, and\ k = capital)$, and N is a variable accounting for network characteristics. $\alpha_c$is the intercept for the cost function.$a_t, a_{tt,}\ a_{yt}, \gamma_{ij}, \gamma_{iy}, \gamma_{it}, \delta_i\ \ and\ \varphi_i$ are parameters to be estimated. The network variable is specified in a linear way following (Goto and Sueyoshi, 2009). Also, I include a dummy variable in the model to distinguish the time period prior to SEC incorporation in 2000 from the period after SEC incorporation.

Homogeneity condition in input prices requires $\sum_i \delta_i = 1, \sum_{ij} \gamma_{ij} = 0, \sum_i \gamma_{yi} = 0, and\ \sum_i \gamma_{it} = 0$. By normalizing total cost and input prices by a chosen input price, we impose the homogeneity condition. There are many studies in the electricity sector that followed this approach (Filippini, 1998; Huang et al. 2010; Fetz and Filippini, 2010; Oh, 2015). In this paper, I will follow the same approach. The symmetry condition $(\gamma_{ij} = \gamma_{ji})$ is imposed in the estimation. Also, the translog cost function requires the approximation of the underling cost function to be made at a local point. Thus, this paper will normalize all data by their means (Filippini, 1998; Goto and Sueyoshi, 2009; Hartarska et al., 2013).

By applying Shephard's lemma, taking the partial derivatives of the cost function with respect to input prices($\frac{\partial lnc}{\partial lnP_i}$), we obtain the following cost share equation:

$$S_i = a_i + \sum_j \gamma_{ij} \ln P_j + \gamma_{yi} lny + \gamma_{it}\ t \qquad (13)$$

where S_i is the cost share equation and a_i is the intercept for the share equations ($f = fuel, e = purchased\ energy, and\ k = capital$). The scale component of total factor productivity growth in equation (11) can be calculated from the translog cost function as below:

$$SC = \left(1 - \frac{\partial lnC}{\partial lny}\right)\dot{y} = (1 - a_y + a_{yy}\ln y + a_{yt}t + \sum_i \gamma_{yi}\, lnP_i)\dot{y} \quad (14)$$

The incorporation of network characteristics in the econometric model allows for distinguishing between economies of output density (EOD), economies of customer density (ECD), and economies of scale (EOS). Economies of output density will be calculated using the following equation:

$$EOD = (\frac{\partial \ln C}{\partial \ln y})^{-1} \quad (14)$$

(Roberts, 1986; Filippini, 1998; Wang and Liao, 2006). Economies of output density occur when EOD is bigger than one and diseconomies of output density occur when EOD is less than one. This means that the average cost decreases as the electricity output sold to a fixed number of customers and service area increases. (Filippini, 1998) and (Roberts, 1986) stated that EOD occur when there is an increase in the demand for electricity from a fixed number of customers in a fixed service area.

Economies of customer density is calculated as:

$$ECD = (\frac{\partial \ln C}{\partial \ln y + \partial \ln N_1})^{-1} \quad (15)$$

where N_1denotes the number of customers. EOD is a measure of the cost of selling more electricity to a fixed area as its population density increases (Filippini,1998). Economies of customer density occur when ECD is greater than one. Conversely, diseconomies of customer density occur when ECD is less than one.

Economies of scale shows the change in average costs of selling more electricity to an increased number of customers and an increased service territory. Economies of scale is expressed as:

$$EOS = \left(\frac{\partial \ln C}{\partial \ln y + \partial \ln N_1 + \partial \ln N_2}\right)^{-1} \qquad (16)$$

when N_2 denotes a variable accounting for the service area. If EOS is greater than one, then a firm utilizes economies of scale. On the other hand, if EOS is less than one, then a firm operates under diseconomy of scale.

Furthermore, the translog cost function allows the calculation of own price elasticity of demand and cross price elasticity of substitution. I will follow the convention in the literature in calculating own and cross price elasticities. Thus, the own price elasticity of demand can be calculated as:

$$\eta_{ii} = \frac{\gamma_{ii}}{S_i} + S_i - 1 \qquad (17)$$

Cross price elasticity of demand is calculated as below:

$$\eta_{ij} = \frac{\gamma_{ij}}{S_i} + S_j \qquad (18)$$

Hicks-Allen elasticity of substitution, which some authors refer to as Allen-Uzawa elasticity of substitution, can be calculated by the following equation:

$$\theta_{ij} = \frac{1}{S_i S_j} a_{ij} + 1 \qquad (19)$$

For all $i = j$.

$$\theta_{ii} = \frac{1}{S_i^2} a_{ii} S_i^2 - S_i \tag{20}$$

For all i.

Morishima elasticity of substitution can be computed as:

$$\sigma_{ij} = \eta_{ij} - \eta_{jj} \tag{21}$$

2.3.3 Data

Data prior to the incorporation of SEC come from the Saudi Arabian Monetary Agency (SAMA) national statistics. Data after SEC incorporation come from the SEC annual report, annual financial statement, and electricity data report. The data is a time-series data from 1970 to 2014. The output (y) is the electricity sold in Gigawatt hours. The inputs are fuel price (P_f), purchased energy price (P_e), labor price(P_l), and capital price (P_k). Fuel price since SEC incorporation is calculated as total fuel expenses divided by total consumed quantity. Purchased energy price since SEC incorporation is calculated as the total purchased energy expenses divided by the total quantity of purchased energy, and labor price is the total payment to employees divided by the total number of employees. Prior to SEC incorporation, I used local fuel price index, local energy price index, and goods and other services price index published by SAMA as proxies for fuel price, energy price, and labor price, respectively. I followed the published literature in calculating capital price. Thus, capital price is calculated as residual cost divided by capital stock (Farsi et al., 2008; Fetz and Filippini, 2010; Oh, 2015). The network variables in this study are the number of subscribers and energy transmission network length. There were some missing observations for labor price, fuel price, purchased energy price, and transmission network length. The missing observations for those input prices and the transmission network length were recovered using the average annual growth rate as reported by SEC. Table 2.1 shows descriptive statistics of the key variables.

Table 2.1 Descriptive Statistics of the Model Key Variables

Variable	Mean	Std Dev	Minimum	Maximum
Output (Gigawatt hrs)	87941.07	77454.42	1690.00	274502.00
Fuel price	104.22	14.02	77.84	124.00
Purchased energy price	168.33	133.48	33.22	519.23
Labor price	109.62	21.24	70.08	163.82
Capital price	0.08	0.03	0.02	0.16
Transmission network length (km-sq)	23664.32	14360.26	6767.06	59797.00
Customers number	2859271.30	2096116.45	216000.00	7602279.00

- All prices are in (1000) Saudi Riyal

As shown in the table, the lowest input price is capital price due to the facts mentioned in the introduction and the company's strong credit rating (AA- and A1 according to Fitch, Standard $ poor's, and Moodey's respectively). This allows it to issue Sukuk (Islamic bonds) and obtain credit from export credit agencies and loans from local and international banks with low interest rates. In addition, the company increased its capital twice in 2002 and 2003. Also, since Saudi Arabia is one of the largest oil producers in the world, the company enjoys reduced fuel prices. The company uses natural gas, crude and heavy oil, and diesel in generating electricity. The output is the total electricity delivered to the subscribers. The total number of subscribers includes residential, agricultural, industrial, and governmental, since the company serves all types of electricity users.

2.4 Model Estimation and Discussion

2.4.1 Estimation Procedures and Results

The data were normalized by labor price and the labor share equation was dropped to avoid the singularity in the variance covariance matrix. Since the data described in the previous section are time-series data, autocorrelation correction was needed. Thus, I followed (Seldona et al., 2000) procedures in correcting autocorrelation, who applied the method developed by (Berndt and Savin, 1975). The method also was applied by other authors to correct for autocorrelation in the translog cost function, such as (Onghena et al., 2014). As stated by (Seldon et al., 2000), care should be taken when correcting for autocorrelation while estimating the cost function and the share equations simultaneously. This is because the share equation includes the lagged error of the cost function and the cost function includes the lagged errors for the share equations, taking into account that the share equation has to sum up to one (adding-up restriction). Therefore, I used a first-order autoregressive error model. The error term for the cost function and the three share equations in this paper case are specified as:

$$\mathcal{U}_{c,t} = \rho_{c,c}\mathcal{U}_{c,t-1} + (\rho_{c,f} - \rho_{c,l})\mathcal{U}_{f,t-1} + (\rho_{c,e} - \rho_{c,l})\mathcal{U}_{e,t-1} + (\rho_{c,k} - \rho_{c,l})\mathcal{U}_{k,t-1} + v_{c,t} \tag{22}$$

$$\mathcal{U}_{f,t} = \rho_{f,c}\mathcal{U}_{c,t-1} + (\rho_{f,f} - \rho_{f,l})\mathcal{U}_{f,t-1} + (\rho_{f,e} - \rho_{f,l})\mathcal{U}_{e,t-1} + (\rho_{f,k} - \rho_{f,l})\mathcal{U}_{k,t-1} + v_{f,t} \tag{23}$$

$$\mathcal{U}_{e,t} = \rho_{e,c}\mathcal{U}_{c,t-1} + (\rho_{e,f} - \rho_{e,l})\mathcal{U}_{f,t-1} + (\rho_{e,e} - \rho_{e,l})\mathcal{U}_{e,t-1} + (\rho_{e,k} - \rho_{e,l})\mathcal{U}_{k,t-1} + v_{e,t} \tag{24}$$

$$\mathcal{U}_{k,t} = \rho_{k,c}\mathcal{U}_{c,t-1} + (\rho_{k,f} - \rho_{k,l})\mathcal{U}_{f,t-1} + (\rho_{k,e} - \rho_{k,l})\mathcal{U}_{e,t-1} + (\rho_{k,e} - \rho_{k,k})\mathcal{U}_{k,t-1} + v_{k,t} \quad (25)$$

As indicated by (Seldon et al., 2000), the ρ differences are estimated as one parameter because we cannot estimate them individually and we are not interested in them.

I estimated the cost function and the share equation simultaneously using seemingly unrelated regression method (SUR). Table 2.2 and table 2.3 show parameter definition and parameters estimate, respectively. As shown in table 2.3, most of the autocorrelation parameters are significant at the one percent level, indicating the correct use of Berndt and Savin's (1975) methodology. Also, Shapiro-Wilk Normality test shows that normality assumption hold for the cost function and for the capital share equation. Moreover, the average R^2 for the cost function and the cost share equations is 0.97. This indicates that the selected variables have explained on average about 97% of the variation in the cost function and the share equation.

Table 2.2 Parameter Definition

Parameter	Definition
$\alpha_c, \alpha_f, \alpha_e, \alpha_k$	Intercept for the cost function, purchased energy, fuel, and capital
a_y, a_t	First order output parameter and first order technology parameter effect
$\delta_f, \delta_e, \delta_e$	Input price parameters
γ_{ij}	Parameters denoting interaction among the variables.
$\rho_{i,j}$ and $(\rho_{i,j} - \rho_{i,j})$	Autocorrelation parameters

Table 2.3 Parameter Estimates

Parameter Estimates					
$\boldsymbol{a_c}$	20.634*** (0.594)	$\gamma_{\boldsymbol{kt}}$	-0.002 (0.003)	$\boldsymbol{a_t}$	-0.208*** (0.029)
$\boldsymbol{a_f}$	0.152 (0.202)	Dummy	-0.530*** (0.067)	$\boldsymbol{a_{tt}}$	0.003*** (0.001)
$\boldsymbol{a_e}$	0.328*** (0.097)	Customers	-0.096 (0.075)	$\gamma_{\boldsymbol{fy}}$	0.078 (0.048)
$\boldsymbol{a_k}$	-0.029 (0.094)	Transmission length	2.163*** (0.310)	$\gamma_{\boldsymbol{ey}}$	0.040* (0.023)
$\boldsymbol{\delta_f}$	-0.217 (0.153)	$\rho_{c,c}$	-1.361*** (0.263)	$\gamma_{\boldsymbol{ky}}$	-0.015 (0.024)
$\boldsymbol{\delta_e}$	0.659*** (0.095)	$(\rho_{c,f} - \rho_{c,l})$	-2.247*** (0.439)	$\gamma_{\boldsymbol{ft}}$	0.039*** (0.005)
$\boldsymbol{\delta_k}$	0.109 (0.101)	$(\rho_{c,e} - \rho_{c,l})$	-1.210*** (0.402)	$\gamma_{\boldsymbol{et}}$	-0.019*** (0.003)
$\gamma_{\boldsymbol{ff}}$	0.047 (0.044)	$(\rho_{c,k} - \rho_{c,l})$	-1.488*** (0.497)	$\rho_{k,c}$	-0.690*** (0.168)
$\gamma_{\boldsymbol{fe}}$	-0.097*** (0.021)	$\rho_{f,c}$	1.481*** (0.271)	$(\rho_{k,f} - \rho_{k,l})$	-0.493** (0.185)
$\gamma_{\boldsymbol{fk}}$	0.179*** (0.012)	$(\rho_{f,f} - \rho_{f,l})$	2.268*** (0.296)	$(\rho_{k,e} - \rho_{k,l})$	0.082 (0.178)
$\gamma_{\boldsymbol{ee}}$	0.097*** (0.021)	$(\rho_{f,e} - \rho_{f,l})$	0.281 (0.315)	$(\rho_{k,e} - \rho_{k,k})$	0.458** (0.180)
$\gamma_{\boldsymbol{ek}}$	-0.033*** (0.008)	$(\rho_{f,k} - \rho_{f,l})$	1.031*** (0.339)		
$\gamma_{\boldsymbol{kk}}$	-0.098*** (0.009)	$\rho_{e,c}$	-0.602*** (0.185)		
$\boldsymbol{a_y}$	1.222*** (0.205)	$(\rho_{e,f} - \rho_{e,l})$	-0.612*** (0.187)		
$\boldsymbol{a_{yy}}$	0.287*** (0.052)	$(\rho_{e,e} - \rho_{e,l})$	0.699*** (0.173)		
$\boldsymbol{a_{yt}}$	-0.016*** (0.006)	$(\rho_{e,k} - \rho_{e,l})$	-0.486** (0.174)	R^2	0.97

Note: Standard errors are in parenthesis.
***Significant at 1%, **significant at 5%, and * significant at 10%.

The primary first order effect of technology (a_t) is negative and significant at the one percent level, indicating that the technology used is cost saving. (Akkemik, 2009) interpreted the coefficient (a_{tt}) as the speed of technological progress. Thus, in this case it implies acceleration of technological progress at a rate of 0.003 percent annually. Table 2.4 shows that the average technical change from 1971-1974 has been almost constant at a rate of 11 percent. After 1975, the technical change rate had been gradually increasing. However, in 1991 the technical change started to fall, due to the Gulf War. Moreover, the technical change rate started to increase gradually after the SEC incorporation in 2000, but it started to decrease from 2008 until 2010 due to the global financial crisis. In relative terms, the parameter γ_{ft} indicates that SEC technology is fuel using, which is due to the subsidized fuel prices it receives from the government, which encourages the company to rely on fuel as a source of input in generating electricity. However, the parameter γ_{et} indicates that SEC technology is a saving technology with respect to purchased energy, and γ_{kt} indicates it is neutral with respect to capital. As stated by Norsworthy and Jang (1992), in absolute term $(a_t + \gamma_{it})$ the Saudi electric sector technology is absolutely fuel, purchased energy, and capital saving. The Saudi electric sector with sample mean characteristics operates with decreasing return to scale because the coefficient (a_y) is greater than one and significant at the one percent level. As interpreted by (Friedlaender et al., 1981), the positive value of (a_{yy}) indicates (asymmetric) U-shaped average cost curve in the Saudi electric sector. The dummy variable is negative and significant at the one percent level indicating that the consolidation of public firms to operate as a one entity (SEC) results in reducing the total cost of electricity generation. Also, an increase in energy transmission network length increases total cost.

2.4.2 Economies of Scale, Technical Change, and Total Factor Productivity Growth

Table 2.4 shows the estimate of economics of output density, economies of customer density, economies of scale, technical change, and total factor productivity growth at the sample mean.

Tables 2.4 Economies of Scale, Technical Change, and Total Factor Productivity Growth

Term	Estimate
Economics of output density (EOD)	1.541***
	(0.219)
Economics of customer density (ECD)	1.810***
	(0.202)
Economies of scale (EOS)	0.368***
	(0.043)
Technical change (TC)	0.129***
	(0.017)
Scale component (SC)	0.037***
	(0.010)
Suggested Total factor productivity growth	0.069***
($T\dot{F}P$)	(0.004)
Literature Total factor productivity growth	0.166***
($T\dot{F}P$)	(0.015)

Note: Standard errors are in parenthesis.
***Significant at 1%, **significant at 5%, and * significant at 10%.

Since the estimates of EOD and ECD are larger than one and significant at the one percent level, this indicates that the Saudi electricity sector operates under economies of output density and economies of customer density, which is consistent to the results found in (Filippini, 1998) and (Roberts, 1986). However, the Saudi electric sector operates under diseconomies of scale. The technical change is positive and significant, but less than one which indicates a cost increase during the average sample period. Furthermore, since the Saudi sector operates with economies of output density, and the estimated scale component is positive and significant, this gives evidence that SEC is increasing its firm size in an attempt to approach the optimal size. Table 2.4 also shows average TFP growth calculated using the proposed method in this paper, equation 13. The Saudi sector has a positive and significant TFP growth with a value of 0.069. However, if we decompose TFP growth by summing SC and technical change as it is done in the literature, the TFP growth would be 0.166. Thus, failure to account for network characteristics in the decomposition of TFP will overestimate the value of TFP growth of the Saudi sector. This gives evidence to support the derived equation (11) in providing a more accurate estimate of the value of TFP growth.

Table 2.5 shows that the average value of economies of scale decrease with increase in firm size which is consistent with (Filippini, 1998) findings. Also, the table shows a comparison between TFP growth using the method described in the literature and the proposed method in this paper. The comparison between the two methods reassures the importance of including network characteristics in TFP growth decomposition. It is clear from the table that the conventional method overestimates TFP growth rate. Using the proposed method, the company had three negative TFP growth rates in 2009-2010, 2010-2011, and 2013-2014, respectively. The average growth rate of technical change, conventional TFP, and the proposed TFP from SEC incorporation until 2014 is 0.09%, 0.02%, and -1.49%, respectively.

Table 2.5 Estimated Average Annual Rate of EOS, Technical Change, and TFP over time

year	EOS	TC	SC	TFP literature	Suggested TFP
1971-1972	0.470	0.113	0.116	0.229	0.131
1972-1973	0.463	0.113	0.142	0.254	0.156
1973-1974	0.453	0.113	0.167	0.280	0.186
1974-1975	0.445	0.113	0.134	0.247	0.155
1975-1976	0.436	0.114	0.147	0.262	0.170
1976-1977	0.425	0.116	0.160	0.275	0.185
1977-1978	0.416	0.117	0.137	0.253	0.166
1978-1979	0.401	0.120	0.174	0.294	0.209
1979-1980	0.387	0.124	0.147	0.271	0.185
1980-1981	0.380	0.126	0.088	0.214	0.127
1981-1982	0.372	0.127	0.075	0.202	0.112
1982-1983	0.367	0.129	0.060	0.188	0.097
1983-1984	0.363	0.130	0.042	0.172	0.080
1984-1985	0.360	0.131	0.035	0.167	0.073
1985-1986	0.358	0.134	0.031	0.165	0.069
1986-1987	0.358	0.140	0.025	0.165	0.068
1987-1988	0.359	0.146	0.016	0.162	0.064
1988-1989	0.358	0.149	0.016	0.165	0.066
1989-1990	0.357	0.149	0.017	0.167	0.067
1990-1991	0.355	0.149	0.017	0.166	0.066
1991-1992	0.355	0.146	0.016	0.162	0.063
1992-1993	0.354	0.143	0.017	0.161	0.061
1993-1994	0.352	0.141	0.021	0.162	0.062
1994-1995	0.351	0.137	0.015	0.152	0.053
1995-1996	0.351	0.135	0.009	0.144	0.044
1996-1997	0.351	0.133	0.008	0.141	0.040
1997-1998	0.351	0.131	0.008	0.140	0.039
1998-1999	0.350	0.130	0.014	0.144	0.043
1999-2000	0.346	0.128	0.014	0.142	0.043
2000-2001	0.342	0.126	0.010	0.137	0.076
2001-2002	0.339	0.127	0.007	0.134	0.066
2002-2003	0.338	0.127	0.008	0.134	0.036
2003-2004	0.340	0.128	0.006	0.135	0.075
2004-2005	0.343	0.130	0.006	0.135	0.077
2005-2006	0.344	0.129	0.010	0.138	0.054
2006-2007	0.345	0.130	0.009	0.138	0.060
2007-2008	0.345	0.128	0.009	0.137	0.054
2008-2009	0.345	0.124	0.011	0.135	0.016
2009-2010	0.346	0.127	0.013	0.140	-0.007
2010-2011	0.346	0.133	0.011	0.144	-0.009
2011-2012	0.346	0.133	0.010	0.143	0.022
2012-2013	0.344	0.132	0.012	0.144	0.055
2013-2014	0.345	0.130	0.011	0.141	-0.001

Moreover, the conventional method can underestimate TFP growth depending on the sign and magnitude of the elasticity of cost with respect to the network variables.

2.4.3 Own Price Elasticity of Demand and Cross Price Elasticity of Substitution

All own price elasticities of demand in table 2.6 and Allen-Hicks elasticities in table 2.7 are negative inelastic, except the price of capital has negative elastic own price elasticity of demand. Surprisingly, the purchased energy has insignificant positive own price elasticity ($\eta_{ee} = 0.454\ and\ \theta_{ee} = 0.027$). Despite the fact that the own price elasticity of purchased energy is statistically insignificant, this result is consistent with (Cho et al., 2004) who found positive own price elasticity of energy and (Gao et al., 2013) who used the dynamic translog model and found positive Allen elasticity of energy. To be consistent with the literature, I focused on the analysis of cross price elasticities of Hicks-Allen and Morishima elasticities in table 2.7 and 2.8, respectively.

Allen-Hicks elasticities show fuel and energy are complements with Morishima cross price elasticity of $\sigma_{fe} = -0.610\ and\ \sigma_{ef} = -0.498$. Fuel and capital are substitutes with elastic cross price elasticity. Also, fuel and labor are substitute with inelastic cross price elasticity. Energy and capital have a strong complementary relationship using Allen- Hicks elasticity. However, Morishima cross price elasticity indicates that the price of purchased energy is elastic substitute with respect to the price of capital, indicating that the increases in the price of energy induces the firm to seek more capital to implement projects that reduces its dependence on purchased energy in generating electricity. Furthermore, the Morishima elasticity shows price of capital has an inelastic complementary relationship with price of purchased energy indicating that the firm uses part of its capital in purchasing energy. Also, Morishima elasticity shows that increases in the price of purchased energy forces the firm to substitute purchased energy to demand more labor for its own operation to reduce its reliance on purchased energy. The results also show that the firm uses labor as a complementary factor with purchased energy to generate electricity. Allen-Hicks elasticity shows that capital and labor are complements and Morishima elasticity shows the same relation. However, when the price of labor increases, the firm uses more capital to procure a technology that substitutes its need for labor.

Table 2.6 Own Price and Cross Price Elasticity of Demand Evaluated at the Mean

	$j = f$	$j = e$	$j = k$	$j = l$
$i = f$	-0.460***	-0.156***	0.479***	0.137*
	(0.103)	(0.049)	(0.028)	(0.079)
$i = e$	-0.958***	0.454	-0.418***	0.922***
	(0.302)	(0.308)	(0.109)	(0.266)
$i = k$	3.373***	-0.479***	-2.551***	−0.343**
	(0.196)	(0.125)	(0.148)	(0.150)
$i = l$	0.134*	0.147***	−0.048**	−0.234***
	(0.078)	(0.042)	(0.021)	(0.083)

Note: Standard errors are in parenthesis.
***Significant at 1%, **significant at 5%, and * significant at 10%.

Table 2.7 Allen-Hicks Elasticity of Substitution Evaluated at the Mean

Elasticity	Estimate
θ_{fe}	-2.228*** (0.701)
θ_{fk}	7.843*** (0.457)
θ_{fl}	0.313* (0.181)
θ_{ek}	-6.850*** (1.790)
θ_{el}	2.100*** (0.606)
θ_{kl}	−0.781** (0.342)
θ_{ff}	-0.383*** (0.044)
θ_{ee}	0.027 (0.022)
θ_{kk}	-0.159*** (0.009)
θ_{ll}	−0.295*** (0.036)

Note: Standard errors are in parenthesis.
***Significant at 1%, **significant at 5%, and * significant at 10%.

Table 2.8 Morishima Elasticity of Substitution Evaluated at the Mean

	$j = f$	$j = e$	$j = k$	$j = l$
$i = f$	0.000	-0.610* (0.341)	3.030*** (0.167)	0.371** (0.154)
$i = e$	-0.498 (0.372)	0.000	2.133*** (0.176)	1.156*** (0.303)
$i = k$	3.833*** (0.252)	-0.933*** (0.312)	0.000	−0.109 (0.193)
$i = l$	0.595*** (0.171)	−0.307 (0.331)	2.504*** (0.154)	0.000

Note: Standard errors are in parenthesis.
***Significant at 1%, **significant at 5%, and * significant at 10%.

2.5 Optimal Scale

(Huang et al., 2010) used the fundamental theory of minimum efficient scale in industrial economics in order to find the minimum point of the long run average cost function. The authors stated that the optimal scale can be found by taking the partial derivatives of the cost with respect to output and setting it equal to 1, ($\frac{\partial \ln C}{\partial \ln y}$ =1). Also, (Hartarska et al., 2013) used the same approach to find the optimal scale. In this paper, I followed the same approach to find the optimal size of SEC. It is important to note that the calculation of optimal scale holds the effect of network characteristics constant. Thus, I recommend for future research to develop an equation for optimal scale that takes into account the impact of network characteristics.

The results show that the optimal scale of output is 303404 Gigawatt hours. The optimal scale is about 3.5 times larger than the sample mean of 87941 Gigawatt hours. Also, the optimal scale is almost 1.7 times larger than the average output produced since SEC incorporation, 181100 Gigawatt hours. The largest output produced in the sample of study as shown in table 1 is 274502 Gigawatt hours, and it belongs to 2014. This largest level of output is still smaller than the long run optimal scale. The optimal scale is approximately 1.11 times larger than the output level produced in 2014.

2.6 Conclusion

The paper has examined Saudi electricity sector's productivity using a translog cost function approach. The results show that the technology employed in the Saudi electricity sector is a cost saving technology. In relative terms, the technology is fuel using, energy saving, and capital neutral. The incorporation of SEC results in cost reduction of power generation. Also, the average cost curve in the Saudi electricity sector is characterized as an asymmetric U-shaped average cost curve. The results also show the presence of economies of output density and economies of customer density. However, the industry operates under the presence of diseconomies of scale. The paper has proposed an extension to the current method of TFP growth decomposition. The proposed method extends the original method by incorporating the network characteristics in the decomposition of TFP growth. The estimated technical change is positive and less than one, indicating a cost increase during the average sample of study. Also, the estimated average TFP growth is positive using both the original method in the literature and the proposed method. However, the proposed method shows that the original method used in the literature generally overestimates TFP growth of the Saudi sector. From 2009—2011, the original method estimated a positive TFP growth while the proposed method estimated a negative TFP growth.

The results show that the own price elasticity of fuel and purchased energy is negative inelastic and negative elastic for capital. The cross price elasticities show that fuel and energy are complementary, fuel and capital are substitutes with elastic cross price elasticities, and fuel and labor are substitute with inelastic cross price elasticity.

The paper estimates the optimal scale of output to be 303404 Gigawatt hours, which is almost 11 percent larger than the maximum output level produced by the company in 2014. Thus, the paper concluded that SEC operates less than the optimal size and it needs to expand its output to reach the optimal scale.

Chapter 3

The Impact of Financing on Economic Growth in Saudi Arabia

3.1 Introduction

Finance in Saudi Arabia is mainly provided by commercial banks and governmental funds. Commercial banks provide credit to public sectors, semi-private sectors, and various private sectors such as agriculture, mining, energy, and services sectors. In addition, they provide credit cards and credit facilities to consumers for a variety of purposes such as health care, education, real estate, merchandise, social, and consumption. On the other hand, governmental funds consist of the Saudi Agricultural Development Fund, Saudi Credit and Saving Bank, Public Investment Fund, Saudi Industrial Development Fund, and Saudi Real Estate Development Fund. The objective of these governmental funds is to promote economic prosperity and spur economic development. The credit granted by these funds aims at the micro (individual) level to support low income citizens, increase the standard of living, and support entrepreneurship. Furthermore, at the macro (sectoral) level it aims at supporting projects that are consistent with the country's development policy and objectives. Figure 3.1 shows the share of commercial banks credit to total credit. Also, the figure shows the share of governmental funds credit to the total credit in Saudi Arabia from 2010 to 2014. The share of commercial banks credit provided to private sectors, semi-private sectors, and governmental sectors in Saudi Arabia represents over 75% of the total credit in Saudi Arabia. This is followed by credit provided by commercial banks to consumers, which represents almost 20% of the total credit. Governmental funds credit ranged from 3% to 4%. Credit card facilities did not exceed 1% of the total credit. Thus, it is obvious that credit given to private sectors, semi-private sectors, and government sectors dominate credit market activities in Saudi Arabia. Total commercial bank facilities, combining consumer loans, credit cards, private sector credit, semi-private sector credit, and public sector credit, represent almost 96% of the total credit market share in Saudi Arabia.

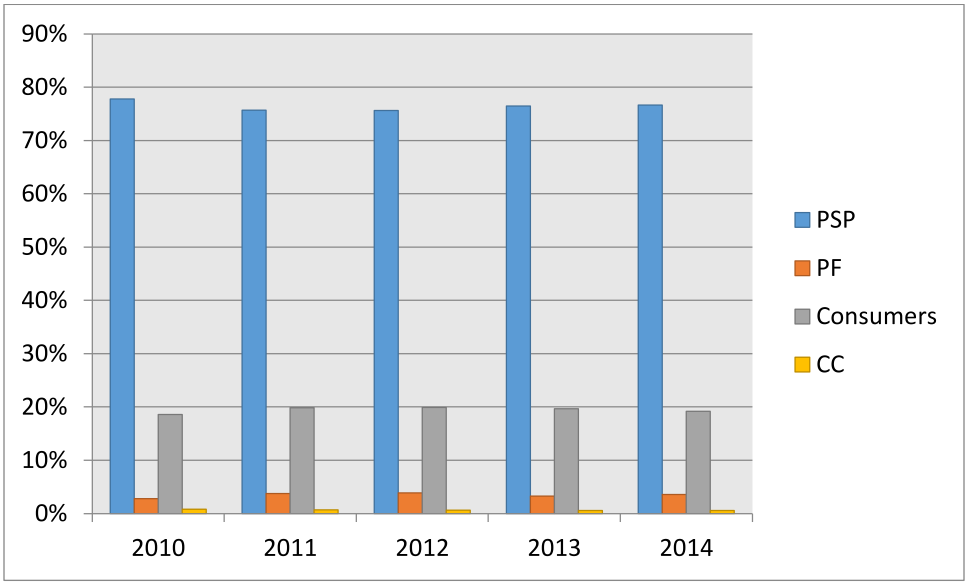

Figure 3.1 Credit Market Share in Saudi Arabia
Note. PSP= credit given by commercial banks to private sector, semi-private sector, and public sector, PF= credit given by governmental funds, Consumers= loans provided by commercial banks to consumers, CC= credit card facilities.

The purpose of this paper is to investigate the impact of overall financing, combining sectoral and individual credit, on economic growth in Saudi Arabia. To my knowledge, this is the first study that evaluates the impact of the overall financing facilities on economic growth in Saudi Arabia. Also, the paper aims to examine the causality between financing and economic growth in Saudi Arabia.

3.2 Literature Review

There are many studies that investigate the relationship between financial development and economic growth. These studies included finance in their analysis as a proxy of financial development. However, studies that investigate the impact of credit on economic growth are few in the economic literature.

(Choong, 2012) found that credit has a positive and significant effect on the per capita GDP growth rate in a panel of 95 developed and developing countries. Önder and Özyıldırım (2013) found that the per capita provincial credit provided by commercial banks in Turkey has a positive and significant effect on local economic growth. Also, they indicated that the state owned banks played a positive role in promoting economic growth. Gozgor and Gozgor (2013) examine the relationship between domestic credit and economic growth as proxied by per capita GDP in twenty Latin American countries. The panel cointegration test showed that there is a long run relationship between domestic credit and per capita GDP in Latin American countries. Also, the direction of causality is from domestic credit to GDP per capita. Uddin, Sjo, and Shahbaz (2013) evaluate the relationship between financial development and economic growth in Kenya using time series data from 1971 to 2011. The authors used domestic credit provided by the banking sector as a percent of GDP, domestic credit to private sector as a percent of GDP, and the ratio of money plus quasi money (M2) to money (M1) as proxies for financial development. These variables were then used to construct a financial development index using principle component analysis. The authors used Cobb-Douglas production function to estimate the relationship between the log of real GDP per capita as the dependent variable and the logs of financial development, real interest rate, labor force, and capital as the independent variables. The authors estimated their model using error correction model (ECM). In the long run, the authors indicated that a one percent increase in financial development increases economic growth by 0.039 percent. Ben, Boujelbène, and Helali (2014) study the impact of financial development on economic growth, using three indicators of financial development: domestic credit, value traded ratio, and issuing banks securities on the financial markets. All these three indicators were divided by GDP. The authors estimated their model using the Autoregressive Distributed Lag model (ADRL). Their results showed that private credit has a positive and significant effect on economic growth in the long run. Their results suggest that a one percent increase in credit increases real GDP per capita by 3.36 percent. Also, they found a bidirectional relationship between GDP per capita and private credit, and they concluded that economic growth and financial development can complement each other. Thus, the supply-leading and the demand-following hypothesis are supported between economic growth and credit in Tunisia. Anyanwu (2014) found an insignificant negative effect of private sector credit on economic growth in a sample of north and sub-Saharan African countries. Yakubu and Affoi (2014) using a simple OLS regression showed that commercial banks credit in Nigeria has a positive effect on GDP. Nwakanma, Nnamdi, and Omojefe (2014) found a long run relationship between the microfinance credit program and economic growth in Nigeria. Also, the causality runs from economic growth to microfinance credit program. Hartarska, Nadolnyak, and Shen (2015) obtain a positive relationship between agricultural credit and GDP growth per rural residents. Pistoresi and Venturelli (2015) indicate that total credit and commercial banks credit, both as a ratio of GDP, positively and significantly affected the per capita GDP growth rate in a panel of 53 regions belonging to Germany, Italy, and Spain. Korkmaz (2015) conclude that banking sector credit affected economic growth in a sample of ten European countries. Kandil, Shahbaz, and Nasreen (2015) examine the impact of globalization on financial development on a sample of 32 developed and developing countries, including Saudi Arabia. The authors concluded that financial development has a positive impact on economic growth, and economic growth spurs financial development. Thus, financial development and economic growth have a complementary relationship. Ananzeh (2016) examine the relationship between bank credit and economic growth in Jordan. The author used real GDP as the dependent variable. Total bank credit to all sectors, bank credit to agricultural sector, bank credit to industrial sector, bank credit to construction sector, and bank credit to tourism sector were used as the independent variables. The author found evidence of long run relationship between the dependent variable and the independent variables. Also, the causality runs from economic growth to credit provided to the agricultural sector. Moreover, the study showed a bidirectional causality between economic growth and credit given to the construction sector.

Al-Zubi, Al-Rjoub, and Abu-Mhareb (2006) examine the relationship between financial development and economic growth in a panel of eleven Arab countries. The sample consists of Algeria, Bahrain, Egypt, Jordan, Kuwait, Morocco, Oman, Saudi Arabia, Sudan, Syria, and Tunisia. The authors found that the ratio of private credit to total domestic credit is insignificant with respect to per capita GDP using the pooled OLS model, random effect model, and fixed effect model. The ratio of private credit to GDP is found to be negative and significant at the one percent level using pooled OLS, as well as at the ten percent level using random effect model. The author showed that credit given to public sectors as a share of domestic credit is positive and significant at the five percent level with respect to the growth rate of per capita GDP using pooled OLS and the fixed effect model. The authors attributed these results to the provision of credit to the public sector and the dominance of public sector on economic activities in the selected Arab countries. Mahran (2012) used the ARDL model to examine the relationship between financial development and real GDP in Saudi Arabia. However, the author found a negative and significant effect of private credit on real GDP. This result was present both in the short run and in the long run. The author attributed this result to the high dependence of the Saudi economy on the oil sector, as well as to the dominant role played by the government in promoting economic growth. According to the author, this did not give the opportunity to the private sector to play an effective role in promoting economic growth. Ageli and Zaidan (2013) found that credit provided by government specialized banks and commercial banks to private sectors has a positive effect on GDP using vector error correction model (VECM). Grassa and Gazdar (2014) examine the impact of total finance, conventional finance, and Islamic finance on economic growth as proxied by the growth rate of real per capita GDP in Gulf Cooperation Council (GCC) countries, excluding Oman. The author found that total domestic credit to private sector as a percentage of GDP is not significant using OLS, Panel estimators (fixed effect and random effect), and GLS. Based on this result, the authors stated that the overall financial system is unimportant to economic growth in the GCC countries. Also, the authors found that conventional finance is insignificant using OLS. However, conventional finance is found to be negatively significant using the panel estimator and GLS. Thus, the authors concluded that conventional finance has a harmful effect on economic growth in the GCC countries. Moreover, Islamic finance is found to have a positive effect on economic growth in the GCC region using OLS, panel estimator, and GLS. In fact, the author found that a one point increase in Islamic finance increases economic growth by 0.05 percentage points. Al-Malki and Al-Assaf (2014) estimate the impact of financial development, which includes credit provided by a banking sector to a private sector as a percentage of GDP, on the real per capital GDP using the ARDL model. They found that private credit has a positive and significant impact on economic growth at the five percent level. A one percent increase in private credit is associated with a 0.44 percent increase in the real GDP per capita. Samargandi, Fidrmuc, and Ghosh (2014) examine the impact of financial development on real GDP per capita of non-oil sector, GDP per capita of oil sector, and total GDP per capita in Saudi Arabia using the ARDL approach. The authors found that financial development has a positive and significant effect on the non-oil sector. However, financial development is found either insignificant or negatively significant with respect to oil and the overall GDP.

This paper aims to fill the gap in economic literature by analyzing the impact of the overall financing activities on economic growth in Saudi Arabia. To my knowledge, there is no study that evaluates the overall effect of credit on economic growth in Saudi Arabia, combining both credit provided at the consumers level and credit provided at the sectoral level.

3.3 Model

In this paper, I will follow Uddin et al. (2013) approach by using a Cobb-Douglas production function and assuming real interest rate and financing activities as determinants of total factor productivity as below:

$$y_t = \Omega l_t^{\beta} k_t^{\phi} \quad (1)$$

Where Ω is a residual withholding the impact of real interest rate and finance. $y_t, l_t, and\ k_t$ denote real GDP per capita, labor force, and capital, respectively. $\beta\ and\ \phi$ denote the variables' partial elasticities.

We can setup the above equation in an estimable form by utilizing the logarithm as below:

$$ly_t = a_0 + \beta_1 lf_t + \beta_2 lr_t + \beta_3 ll_t + \beta_4 lk_t + u_t \quad (2)$$

Where $f_t\ and\ r_t$ stand for finance and real interest rate, respectively.

3.4 Data

The data for this paper comes mainly from the Saudi Arabian Monetary Agency (SAMA). The real per capita GDP comes from the World Bank, world development indicator. Table 3.1 shows descriptive statistics of the key variables.

Table 3.1 Descriptive Statistics of the Key Variables

Variable	N	Mean	St Deviation	Minimum	Maximum
GDP per capita	45	90705.37	54680.10	54916.68	241375.96
Real interest rate	45	9.025	6.853	0.916	29.76
Public labor force	45	560696.82	301736.25	117278.00	1240748.00
Capital	45	0.204	0.043	0.088	0.300

The total number of observations used in this study are 45 observations from 1970 to 2014. The variables listed in table 3.1 are real GDP per capita in Saudi Riyal, real interest rate, public labor force, and capital. Public labor force has been used instead of total labor force due to the unavailability of adequate statistics for total labor force. Also, due to the unavailability of lending interest rate, I used deposit interest rate. There were some missing observations for the nominal interest rate that were recovered using a linear trend method following Coelli, Rahman, and Thirtle, (2003). Capital is the share of gross fixed capital formation to GDP.

3.5 Financing Index

There are various sources of finance in Saudi Arabia that differ by the end user. Estimating the impact of those funding sources using equation (2) separately will result in multicollinearity and endogeneity issues. On the other hand, aggregating them in one variable may obscure the true relationship of those sources of funding on economic growth. This is due to the fact that this aggregation overlocks the weight of each funding source on the total aggregated variable. Thus, it is important to derive a comprehensive financing activity index that takes into account commercial banks loans to consumers, private sectors, semi-private sectors, government sectors, and credit card facilities. Also, the index includes total governmental funds financing. Therefore, the financing index will capture the overall financing activities in Saudi Arabia, both at the micro level (individual level) and at the macro level (sectoral level). Consequently, the effect of the overall financing activities in Saudi Arabia on economic growth can be better examined.

I used the principal component analysis to construct the financing index following Uddin et al. (2013), Samargandi et al. (2014), and Samargandi, Fidrmuc, and Ghosh (2015). The variables I used in constructing the financing index are the overall credit provided by commercial banks to public sectors, private sectors, and semi-private sectors as a percentage of GDP. Total credit provided by governmental funds as a percentage of GDP, the share of total consumer loans provided by commercial banks to GDP, and the share of credit card facilities to GDP. The results of the principal component analysis is shown in Table 3.2. I selected the first principal component for the construction of the financing index since it has the largest eigenvalue and it accounts for 81.3% of the standardized variance. Additionally, the first component is a liner combination of the mentioned financing activities with weight given by the eigenvectors.

Table 3.2 Principal Component Analysis

Component	Eigenvalue	Difference	Proportion	Cumulative	Eigenvectors	PC 1
PC 1	3.256	2.621	0.813	0.813	CBC	0.535
PC 2	0.631	0.557	0.158	0.971	GFC	0.427
PC 3	0.075	0.034	0.019	0.990	ConC	0.516
PC 4	0.041		0.010	1.0000	CC	0.516

Note. CBC=commercial bank credit, GFC= governmental funds credit, ConC= consumer loans, CC= credit cards.

Figure 3.2 plots the derived financing index. As shown in the figure, the index ranged in value from 0.015 to 0.311 with a tendency to increase over time. A quick look at the graph shows that the financing index is sensitive to global and local political and economic events. In 1990, the index dropped from 0.12 to 0.08 in response to the Gulf War. The index decreased in 1999 and 2000 in response to the decline in oil prices. The index seems to be slightly affected by the 2006 stock market crash. Also, the index plunged in 2011 due to the Arab spring.

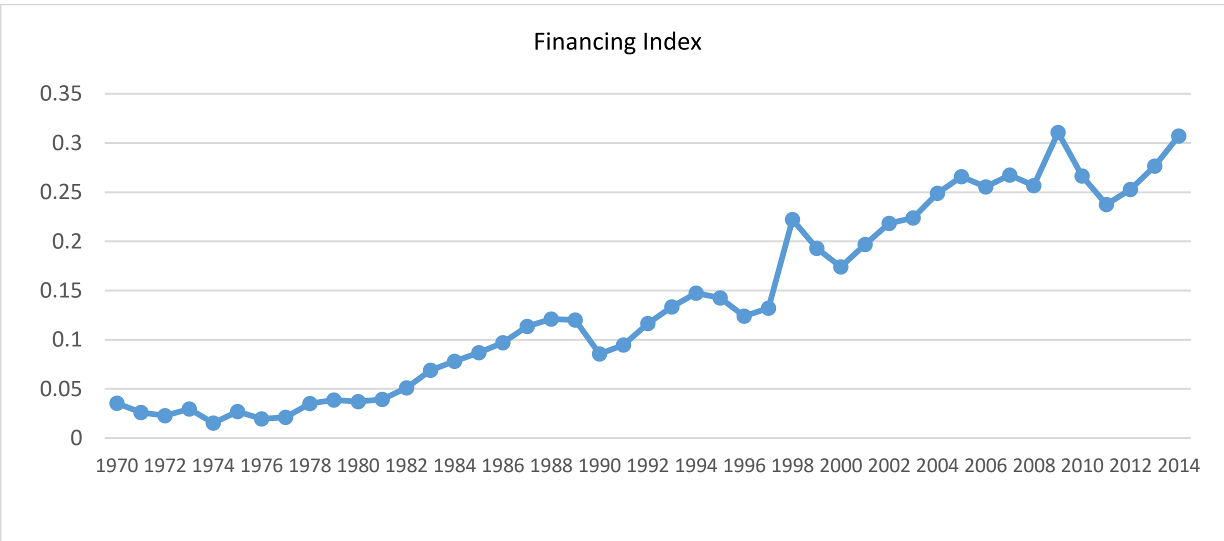

Figure 3.2 Financing Index in Saudi Arabia

3.6 Estimation Procedures and Results

It is well known in time series litrature that running regression on a nonstationary data results in spurios regression Brooks (2014).Thus, the first step in the analysis is to conduct a unit root test. The results of the augmented Dickey Filler test as reported in table 3.A1 in Appendix A show that all the variables are stationery at the first difference. Since all the variables are integrated of order 1, the long run relationship of the series can be examined using Johnson cointegration techniques. As indicated by Gökçe and Çankal (2013) the first step of the Johnson cointegratin is the determination of the optimal lag length.

The optimal lag length, as indicated by Akaike Information Criterion (AIC), is 3. The results of Johnson cointegration test, using both the trace statistcs and the maximum eigenvalue test in table 3.A2 and 3.A3 in Appendix A, rejected the null hypothesis of no cointegration at the five percent significance level. This confirms the existance of a long run relationship among the variables of interest in this paper. If the results of the trace and maximum eigenvalue test differ, it is recommended to rely on maximum eigenvalue test in case of a small sample as indicated by Mukhtar and Rasheed (2010). In this paper, I relied on the maximim eigenvalue test, which indicates one cointigrating vector. The final step is to estimate the vector error correction model (VECM).The VECM can be expressed as:

$$\Delta ly_t = \beta_0 + \varphi_1 \Delta ly_{t-1} + \varphi_2 \Delta lf_{t-1} + \varphi_3 \Delta lr_{t-1} + \varphi_4 \Delta ll_{t-1} + \varphi_5 \Delta lk_{t-1} + \delta_1 ly_{t-1} + \delta_2 lf_{t-1} + \delta_3 lr_{t-1} + \delta_4 ll_{t-1} + \delta_5 lk_{t-1} + \varepsilon_t \quad (3)$$

The long run elasticities can be calculated as $-(\delta_i/\delta_1)$. For example, the financing elasticity with respect to real GDP per capita is calculated as $-(\delta_2/\delta_1)$.

Table 3.A4 in Appendix A reports parameter estimates and model diagnosis as well. The results of the diagnosis check indicate no evidence of autocorelation and the residuals of the financing index are normaly distrubited. The residuals of the other variables are off normal. However, all the variables are homoscedastic. The estimated cointegration vector, long run parameter (β), is:

$$ly_t = 13.55 + 0.30\, lf_t - 0.25\, lr_t - 1.29\, ll_t - 0.10\, lk_t \quad (4)$$

To ensure that the estimated cointegration vector (4) is significantly different from zero, I imposed restrictions on the cointegration vector. These restrictions test if the estimated long run elasticities are significantly different from zero. The results of the test as shown in Table 3.3 confirm that all the estimated long run elasticities are significantly different from zero at the one percent level, except the elasticity of capital. The test indicates that the elasticity of capital is not significantly different form zero.

Table 3.3 Likelihood Ratio Test on the Long Run Coefficient (β)

Restrictions	Chi-Square	p
$lf = 0$	51.54	<.0001***
$lr = 0$	56.91	<.0001***
$ll = 0$	49.73	<.0001***
$lk = 0$	1.71	0.7883

*** = significant at the one percent level.

The estimated long run elasticity of financing with respect to real GDP per capita is positive. It indicates a one percent increase in credit increases real GDP per capita growth by 0.30 percent. Conversely, interest rate has a negative influence on economic growth in the long run. The negative effect of interest rate on the Saudi Arabia's GDP is consistent with Algahtani (2015) findings. Public labor force has the largest negative impact on economic growth. This can be attributed mainly to the low labor productivity in the public sector. In the short run, capital has a positive effect on economic growth, and financing has a negative effect on economic growth. The negative effect of financing in the short run indicates that most of the short run loans are used for consumption purposes. Thus, they are not invested in productive projects. Furthermore, public labor force and interest rate do not have an effect on economic growth in the short run.

SAMA reported two statistics for fixed capital formation. The value of capital used in estimating equation (4) is fixed capital formation statistics that do not include changes in inventory. To further investigate the impact of capital on economic growth, I re-estimate the model using the second statistics for fixed capital formation that includes changes in inventory. The estimated long run parameter (β) is:

$$ly_t = 2.74 + 0.20\, lf_t - 0.10\, lr_t - 1.08\, ll_t + 0.59\, lk_t \quad (5)$$

Furthermore, the results of the likelihood test (available on request) indicates that all elasticities, including capital, are significantly different from zero. Thus, a one percent increase in capital increases economic growth by 0.59 percent.

Lastly, I conduct Granger causality test between finance and economic growth as proxied by real GDP per capita. The null hypothesis of the first Granger-Causality test is that economic growth is influenced by itself, and not by financing. Based on the result of Wald test in table 3.4, I reject the null hypothesis at the one percent significance level. Thus, economic growth is influenced by financing. Furthermore, the null hypothesis of the second test is that financing is influenced by itself, and not by economic growth. The Granger-Causality Wald test indicates that financing is not influenced by economic growth. Thus, I conclude that the supply-leading hypothesis hold for the case of Saudi Arabia. However, the results of the Wald test should be interpreted with caution because it is sensitive to different specifications.

Table 3.4 Granger-Causality Wald Test

Test	Chi-Square	p
Economic growth is not influenced by financing	15.04	0.0018***
Financing is not influenced by economic growth	4.77	0.1897

*** = significant at the one percent level.

3.7 Robustness Check

The purpose of this section is to test the robustness of the results obtained in the previous section. Particularly, this section aims to test how sensitive is the relationship between financing and real GDP per capita to different specifications. The first robustness check is to keep the same variables, but to use different specifications for the VECM. As shown in table 3.5 using different specifications, 1– 3, for the VECM model did not affect the positive impact of financing on economic growth. In scenario 4, I added oil price to the model as represented by Brent since Saudi Arabia's economy relies on oil revenue. The result of the financing variable is still insensitive to the addition of oil prices. Scenario 4 indicates that increases in oil prices have a positive impact on economic growth. In scenario 5, I added a dummy variable to control for the effect of different kings who ruled Saudi Arabia. The results showed that changes in kings have contributed positively in real GDP per capita growth. The final specification is to add both oil prices and the king dummy as shown in scenario 6. The results also confirm the robustness of the earlier findings of this paper that financing has a positive effect on economic growth. Furthermore, I reran the robustness check, 1–6, by using the value of fixed capital formation that includes changes in inventory. The results I obtained (available on request) confirms the insensitivity of the positive influence of financing on economic growth. Moreover, the results showed that capital has a positive influence on economic growth and the positive effect of oil prices on economic growth was sensitive to different specifications.

Table 3.5 Robustness Check of the Long Run Parameter (β)

Variable	1	2	3	4	5	6
lf	0.307	0.200	0.206	0.123	0.447	0.284
lr	-0.256	-0.193	-0.200	-0.215	-0.250	-0.128
ll	-1.299	-1.237	-1.240	-1.400	-1.556	-1.698
lk	-0.095	-0.076	-0.077	-1.026	-0.164	-1.209
Brent	–	–	–	0.382	–	0.414
King	–	–	–	–	0.067	0.172

Note. 1= No separate drift, but a constant enters via the error correction term, 2= there is a separate drift and a linear trend enters via the error correction term, 3= Separate linear trend, 4= adding oil price, 5= adding president dummy, and 6=adding both oil price and president dummy.

3.8 Conclusion

This paper showed that financing activities in Saudi Arabia is dominated by commercial banks. Public funds credit represents a small share of the overall credit market in Saudi Arabia. The paper derived a financing index that was a composite of public funds credit and credit facilities provided by commercial banks. The index was developed using the principle component analysis. The derived index reacted to economic and political events such as the Gulf War and the Arab Spring. The Johnson cointegration approach confirmed the existence of long run relationship between real GDP per capita, financing, real interest rate, public labor force, and capital. The long run parameter (β) estimated using the VECM showed that financing has a positive effect on economic growth. On the other hand, real interest rate and public labor force negatively affected economic growth in the long run. Public labor force had the largest negative influence on economic growth. Conversely, Capital has a positive effect on economic growth in the long run. Moreover, the paper showed that short run loans are directed toward consumption and not invested in productive projects. To confirm the robustness of the results, I conducted various robustness checks using different specifications for the VECM. Also, I added oil prices and a dummy variable representing different kings who ruled Saudi Arabia during the timeframe of this study. The positive influence of financing on economic growth was shown to be robust with respect to different specifications. Furthermore, increases in oil prices and changes in kings had a positive effect on real GDP per capita growth. Moreover, the results of Granger-Causality Wald test showed that economic growth is influenced by financing.

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Appendix A
Supplementary Tables

Table 1.A1 Nitrogen Fertilizer Companies in the GCC

Company's Name	Owners	Plant Location
Saudi Arabian Fertilizer Company (SAFCO)*	SABIC 42.99%, General Organization for Social Insurance 15.4%, Public Pension Agency 15.4%, and public shareholders 41.61%. Established 1965	Saudi Arabia
National Chemical Fertilizer Company (Ibn Al-baytar)	50/50 SABIC with SAFCO established in 1985	Saudi Arabia
Al-Jubail Fertilizer Company (Al-Bayroni)	50/50 SABIC with Taiwan Fertilizer Company formed 1979	Saudi Arabia
Qatar Fertilizer Company (QAFCO)*	75% Industries Qatar and Yara International 25%. Established in 1969	Qatar
Ruwais Fertilizer Company (FERTIL)	Shareholding ration of 2:1 between Abu Dhabi National Oil Company (ADNOC) and TOTAL. Established in 1980	United Arab Emirates (UAE)
Oman India Fertilizer Company (OMIFCO)	50% by Oman Oil Company SAOC (OOC), 25% by Indian Farmers Fertilizer Cooperative Limited (IFFCO) & 25% by Krishak Bharati Cooperative Limited (KRIBHCO).Founded in 2003	Oman
Petrochemical Industries Company (PIC)*	Kuwait Petroleum Corporation. Completion of fertilizer plant was in 1966.	Kuwait
Gulf Petrochemical Industries Corporation (GPIC)*	Equally Owned by the government of Bahrain, SABIC, and PIC. Established in 1979.	Bahrain

*Firms with asterisks represent the sample of this paper

Table 3.A1 Augmented Dickey-Fuller unit root test (τ)

Variables	In level I (0)		First Difference I (1)	
	Intercept	Intercept and trend	Intercept	Intercept and trend
ly	-2.26	-1.02	-3.37***	-4.14**
lf	-0.74	-2.88	-8.92***	-8.83***
lr	-0.19	-1.30	-3.53**	-3.50**
ll	-1.42	-1.56	-4.66***	-5.04***
lk	-2.71	-2.72	-7.72***	-7.72***

*** and ** denote significance level at the one and five percent, respectively.
ly, lf, lr, ll, and lk = the logarithm of real GDP per capita, financing, real interest rate, public labor force, and capital.

Table 3.A2 Johnson cointegration test (Trace test results)

Number of relations	Eigenvalue	Trace statistics	p
$H_0: r = 0, H_1 r = 1$	0.7578	112.0637*	<.0001
$H_0: r \leq 1, H_1 r = 2$	0.4309	52.5063*	0.0170
$H_0: r \leq 2, H_1 r = 3$	0.3332	28.8284	0.0640

Note. Trace statistics indicates two cointegrating equations at the five percent significance level.
*Denotes the rejection of the null hypothesis at the five percent significance level based on (MacKinnon, Haug, & Michelis, 1999).

Table 3.A3 Johnson cointegration test (Maximum eigenvalue test results)

Number of relations	Eigenvalue	Max eigen statistics	p
$H_0: r = 0, H_1 r = 1$	0.7578	59.5574*	<.0001
$H_0: r \leq 1, H_1 r = 2$	0.4309	23.6779	0.1447

Note. Max eigenvalue test indicates one cointegrating equation at the five percent significance level.
*Denotes the rejection of the null hypothesis at the five percent significance level based on (MacKinnon, Haug, & Michelis, 1999).

Table 3.A4 Model parameter estimate and diagnoses

Variable	Estimate	Variable	Estimate	Variable	Normality		ARCH	
					Chi-Square	p	F-Value	p
C	13.556 (2.248)			ly	22.02	<.0001	0.03	0.8727
ly_{t-1}	-0.466 (0.077)	Δly_{t-1}	0.530 (0.131)	lf	3.71	0.1563	0.50	0.4849
lf_{t-1}	0.139 (0.023)	Δlf_{t-1}	-0.129 (0.051)	lr	12.79	0.0017	0.03	0.8666
lr_{t-1}	-0.118 (0.020)	Δlr_{t-1}	0.016 (0.033)	ll	184.17	<.0001	0.03	0.8669
ll_{t-1}	-0.599 (0.099)	Δll_{t-1}	-0.051 (0.194)	lk	11.52	0.0031	0.73	0.3986
lk_{t-1}	-0.048 (0.008)	Δlk_{t-1}	0.260 (0.066)					
Durbin Watson	2.01	R-square	0.73					

Note. Standard error in parenthesis.

Appendix B
Comparative Static Derivation

Let the firm's objective function be defined as:

$$\max(X)\ \pi = p_1q_1 + p_2q_2 - (g-s)X - wL - FC$$

Since both ammonia and urea depend on the same input in the production process, the above equation can be written as:

$$\pi = PQ(X,L) + sX - gX - wL - FC$$

By taking the derivatives of $\frac{\partial \pi}{\partial X}$ and $\frac{\partial \pi}{\partial L}$, and expressing them as implicit functions, we get:

$$F^1(X,L;g,s,w,P) = PQ_X(\bar{X},\bar{L}) - g + s = 0$$
$$F^2(X,L;g,s,w,P) = PQ_L(\bar{X},\bar{L}) - w = 0$$

From these first order conditions, we can determine the effect of a change in exogenous variables (g,s,w,P) on the optimal value of the endogenous variables $(\bar{X},\ \bar{L})$ by using comparative statics (Dowling, 2012) as follow:

$$\begin{bmatrix} PQ_{xx} & PQ_{xL} \\ PQ_{Lx} & PQ_{LL} \end{bmatrix} \begin{bmatrix} \frac{\partial \bar{X}}{\partial g} \\ \frac{\partial \bar{L}}{\partial g} \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

Micro theory states that a profit maximizing firm will only produce where the marginal productivity of inputs is declining. Thus, at the optimal level of production $Q_{xx} < 0\ and\ PQ_{LL} < 0$. Therefore, by using Cramer's rule we get the following:

$$\frac{\partial \bar{X}}{\partial g} = \frac{\begin{bmatrix} 1 & PQ_{xL} \\ 0 & PQ_{LL} \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{PQ_{LL}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} < 0 \qquad \text{(A)}$$

As mentioned in the theory section of the paper, if I assume the sign of Q_{Lx} and Q_{xL} to be positive.

$$\frac{\partial \bar{L}}{\partial g} = \frac{\begin{bmatrix} PQ_{xx} & 1 \\ PQ_{Lx} & 0 \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{-PQ_{Lx}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} < 0 \qquad \text{(B)}$$

$$\frac{\partial \bar{X}}{\partial w} = \frac{\begin{bmatrix} 0 & PQ_{xL} \\ 1 & PQ_{LL} \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{-PQ_{xL}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} < 0 \qquad \text{(C)}$$

$$\frac{\partial \bar{L}}{\partial w} = \frac{\begin{bmatrix} PQ_{xx} & 0 \\ PQ_{Lx} & 1 \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{PQ_{xx}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} < 0 \qquad \text{(D)}$$

$$\begin{bmatrix} PQ_{xx} & PQ_{xL} \\ PQ_{Lx} & PQ_{LL} \end{bmatrix} \begin{bmatrix} \frac{\partial \bar{X}}{\partial s} \\ \frac{\partial \bar{L}}{\partial s} \end{bmatrix} = \begin{bmatrix} -1 \\ 0 \end{bmatrix}$$

$$\frac{\partial \bar{X}}{\partial s} = \frac{\begin{bmatrix} -1 & PQ_{xL} \\ 0 & PQ_{LL} \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{-PQ_{LL}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} > 0 \qquad \text{(E)}$$

$$\frac{\partial \bar{L}}{\partial s} = \frac{\begin{bmatrix} PQ_{xx} & -1 \\ PQ_{Lx} & 0 \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{PQ_{Lx}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} > 0 \qquad \text{(F)}$$

$$\begin{bmatrix} PQ_{xx} & PQ_{xL} \\ PQ_{Lx} & PQ_{LL} \end{bmatrix} \begin{bmatrix} \frac{\partial \bar{X}}{\partial P} \\ \frac{\partial \bar{L}}{\partial P} \end{bmatrix} = \begin{bmatrix} -Q_x \\ -Q_L \end{bmatrix}$$

$$\frac{\partial \bar{X}}{\partial P} = \frac{\begin{bmatrix} -Q_x & PQ_{xL} \\ -Q_L & PQ_{LL} \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{P(-Q_xQ_{LL} + Q_LQ_{xL})}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{(Q_LQ_{xL} - Q_xQ_{LL})}{P(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} > 0 \qquad \text{(G)}$$

$$\frac{\partial \bar{L}}{\partial P} = \frac{\begin{bmatrix} PQ_{xx} & -Q_x \\ PQ_{Lx} & -Q_L \end{bmatrix}}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{P(-Q_LQ_{XX} + Q_XQ_{LX})}{P^2(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} = \frac{(Q_xQ_{LX} - Q_LQ_{XX})}{P(Q_{xx}Q_{LL} - Q_{Lx}Q_{xL})} > 0 \qquad \text{(H)}$$