ESSAYS ON OIL AND BUSINESS CYCLES IN SAUDI ARABIA

by

BANDAR A. ABA ALKHAIL

B.S., King Saud University, Riyadh, 1999
M.A., Washington State University, Pullman, 2003

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Economics
College of Arts and Sciences

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Manhattan, Kansas

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Abstract

This dissertation consists of three chapters. Chapter one presents a theoretical model using a dynamic stochastic general equilibrium (DSGE) approach to investigate the role of world oil prices in explaining the business cycle in Saudi Arabia. This model incorporates both productivity and oil revenue shocks. The results indicate that productivity shocks are relatively more important to business cycles than oil shocks. However, this model has some unfavorable features that are associated with both investment and labor hours.

The second chapter presents a modified theoretical model using DSGE approach to examine the role of world oil prices versus productivity shocks in explaining the business cycles in Saudi Arabia. To overcome the unfavorable features of the baseline model, the alternative model adds friction to the model by incorporating investment portfolio adjustment. Thus, the alternative model produces similar dynamics to that of the baseline model but the unfavorable characteristics are eliminated. Also, this chapter conducts sensitivity analysis.

The objective of the third chapter is to empirically investigate how real world oil price and productivity shocks affect output, consumption, investment, labor hours, and trade balance/output ratio for Saudi Arabia. This chapter complements the theoretical model of the previous chapters. In addition, this study builds a foundation for future studies in examining the impact of real world oil price shocks on the economies of key trade partners of Saudi Arabia.

The results of the third chapter show that productivity shocks matter more for macroeconomic fluctuations than oil shocks for the Saudis' primary trade partners. Therefore, fears of oil importing countries appear to be overstated.

As a whole, this research is important for the following reasons. First, the empirical model is consistent with the predictions of our theoretical model in that productivity is a driving

force of business cycles in Saudi Arabia. Second, the policymakers in Saudi Arabia should be more concerned with increasing productivity through adopting new technologies that increase economic prosperity. Therefore, the policymakers should continue diversifying economic resources and reduce their reliance on oil.

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Dedication

To my Country, Saudi Arabia

To my Family in Saudi Arabia

CHAPTER 1 - The Role of World Oil Price Shocks in Explaining Business Cycles in a Small Open Economy: The Case of Saudi Arabia

1.1. Introduction:

The Saudi Arabian economy has a unique position in the Middle East and world economies for multiple reasons. Saudi Arabia has more than one fourth of the world's known oil reserves, producing thirteen percent of the total world oil. The Saudi Arabian economy ranks as the sixth largest in Asia and contributes one-fifth of the total Gross Domestic Product (GDP) of the Middle East region (Ministry of Petroleum, SA).

In addition, Saudi Arabia, along with the rest of the world, is heavily engaged in international trade. A large portion of its trade transactions occur with developed countries. These transactions have been growing rapidly in scope and in number in recent decades. This implies that Saudi Arabia's economy may be more responsive to business cycles initiated in other countries. As an economy becomes more integrated with other world economies, a recession or booming cycle beginning in a developed country is often spread to developing countries. This is especially true for those countries with less of a variety of exports and those that depend greatly on a small range of raw materials.

Price shocks can impact a country's economy over several years. For example, the sudden sharp increase in world oil prices in 1979 as a result of the Iranian revolution had a positive effect on some oil exporting countries due to sharp price increases. However, later it carried such an adverse impact that by 1986, the world oil price had declined significantly, reaching eight dollars a barrel.

During the last few decades, oil prices have been quite volatile. Hence, to maintain economic stability, authorities of oil-exporting countries have attempted to implement policies that reduce their countries' exposure to world oil price swings that often result from price shocks associated with oil demand in other parts of the world, especially industrial countries that import large amounts of crude oil.

Saudi Arabia, through its relatively large production capacity and through its membership in the Organization of Petroleum Exporting Countries (OPEC), has a potentially vulnerable economy because world oil price fluctuations could be transferred to the Saudi economy. However, the quantitative features of this link have not been carefully explored. Therefore, the objective of this study is to investigate the role of world oil prices in explaining business cycles in Saudi Arabia. There are many studies which use the Dynamic Stochastic General Equilibrium approach (DSGE) to explain business cycles in different countries, including both developed and developing countries. A smaller part of the literature examines the role of world oil prices by explaining business cycles, such as the study by Schmidt and Zimmermann (2005). Thus, current literature does not use DSGE models to gauge the quantitative importance of oil shocks on the Saudi Arabian business cycle. This study intends to fill that gap.

To achieve this objective, I derive a DSGE model that allows for the world oil price and productivity shocks. Second, I calibrate the model to the Saudi Arabian economy. Next, I compare the moments from the theoretical model with both single and multiple shocks with that obtained from the actual data to see the extent to which business cycles in Saudi Arabia can be explained by total oil revenue shock. Then, I use an impulse response function to evaluate the role of world oil price shocks. Finally, I present implications of the findings and interpretations in accordance with economic theory.

The chapter is organized as follows: Section 1 contains an introduction on the subject and economic background. Section 2, presents a literature review of the relevant studies that utilize Dynamic Stochastic General Equilibrium models for different countries. Section 3 illustrates the detailed derivation of the theoretical model and the calibration of the DSGE model. Section 4 gives an outline of the data and sources. Section 5 documents the stylized facts of business cycles for Saudi Arabia. Section 6 displays impulse response functions and analyzes these results. Concluding remarks, policy recommendations, and limitations are given in Section 7.

1.2. Economic Background

Energy is important for global economies and their development. Reliance on a specific source of energy is often associated with the technology used and level of urbanization. The high world consumption of oil is due to both the economic and environmental advantages of crude oil as a source of energy given other current alternatives. In 1974, concerns for finding alternative sources for crude oil were strongly promoted by oil-importing countries as a result of a sudden sharp increase in oil prices. As a result, the International Energy Agency (IEA) was established to help production and consumption countries coordinate with each other. In addition, the IEA conducted comprehensive research in the efficient use of existing sources of energies. The IEA found that oil was the most utilized source of energy in the world. Table 1-1 reveals that over the last decade, the share of oil in the world energy market appears to be steady.

Thus, oil is likely to continue to be important for both oil-importing countries who use oil in producing final goods, and for oil-exporting countries who use oil income to finance import purchases.

Table 1.1 World Consumption of Energy by Category.

Year	Oil	Natural Gas	Nuclear	Coal	Hydroelectricity	World Total
1995	38.0%	22.6%	6.1%	26.6%	6.7%	100.0%
1996	37.7%	23.0%	6.2%	26.6%	6.5%	100.0%
1997	38.4%	22.7%	6.1%	26.2%	6.6%	100.0%
1998	38.5%	23.1%	6.2%	25.6%	6.7%	100.0%
1999	38.7%	23.2%	6.3%	25.1%	6.7%	100.0%
2000	38.1%	23.6%	6.3%	25.4%	6.6%	100.0%
2001	38.0%	23.7%	6.4%	25.5%	6.4%	100.0%
2002	37.7%	24.0%	6.4%	25.5%	6.4%	100.0%
2003	37.2%	23.8%	6.1%	26.7%	6.2%	100.0%
2004	36.9%	23.6%	6.1%	27.2%	6.3%	100.0%
2005	36.4%	23.5%	6.0%	27.8%	6.3%	100.0%

Source: BP statistical Review of world oil industry.

1.2.1 The story of oil in Saudi Arabia

In 1923, Saudi Arabian oil was discovered. [1] The first search was done on the eastern side of the country by a British company known as Eastern and General Syndicates. However, this company discontinued its oil exploration in 1928 as they could not find oil. In 1932, King Fisal bin Abdulaziz, the king of Saudi Arabia, could not arrive at an agreement with British companies searching for oil in eastern Saudi Arabia as they doubted the existence of oil. However in 1933, the king signed a contract with Standard Oil of California, an American company. This contract gave the company an oil concession for sixty years and allowed them to begin exploring for oil on the eastern side of the country. Two months later, the company changed its name to California Arabian Standard Oil Company (CASOC). The first oil well was drilled in 1935 in the field of Damamm and was named Oil Well One.

[1] Information in this subsection is obtained from the Discovery of Oil in Saudi Arabia (2002), the Saudi Arabian Economy (1994), and ARAMCO (2006).

One year later, CASOC, in cooperation with a company known as Texas Oil, made an amendment to their oil concession in Saudi Arabia, extending it to 66 years. Saudi Arabia began exporting oil to international markets in 1938. CASOC Oil Company was renamed again in 1944 to become Arabian American Oil Company (ARAMCO). By 1948, four American oil companies obtained shares in ARAMCO. The splits were 30%, 30%, 30%, and 10% for Texas Oil Company, Standard Oil of California, Standard Oil of New Jersey, and Socony Vacuum, respectively (ARAMCO 2006). In 1968, the government of Saudi Arabia started to negotiate with ARAMCO to have some share in the company. By 1973, the Saudi government owned 25% of the oil concession. This share increased to 60% in 1974. The Saudi government has had full ownership of ARAMCO since 1980.

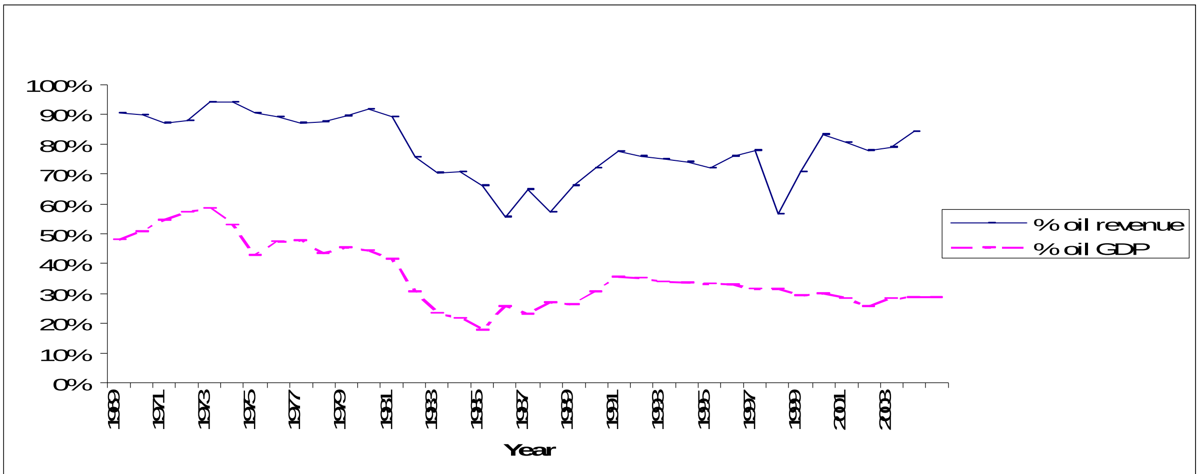
1.2.2 The importance of the oil sector in Saudi Arabia

The social and economic improvement of life for the Saudi people is associated with the discovery of oil. Prior to this discovery, the majority of the Saudi people lived in semi-desert territories. As oil became increasingly important to the economy, which is typically associated with increases in the standard of living, the people gradually began to move into urban areas.

Empirical evidence supports the significant role of oil in the economic development of Saudi Arabia. High government oil revenue helps in financing the building of infrastructure and development projects which often require large amounts of capital investment. As a result, economic growth in Saudi Arabia is affected by government oil revenue. In 1973, Oil Gross Domestic Product (oil-GDP) accounted for approximately sixty percent of the Real Gross Domestic Product of Saudi Arabia.

Figure 1-1 presents the share of oil-GDP in total GDP and share of oil revenue in total government revenue.[2] The dashed line shows that the percentage of oil-GDP decreased over the last three decades, although oil-GDP continues to contribute about thirty percent of the total GDP. The highest share of oil-GDP in total GDP occurred during the period of 1971 to 1973. Thereafter, the percentage of oil-GDP drastically declined. The share of oil-GDP reached 43 percent in 1975 compared to 51 percent in 1970. The lowest share of oil-GDP in total GDP was 18 percent in 1985. During the past five years, the percentage of oil-GDP in total GDP has never exceeded 29 percent. Since the 1970s, policymakers in Saudi Arabia have adopted comprehensive plans in order to achieve economic diversification (Ministry of Economic and planning, 2006). The decreased percentage in oil-GDP was a result of the efforts by policymakers in Saudi Arabia to diversify economic resources.

Figure 1.1 Share of Oil of Total Government Revenue and of GDP



Source: Saudi Arabian Monetary Agency for the percentage of oil revenue, annual report, 2005, the Ministry of Economics and planning for the percentage of oil-GDP.

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[2] I calculate the percentage as follows, for shares of oil revenue to total government revenue as $\frac{GOR}{TGR} \times 100$ where GOR is government oil revenue and TGR is total government revenue. Also, the share of oil GDP to Total GDP as $\frac{OGDP}{GDP} \times 100$ where OGDP is oil-GDP and GDP is Gross Domestic Product.

The Saudi economy's reliance on oil revenue enables policymakers to finance government expenditure on development projects. Hence, oil revenue largely contributed to fixed capital investments, especially during the 1970s. In addition, the solid line in Figure 1-1 reveals that the percentage of government oil revenues reached 94 percent of the total government revenue in 1974 in comparison with 89 percent in 1969. This increase in the percentage of oil revenue is attributed to the oil price increase of 1974. The percentage of government oil revenue has fluctuated over time, but it continues to be high and important to the level of the economy. However, the percentage of oil revenue in total government revenue dropped to 66 percent as a result of the increase in total government revenue from other sources. The percentage of government oil revenue declined, reaching fifty-six percent in 1998, due to low oil prices.

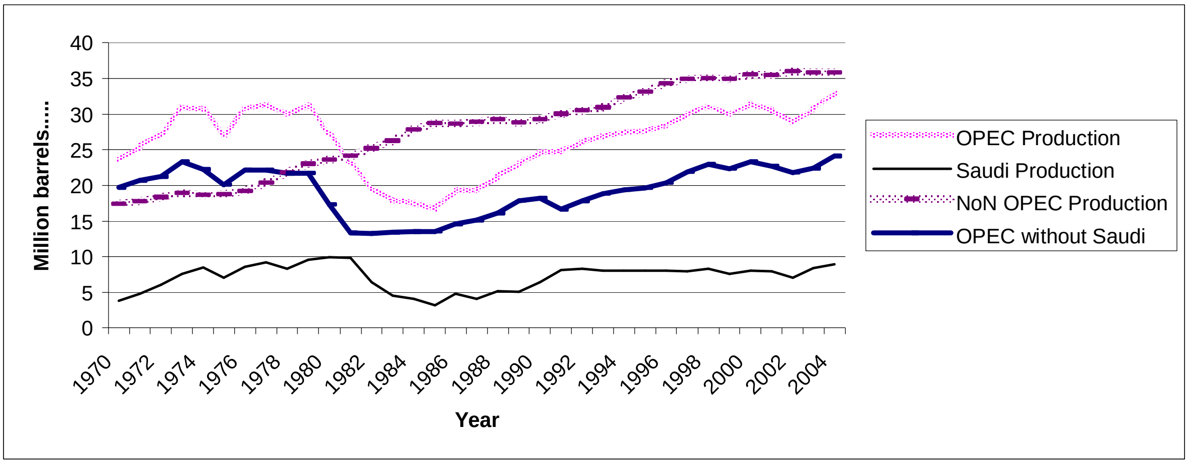
The definition of total revenue is $TR = P * Q$, where P represents the price, and Q is the quantity produced, From this equation, one can see that it is vital to closely investigate the world oil price and oil production for the country of Saudi Arabia as well as other producers in the international oil market.

1.2.3 World oil prices and Saudi's production

There is no doubt that Saudi Arabia is an important component of the international oil market in terms of its relatively large production capacity, enormous oil reserves and its distinct position in OPEC. However, given the enormity of the oil market and vast array of forecasting on price, it is nonetheless a reasonable approximation to assume that Saudi Arabia is a price taker in this market. When comparing the trends in OPEC with Saudi's production to OPEC without Saudi's production (Figure 1-2), I notice no significant disproportionate change in the trend. For example, oil production by OPEC and OPEC without Saudi production decreased in

1974. The decrease in OPEC production without Saudi's production was in greater proportion compared to the increase in oil production by Saudi. In addition, oil production declined in 1980 by 3.99 and 4.36 million barrels for OPEC with Saudi production and OPEC without Saudi production respectively, while oil production increased by 370 thousands and 580 thousands barrels for Saudi and non OPEC countries, respectively.

Figure 1.2 Oil Production by Producers

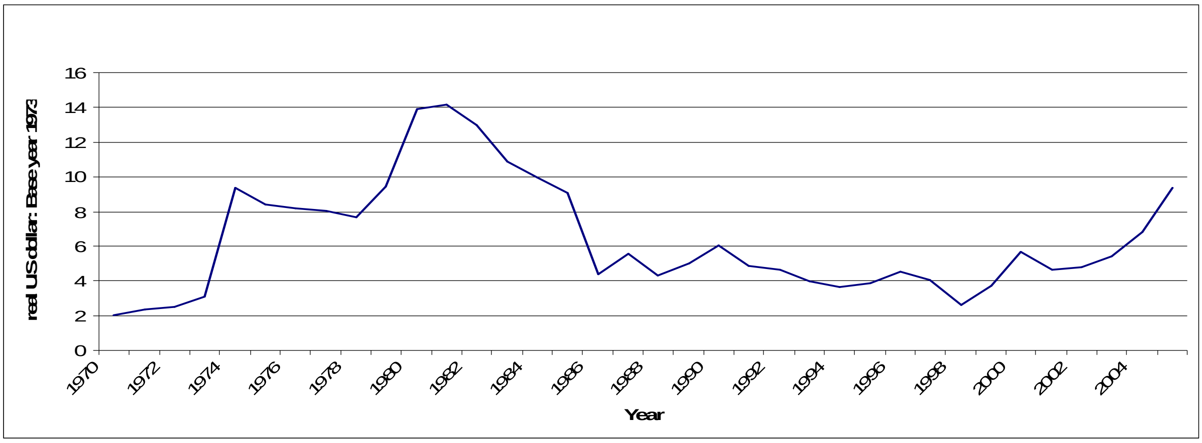


Source: BP statistical review of the world oil industry (2006).

Therefore, Saudi Arabia is a member of OPEC, but not the dominant factor in OPEC's oil quantity produced over time. The increase in Saudi's oil production did not have any significant impact in preventing the oil crisis of 1973-1974, yet prices peaked during this period (Figure 1-3). According to Alabeed and Ateeah (1994), the high price of oil in the 1970s was due to many reasons including the increase in world demand for oil due to industrial revolution and accelerating economic development, the fact that the United States became a major oil importer in 1970, and the increased use of crude oil as a raw material for many petrochemical products. Also, during 1979-1982, Saudi's production of oil was steady, while prices rose significantly due to the Iranian revolution. In addition, Alabeed and Ateeah (1994) indicate that low oil prices during the 1980s could be attributed to the increase in technological efficiency in the use of energy and the sluggish state of world economic activities, specifically in industrial countries.

The sharp decrease in oil prices in 1985 was attributed to a variety of factors, including an increase in production by non-OPEC producers, lower demands for energy, and the depreciation of the U.S. dollar (Alabeed and Ateeah 1994)**.**

Figure 1.3 Real World Oil Price



Source: Organization of Petroleum Exporting Countries OPEC (2005).

In 1988, Saudi production and world prices moved in the same direction. Since the second Gulf war, Saudi production has been steady while international prices have fluctuated and have recently shown a tremendous increase. In 2004, real oil prices (nominal prices were adjusted using the consumer price index for industrial countries and 1970 as the base year) increased by 25% to reach 6.8 dollars per barrel in comparison to about 5.44 dollars per barrel, the price from previous years. Real oil prices increased approximately 91% from its price in 1975 and 52.7% from its price in 1980, while the real price of oil increased about 74.5% from its price in 1975 and about 43.1% from its price in 1980. During the last couple of decades, real oil prices reached their highest record in 2004 and their lowest in 1998 (SAMA 2005).

According to the IEA, estimated world oil production increased by 4.2% in 2004 compared to 2003. The contribution to this increase in world oil production resulted from the increase in OPEC's production of 7.5%, while the production by members of Organization for Economic Co-operation and Development (OECD) and the United States decreased by 1.6% and 1.9% respectively. Also, production increased for non-OPEC producers, mainly the former Soviet Union countries, whose production increased by 8.4%. In addition, production increased by 2.4%, 3%, and 1.1% in China, Canada, and Mexico respectively.

The recent price jump is attributed to political instability in the Middle East and recent high economic growth in India and China. Therefore, I can argue that despite Saudi's big role in oil production, empirical evidence shows that its behavior as a major oil producer has an insignificant impact on oil prices.[3] Hence, oil prices can reasonably be modeled as exogenous to the Saudi economy. Also, the correlation between Saudi's oil production and world oil prices is positive, but if scaled is 0.16. As Barsky and Kilian (2004) point out, "it is commonly believed that there is a close link from political events in the Middle East to changes in the price of oil." According to Guo and Kliesen (2005) "A vast majority of the largest daily oil future price changes in our data are associated with exogenous events such as wars or political instability in the Middle East." The argument that the significant oil prices changes are largely driven by exogenous forces is also supported in a number of studies such as Hamilton (1983 and 1985). Schmidt and Zimmermann (2005) indicated that the Iranian revolution in 1979 -1980 was an exogenous force that led to a shock in world oil prices. In addition, the invasion of Iraq by the United States in 2003 was an "exogenous source" of the shock in market oil prices.

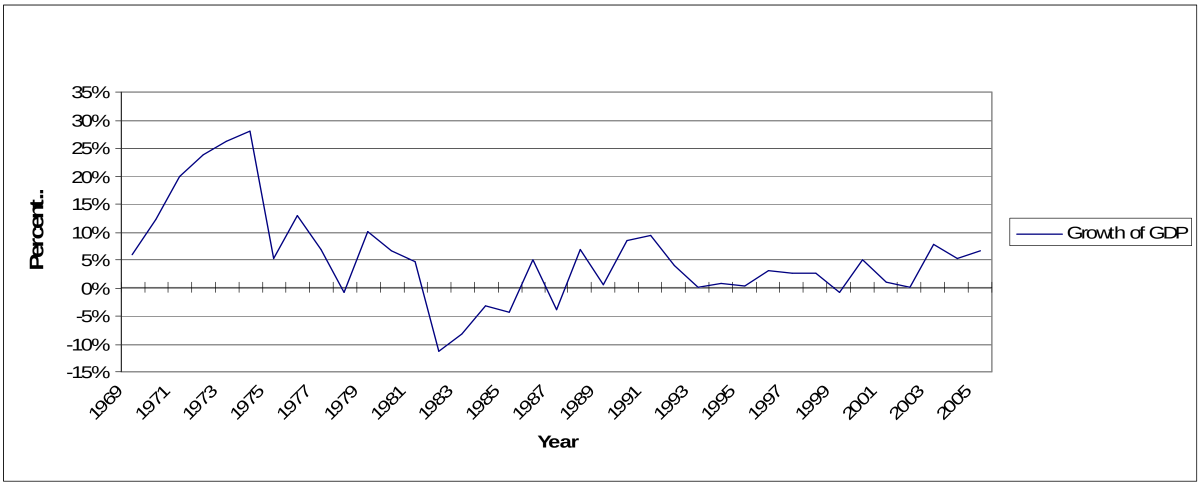
[3] This evidence is supported by econometrics tests, such as causality test, after choosing the appropriate lag length based on SIC and AIC criteria. Results related to this is presented in chapter three.

1.2.4 World oil prices and Saudi economic performance

Saudi policymakers achieved some success in increasing the degree of economic diversification in Saudi Arabia, yet the share of oil-GDP never went below 26% of its output over the last three decades. Given the fact that the economy of Saudi Arabia depends upon the export of oil and that world oil prices fluctuate over time, the rate of economic growth for the country is also expected to fluctuate.

Figure 1-4 reveals that during the 1969-1973 period, the Saudi Arabian economy grew at an accelerated rate. The high level of economic growth was due to the low level of economic development during that period. This period can be characterized as a period of high economic growth with an average annual growth rate of 18%. The second period, 1974-1982, is characterized as moderate economic growth, with an average annual growth of 5%. The period of 1983-1999 is characterized as a period of low growth, with an average annual increase of 1%. From 2000 to 2005, the Saudi economy grew an average of 4% annually.

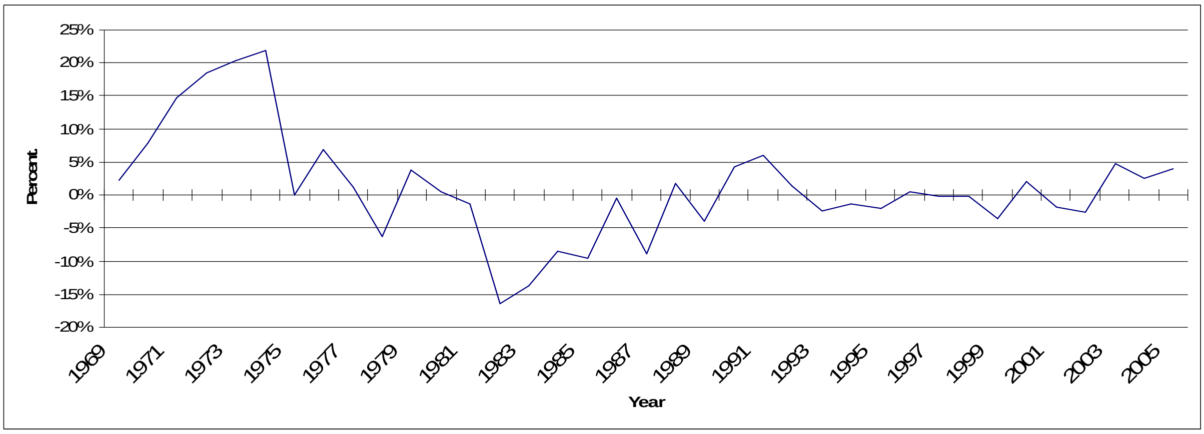
Figure 1.4 Percentage Growth of GDP



Source: Saudi Arabian Monetary Agency, SAMA (2006).

Figure 1-5 shows that the growth rate of per capita GDP fluctuated during the 1970s and continues to show no trend afterwards.

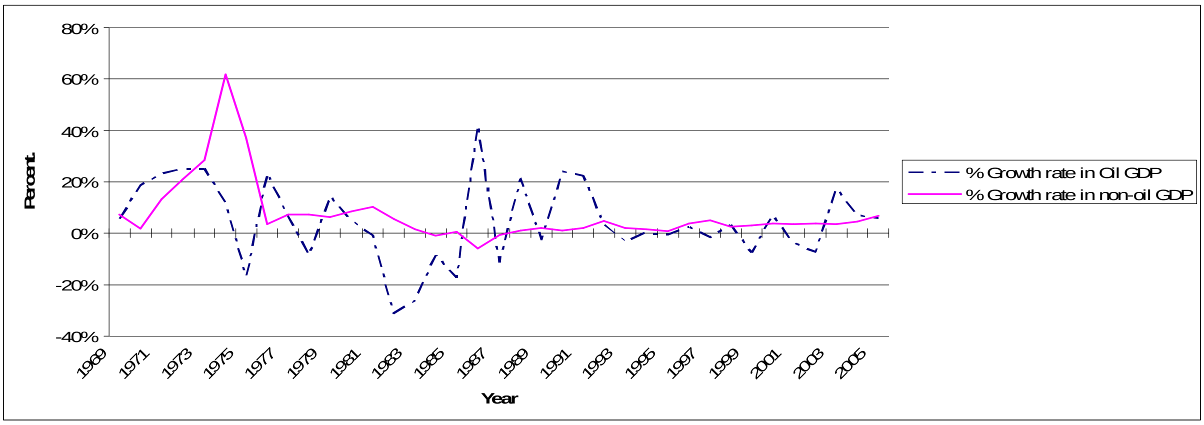
Figure 1.5 Real Per Captia Growth Rate of GDP



Source: GDP obtained from SAMA, and population data obtained from International Financial Statistics (IFS), 2006.

Figure 1-6 provides insights on the decomposition of oil-GDP and non-oil-GDP over the past three decades. The growth of oil-GDP shows more volatility relative to the growth of non-oil-GDP and the movements are rarely parallel to each other. This does not support the existence of capital interaction between the oil-GDP sector and non-oil-GDP. In addition, the high growth in total GDP in 1970 is accounted for in large part by non-oil-GDP. Thus, the high growth rate in the 1970s could be attributed to what is known as transitional growth in the non-oil sector. From empirical evidence of economic growth in Saudi Arabia, I argue that the Saudi Arabian economy is getting closer to its long-run balanced growth path.

Figure 1.6 Decomposition of GDP Growth



Source: Saudi Arabian Monetary Agency, SAMA 2006.

Progress, with respect to economic diversification, appears in the increasing weight of non-oil-GDP. Therefore, there is no doubt that high oil prices early in 1970 had significant impacts on Saudi Arabia's infrastructure, given the extremely low level of country development at the time. However, this does not necessarily mean that oil price volatility is quantitatively important to the overall volatility of the Saudi Arabian economy. As mentioned above, a key point of this chapter is to address this issue.

1.2.5 The importance of the non-oil sector in Saudi Arabia

In many circumstances, the economy of Saudi Arabia grew even when the price and production of oil decreased. For example, although the world's real oil price declined by 51% in 1986, the economy grew at the rate of 5%. In addition, despite a decline in both oil prices and production by 1% and 10% respectively in 1997, the economy continued to record an annual growth of 3%. Hence, the economy of Saudi Arabia is based on more than just oil. Indeed, the majority of jobs created in Saudi Arabia are in the non-oil sectors. These new employment opportunities include service, educational, and industrial occupations. In addition, the increasing number of tourists arriving in Saudi Arabia, especially Muslims traveling to the two holy Mosques in Mecca and Medina, exceeds seven million every year. The total expenditure on tourism reached about 9.5 billion dollars in 2004 (Supreme Commission for Tourism, SA).[4]

As a result of some economic polices, the Saudi economy has been successful in overcoming the sharp fluctuations in the world oil market and downturns in oil revenues during different periods. This would not have happened without continuous growth in non-oil-GDP. The share of non-oil-GDP in total GDP grew from 34% during the 1970s, to about 70% in 2002. The non-oil-GDP consists of two sectors, the government sector and the private sector. In 2005,

[4] Only post-2002 data about tourism is available.

the private sector constituted about 53% of the total GDP, while the government sector constituted about 18%. Based on the above facts, I can argue that the non-oil sectors have played a quantitatively crucial role in the Saudi economy.

In the next section, I briefly present the development of real business cycles theories and their distinctive features. Further, I consider the contribution of macroeconomic literature in explaining the values of various shocks on different small open economies.

2.1. Literature Review

The baseline real business cycle was extended from the Ramsey–Cass–Koopmans Model. Hence, in Real Business Cycle (RBC) models, the household maximizes its utility as a function of both consumption and leisure. In addition, business cycle models are distinctive for including shocks in the model to allow fluctuations to the economy. For example, with positive productivity shocks, the household may work more because leisure becomes more expensive. According to real business cycle theory, the economic fluctuations are Pareto Optimal and require no government intervention. In a scenario where there is no shock to the economy, it will converge to the non stochastic balanced growth path.

Many studies extend the baseline real business cycle model through a composite labor component in the labor force by applying different definitions. Rogerson (1988), Hanson (1985, 1992), and Wright (1992) show that allowing more variability in labor as a function of shocks will improve the fitness of Prescott's model (Romer, 2001). Furthermore, other studies discuss business cycle aspects in both developed and developing countries. A few studies (Baldini, 2005) have examined the real business cycle feature in oil producing countries. Other studies (Kose, 2002) have discussed the aspect of business cycles in small open economies. In this section, I present the studies relevant to the subject in two categories. Part I contains studies discussing business cycles in major oil exporting countries. In Part II, I present studies that attempt to explore the sources of business cycles in small open economies using RBC models.

Part I

Baldini's (2005) study examines the stylized facts of the business cycle in Venezuela. He compares the fiscal policy behavior in Venezuela with a "selected group of emerging market economies"[5] and studies the behavior of the fiscal policy during the business cycle. To achieve these objectives, he uses a modified Hodrick-Prescott filter, and band-pass approach. Baldini uses quarterly data for Venezuela covering the period 1990-2003. The data in real terms includes aggregate GDP, non-oil GDP, oil GDP, world oil prices, aggregate revenue, oil revenue, non-oil revenue, seigniorage, aggregate expenditure, oil primary expenditure, and non-oil primary expenditure. Baldini finds that non-oil primary expenditure, which contributes 80% of the aggregate expenditure, to be procyclical and positively correlated with aggregate GDP up to 50%.

Moreover, his results show that there is no correlation between oil revenue and the non-oil primary balance. He concludes that fiscal policy followed the "optimal path" during the entire era of the study. However, the study shows the existence of high fluctuations in non-oil primary expenditures as well as reasonable correlation with oil revenue, implying that during 1995-2003 the fiscal policy was "deviating from an optimal path."

Bjorland (2000) studies business cycles in Norway. The author investigates the stylized facts of business cycles using different de-trending techniques. The study uses quarterly data covering the period from 1967:01 to 1994:01. Focusing on the Hodrick-Prescott filter method, the author finds that investment is more volatile than consumption, and consumption is more

[5] This includes Southeast Asian countries, Pakistan, India, Brazil, Morocco, Chile, Jordan, Argentina, Uruguay, South Africa, Turkey, Colombia, Mexico, Egypt, and Panama.

volatile than output. Bjorland points out that consumption and investment are procyclical under all de-trending methods. Also, the author investigates aspects of international business cycles by examining the cross correlations in output between Norway, Finland, Sweden, Germany, UK, and US. The findings suggest that the output in Norway is procyclical to the output in all countries included in the study.

Part II

In Kose's study (2002), he attempts to answer the question of how much world price shocks explain business cycle fluctuation in non-oil exporting developing countries. The author builds an RBC model where there are five shocks, including shocks in the relative prices of capital, intermediate inputs, the world interest rate, and productivity shocks in the sectors of non-tradable final goods and primary goods. An important thing to point out in Kose's model is that he allows the country to experience the possibility of high spending and investment levels financed through borrowing.[6] Moreover, the author endognizes the discount factor to achieve stationarity. The annual data for the paper cover 28 non-oil exporting, developing countries for the period 1970 to 1992. The data were not available for the labor hours worked variable, thus the author used an employment indicator as a proxy. Kose presents the business cycle properties for macroeconomic variables after applying the Hodrick –Prescott filter (HP) to de-trend the data. He then compares the measures of volatility and co-movement obtained from the real data and those from the RBC model with five shocks. Kose goes on to compare measures for the data with those obtained from each of two models—the first with price shocks and the second with productivity shocks.

[6] For example, if the agent lives only two periods, he/she can consume much in the first period and invest much in the same period by allowing him/her to borrow; this is done by including a capital adjustment cost equation in the model.

The results from the model with relative price shocks tend to be closer to the actual data. Further, the author utilizes the shocks variance decomposition methodology to find out how much the relative price shocks explain the variation in some macroeconomic variables. The findings support the importance of the relative price shocks, which explain up to 88% and 90% of the variation in output and investment, respectively. Finally, Kose examines the impulse response function and indicates that a one standard deviation temporary increase in productivity will result in output, consumption, and investment increases of about 2%, 0.8%, and more than 2%, respectively. In addition, he shows that an increase in the relative prices of both capital and intermediate inputs shows an impact of a negative productivity shock scenario.

Mendoza (1991) investigates the ability of a theoretical RBC model to mimic the stylized facts of the Canadian economy as an example of a small open economy. The author induces stationarity to the model by endogenizing the discount factor. Thus, individual preferences depend on the past consumption. Mendoza indicates that leaving the discount factor constant will cause either a non-stationary equilibrium "if the interest rate and the rate of time preferences are not preset to be equal, or if the two are equal, the economy is always at steady state equilibrium that is consistent with any initial level of foreign asset holdings." Mendoza adds the capital adjustment cost to allow some variability for investment giving the advantage of imperfection in financial markets. He examines the role of shocks to both the world real interest rate and productivity. The author calibrates most of the parameters in the model. Some of the parameters used in the study were obtained from other studies. The world real interest rate was taken from Kydland and Prescott (1982), while the parameter for capital accumulation adjustment was chosen after many simulation attempts. Mendoza avoids using the Solow residual as a measure for productivity because it produces high variability for the case of the Canadian economy.

Mendoza uses annual data from 1946 to 1985. The findings support the lack of importance of the world real interest rate shocks in accounting for real business cycle fluctuations. However, the paper finds the importance of allowing capital accumulation cost with a small value for its coefficient. However, the model does not mimic some features of the real data.

In contrast to Mendoza (1991), Blankenau et. al. (2001) found that the world real interest rate can be important in explaining business cycles in a small open economy. The objective of their study is to examine the importance of the world real interest rate in a small open economy using a different methodology but a similar dynamic stochastic general equilibrium model as Mendoza (1991). The authors include four exogenous shocks in the model. The exogenous shocks include world real interest rate shock, productivity shock, preference shock, and depreciation shock. The authors use the model to back out realizations of the effective world real interest rate. They apply the theoretical model to the Canadian economy using quarterly data from 1961 to 1996. The authors use the variance decomposition following the recursive ordering approach to examine the importance of the world real interest rate. They find that shocks to the world real interest rate explain approximately one third of the variation in output and more than 50% of the variation in net exports.

Schmidt and Zimmermann (2005) examine the importance of oil shocks in explaining the business cycles in Germany. They build a DSGE model allowing for world oil price shocks. The authors calibrate most of the parameters in the model to the German economy. They also account for the degree of economic openness by using a model that allows for Germany's economy to change from closed to open during different time frames. They split the period from 1970 to 2002 into two segments: 1970 to 1986 and 1987 to 2002. The difference between these two models is that the interest rate is endogenous for a closed economy and exogenous for an open economy model. In addition, they use different values of capital adjustment cost as needed to mimic the investment to output volatility. The closed economy model was able to mimic some stylized facts of business in the first sub-period; while the open economy model did a better job in the second sub-period. The findings did not support the importance of oil price shocks in explaining business cycles in Germany for the two sub-periods. The oil price shocks explain only 15% in the first sub-period and only 8% in the second-sub period.

Kose and Riezman, (2001) investigate the role of trade shocks on some African economies. To achieve this objective, they build a non-stationary DSGE Model for a small open economy. To overcome the non-stationarity problem in their benchmark model, they de-trend the artificial data using a Hodrick Prescott filter. The framework of the model consists of five shocks. These shocks include shocks to prices of exports, imports, intermediate inputs, world interest rate, and productivity shocks. The authors indicate that including shocks to both export and import prices is a better method than using shocks to the terms of trade. They find that shocks to the terms of trade are not important in explaining business cycles in African economies, as Mendoza (1995) indicated.

Kose and Riezman, (2001) calibrate their model using the Solow residual as a proxy for the productivity and the London Interbank Offer Rate in real terms for the world real interest rate. They use the world real interest rate to calibrate the preference parameter, β, from first order conditions (FOCs).[7] The benchmark model was successful in mimicking some of the business cycles features in African economies. The study finds that the trade shocks explain

[7] The model is not stationary, and hence the first order condition (FOC) with respect the debt will yield $\beta = \frac{1}{(1+r)}$ where both β, and r are exogenous in the model.

about half of the variation in output. The findings did not support the importance of the world real interest, as it explains less than 1% of output variability.

3.1 Theoretical Framework

Although the existing literature investigates business cycles in small open economies, the research neglects oil exporting countries. Schmidt and Zimmermann (2005) perform a relevant study on the effects of world oil price shocks on the German business cycle, while other papers show the effects of oil but not in a general equilibrium framework. This chapter investigates whether or not oil price shocks are important in explaining business cycles in Saudi Arabia using a general equilibrium approach.

Business cycle theorists explore the features of macroeconomic fluctuation in small open economies using a microeconomic foundation. Macroeconomic fluctuations result from exogenous external shocks that affect the actions of agents as they maximize their welfare. In this chapter, I build a Dynamic Stochastic General Equilibrium (DSGE) model with shocks to the total oil revenue and productivity. The real business cycle (RBC) model utilizes a similar framework as previous studies in the literature (Stadler 1994). Initially, I present a non-stationary DSGE model for a small open economy. Then, I induce stationarity in the model and allow for capital adjustment cost. Next, I present a DSGE model that accounts for shocks in the world price of oil and the log linearization of the model at the non stochastic stationary point.

3.1.1 Nonstationary model for a small open economy

For two reasons, I briefly present a standard RBC model that differs from the model I use. First, this will make clearer how my model deviates from the standard model. Secondly, it allows me to demonstrate why this model becomes non-stationary when adapted to the small open economy framework. This will explain the need for endogenizing the discount factor.

In the standard model, the economy consists of a large number of infinitely lived households. The technology used in production is the standard Cobb Douglas production function that consists of capital and labor. With this technology, the labor share is assumed to be constant, which is consistent with the empirical evidence of the stylized facts that labor share is un-trended (Kaldor, 1961).

Hence,

$$y_t = A_t k_t^{\alpha} n_t^{1-\alpha}$$

where y_t represents output per effective unit of labor, A_t is a technology scalar such that $A_t \sim (0,1)$, k_t is physical capital per effective unit of labor, and n_t is the time a representative agent spends in working. α is the capital share such that $0 < \alpha < 1$.

This model assumes that there is only one type of exogenous shock. This productivity shock is assumed to follow an AR(1) process:

$$\ln A_t = \rho_1 \ln A_{t-1} + \varepsilon_t^1$$

where $0 < \rho_1 < 1$ and $\varepsilon_t^1 \sim NII(0, \sigma_1^2), \varepsilon_t^1 \in (0,1)$. The condition concerning the coefficient $|\rho_1| < 1$ is required for stationarity (Enders 2004).

The capital accumulation equation is

$$k_{t+1} = i_t + (1-\delta)k_t.$$

where k_{t+1} represents the physical capital stock at the subsequent period which is the combination of the current investment i_t plus the net of current physical capital $(1-\delta)k_t$ and $\delta \in (0,1)$ represents the depreciation rate.

Since I have an open economy, I enable the agent to trade in bond markets according to the world interest rate. Therefore, the net trade equation is:

$$NT = b_t - (1 + r_{t-1}) b_{t-1}$$

where NT represents the net trade in bonds, b_t indicates the bonds current period, and r_t is the rate of return on bonds.

We rule out a Ponzi game, with the following transverality condition.

$$\lim_{i \to \infty} E_t \frac{b_{t+i}}{\prod_{t=1}^{i} (1 + r_t)} \leq 0$$

where E_t is the expectation operator. With no Ponzi game, I am not allowing infinite borrowing at a high interest rate because “it would be suboptimal for households to accumulate positive assets forever at rate r or higher” (Barro and Sala-i-Martin 2004).

The objective of the representative household is to maximize the discounted expected lifetime utility:

$$\max_{c_t, n_t} \ \mathrm{U} = \mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{[c_t - n_t^{\chi} / \chi]^{1-\theta} - 1}{1-\theta} \right],$$

where c_t represents the current consumption, and n_t is labor hours such that the representative household constraint is $n_t + l_t = 1$ where l_t is leisure time. β^t is the discount factor rate where $0 < \beta < 1$, and θ is the parameter of intertemporal elasticity of substitution for labor supply, where $\theta > 0$. χ is a scalar. Also, I can write the resource constraint as:

$$y_t = (1 + r_{t-1}) b_{t-1} + c_t + i_t - b_t.$$

Thus, the representative household uses the international bond market to smooth consumption over their time horizon.

As this is a Walrasian economy I solve the social planner problem, which is simpler. The social planner chooses $\{c_t, n_t, b_t, y_t, k_{t+1}, i_t : t \geq 0\}$ to maximize the expected lifetime utility subject to the resource constraint. The typical methodology for solving the problem is first to set up the Lagrangean as follows:

$$L = E_t \sum_{t=0}^{\infty} \beta^t \left(\left[\frac{[c_t - n_t^{\chi}/\chi]^{1-\theta} - 1}{1-\theta} \right] + \lambda_t \left(A_t k_t^{\alpha} n_t^{1-\alpha} + b_t - (1+r_{t-1}) b_{t-1} - c_t - k_{t+1} + (1-\delta) k_t \right) \right),$$

where, λ_t is the Lagrangean Multiplier for the constraint at time t.

The First Order Conditions (FOCs) for c_t, n_t, b_t, k_{t+1}, and λ_t respectively, are:

$$\lambda_t = [c_t - n_t^{\chi}/\chi]^{-\theta}, \tag{1.1}$$

$$[c_t - n_t^{\chi}/\chi]^{-\theta} n_t^{\chi-1} = \lambda_t A_t (1-\alpha) k_t^{\alpha} n_t^{-\alpha}, \tag{1.2}$$

$$\lambda_t = \beta(1+r) E_t \lambda_{t+1}, \tag{1.3}$$

$$\lambda_t = \beta E_t \lambda_{t+1} \left[A_{t+1} \alpha k_{t+1}^{\alpha-1} n_{t+1}^{1-\alpha} + (1-\delta) \right], \text{ and} \tag{1.4}$$

$$y_t = (1+r_{t-1}) b_{t-1} + c_t + k_{t+1} - (1-\delta) k_t - b_t. \tag{1.5}$$

To see the problem with non stationarity in the model, consider equation (1.1). This shows that in a steady state with c and n constant, λ_t will need to be constant. Equation (1.3) shows that $\lambda_t = \lambda_{t+1}$ occurs only if $\beta = \frac{1}{1+r}$. Thus, either β or r must adjust to allow this condition to hold. In a closed economy model, r is endogenous and adjusts. In an open economy model, r is exogenous by assumption. Thus, I either need to choose a different theoretical model or I need to endogenize β.

To induce stationarity, I endogenize the discount factor using a modified version of Uzawa's preferences (Schmitt-Grohe and Uribe 2003) as in Mendoza (1991) and Kose (2002). The model is said to be stationary when its steady state values are independent of the initial condition. Stated differently, the stationarity of the model occurs when the long run effect of a shock is eliminated.

Hence, I induce stationarity in the model by endogenizing the discount factor using a modified version of Uzawa's preferences as follows:

$$\nu_{t+1} = \beta(c_t, n_t)\nu_t, \quad t \geq 0 \text{ where } \nu_0 = 1,$$

where β, is the discount factor that is a function of the agent's past consumption. Formally, β can be defined as follows:

$$\beta(c_t, n_t) = [1 + c_t - n_t^{\chi}/\chi]^{-\Omega},$$

where c_t represents the current consumption, χ is a scalar, and Ω is the elasticity of the discount factor with respect to $c - \chi^{-1}n^{\chi}$. The parameter Ω determines the steady state values of the model and the speed of convergence to the long balance growth path (Schmitt-Grohe and Uribe 2003).

3.1.2 Stationary model for a small open economy with physical capital adjustment

I modify the above simple model in important ways to generate what I call the baseline model. As mentioned above, to induce stationarity I endogonize the discount factor so that it is a function of average consumption and labor hours. The idea of endogenizing the discount factor has been used in studies such as (Mendoza 1991) and (Kose 2002). As stated by Helpman and Razin (1982), in the case of disequilibrium associated with non-stationarity where the discount factor is greater than the exogenous international interest rate, the agent will intend to decrease foreign assets which will decrease future consumption. Therefore, "the constant-discount representation of preferences can not produce such well-defined dynamics" (Mendoza 1991).

The above model does not allow for cost adjustment of the physical capital. The capital adjustment cost introduced by (Mendoza 1991) is needed to overcome the problem of massive investment volatility in response to changes in the international interest rate. This is discussed further in the next subsection. I have introduced a capital adjustment cost to avoid enormous volatility in investment in response to changes in the international interest rate. Since the economy is open to the world, there is no restriction on foreign ownership of domestic capital. This also implies that the domestic agent can trade in the international market at the given international interest rate.

The resource constraint can be written as:

$$y_t - \Gamma(k_{t+1} - k_t) \geq (1 + r_{t-1})b_{t-1} + c_t + i_t - b_t ,$$

where Γ is the physical adjustment cost parameter. The resource constraint states that consumption, investment, and net trade balance cannot surpass the gross domestic product minus the adjustment cost.

> With this configuration of adjustment costs, the cost of changing the capital stock by a fixed amount increases with the speed of the desired adjustment, giving agents an incentive to undertake investment changes gradually. This allows the model to produce fluctuations in the relative price of investment and consumption goods, which is given by the marginal rate of technical substitution between I_t, and c_t .
> (Mendoza 1991: pp 800)

These first and second changes from the model presented above are in the line with what is done in the literature. The third modification in this chapter is added to investigate the role of world oil prices in explaining business cycles in Saudi Arabia. To address that issue, I consider the total revenue from oil in the model. Specifically, the oil price shocks can be captured by total oil revenue. The Saudi Arabian oil revenue depends on many factors including the share of the Saudi production in total world oil production as well as world oil prices that are exogenous to the Saudi economy. Thus, oil revenue enters the model as an exogenous variable.

3.1.3 Stationary model for a small open economy with both a productivity shock and an oil shock

With these modifications, the economy consists of a large number of infinitely lived households. The technology used for production follows a Cobb Douglas form:

$$y_t = A_t k_t^{\alpha} n_t^{1-\alpha} + R_t .$$

The y_t represents total output. The A_t, k_t, and n_t are productivity shocks, physical capital, and labor hours, respectively; together, they represent the non-oil GDP. R_t is oil revenue and is treated as an exogenous endowment in the model.

In this model, the economy can be hit by productivity shocks and oil revenue shocks where both shocks follow an AR(1) process:

$$\ln A_t = \rho_1 \ln A_{t-1} + \varepsilon_t^1 ,$$

and

$$\ln R_t = \rho_2 \ln R_{t-1} + \varepsilon_t^2 ,$$

where $0 < \rho_1 < 1$, and $0 < \rho_2 < 1$, $\varepsilon_t^1 \sim NII\,(0, \sigma_1^2), \varepsilon_t^1 \in (0,1)$, and $\varepsilon_t^2 \sim NII\,(0, \sigma_2^2)$, $\varepsilon_t^2 \in (0,1)$. The restrictions concerning the coefficients of the AR(1) process for both shocks ρ_i, where $i = 1,2$, need to be less than unity in absolute value.

The capital accumulation equation is

$$k_{t+1} = i_t + (1-\delta)k_t,$$

where k_{t+1} represents the physical capital stocks at time $t+1$, i_t is the current investment, $(1-\delta)k_t$ is net physical current capital and δ represents the depreciation rate such that $\delta \in (0,1)$.

The representative household is able to borrow capital to build investment from the international market. Hence, the net trade equation is:

$$NT = b_t - (1+r_{t-1})b_{t-1},$$

where NT represents the net trade in bonds, b_t indicates bonds current period, and r_t is the rate of return on bonds.

I disallow an unlimited borrowing by ruling out the Ponzi scheme:

$$\lim_{i\to\infty} E_t \frac{b_{t+i}}{\prod_{t=1}^{i}(1+r_t)} \leq 0.$$

In addition, I can eliminate the individual impact on discount rate by endogenizing the discount factor with no internalization. This formulation is used by Schmitt-Grohe and Uribe (2003). They pointed that "….. the discount factor depends not upon the agent's own consumption and effort, but rather on the average per capita levels of these variables". They indicated that inducing the stationarity in either way will yield the same results.

Using notations, I write preferences as follows:

$$\nu_{t+1} = \beta(\tilde{c}_t, \tilde{n}_t)\nu_t, \qquad (2.1)$$

$$t \geq 0 \text{ where } \nu_0 = 1,$$

where $\tilde{c}_t$ and $\tilde{n}_t$ represent the average per capita consumption and labor hours respectively which is exogenous to the representative agent. More specifically, I define

$$\beta(\tilde{c}_t, \tilde{n}_t) = [1 + \tilde{c}_t - \tilde{n}^{\chi}{}_t / \chi]^{-\Omega}.$$

Then, I use the Lagrangean multiplier, where the social planner maximizes the expected lifetime utility subject to the source constraint in the economy:

$$L = E_t \sum_{t=0}^{\infty} \nu_t \left(\begin{array}{l} \left[\frac{[c_t - n_t^{\chi}/\chi]^{1-\theta} - 1}{1-\theta} \right] + \\ \lambda_t \left(A_t k_t^{\alpha} n_t^{1-\alpha} + R_t + b_t - (1 + r_{t-1}) b_{t-1} - c_t - k_{t+1} + (1-\delta) k_t - \frac{\Gamma}{2} (k_{t+1} - k_t)^2 \right) \end{array} \right),$$

where Γ represents the parameter of capital adjustment cost and $\Gamma(0) = \Gamma^{'}(0) = 0$ by assumption (Schmitt-Grohe and Uribe, 2003).

The FOCs for c_t, n_t, b_t, k_{t+1}, and λ_t respectively, are:

$$\lambda_t = [c_t - n_t^{\chi}/\chi]^{-\theta}, \quad (3.1)$$

$$[c_t - n_t^{\chi}/\chi]^{-\theta} n_t^{\chi-1} = \lambda_t (1-\alpha) A_t k_t^{\alpha} n_t^{-\alpha}, \quad (3.2)$$

$$\nu_t \lambda_t = \nu_{t+1} (1+r) E_t \lambda_{t+1}, \quad (3.3)$$

$$\lambda_t [1 + \Gamma(k_{t+1} - k_t)] \nu_t = \nu_{t+1} E_t \lambda_{t+1} \left[\alpha A_{t+1} k_{t+1}^{\alpha-1} n_{t+1}^{1-\alpha} + (1-\delta) + \Gamma(k_{t+2} - k_{t+1}) \right], \text{ and} \quad (3.4)$$

$$b_t = (1 + r_{t-1}) b_{t-1} + c_t + k_{t+1} - (1-\delta) k_t + \frac{\Gamma}{2} (k_{t+1} - k_t)^2 - A_t k_t^{\alpha} n_t^{1-\alpha} - R_t. \quad (3.5)$$

Using the functional form for (2.1) in (3.3) and (3.4) so that the FOCs for c_t, n_t, b_t, k_{t+1}, and λ_t respectively become:

$$\lambda_t = [c_t - n_t^{\chi}/\chi]^{-\theta}, \quad (4.1)$$

$$[c_t - n_t^{\chi}/\chi]^{-\theta} n_t^{\chi-1} = \lambda_t (1-\alpha) A_t k_t^{\alpha} n_t^{-\alpha}, \quad (4.2)$$

$$\lambda_t = [1 + \tilde{c}_t - \tilde{n}^{\chi}{}_t / \chi]^{-\Omega} (1+r) E_t \lambda_{t+1}, \quad (4.3)$$

$$\lambda_t [1 + \Gamma(k_{t+1} - k_t)] = [1 + \tilde{c}_t - \tilde{n}_t^{\chi}/\chi]^{-\Omega} E_t \lambda_{t+1} \left[\alpha A_{t+1} k_{t+1}^{\alpha-1} n_{t+1}^{1-\alpha} + (1-\delta) + \Gamma(k_{t+2} - k_{t+1}) \right], \text{and} \quad (4.4)$$

$$b_t = (1 + r_{t-1}) b_{t-1} + c_t + k_{t+1} - (1-\delta) k_t + \frac{\Gamma}{2} (k_{t+1} - k_t)^2 - A_t k_t^{\alpha} n_t^{1-\alpha} - R_t. \quad (4.5)$$

Since I will solve this system by log-linearization around the non-stochastic steady state, I first solve for this steady state. At the steady state, I have $\tilde{c}_t = c_t$ and $\tilde{n}_t = n_t$, which implies that in equilibrium, agent and average per capita consumption and labor hours are the same.

Hence, FOCs at steady state become:

$$\lambda = [c - n^{\chi}/\chi]^{-\theta} \ , \tag{5.1}$$

$$[c - n^{\chi}/\chi]^{-\theta} n^{\chi-1} = \lambda(1-\alpha)k^{\alpha} n^{-\alpha} \ , \tag{5.2}$$

$$1 = [1 + c - n^{\chi}/\chi]^{-\Omega}(1+r) \ , \tag{5.3}$$

$$1 = [1 + c - n^{\chi}/\chi]^{-\Omega}\left[\alpha k^{\alpha-1} n^{1-\alpha} + (1-\delta)\right], \text{and} \tag{5.4}$$

$$k^{\alpha} n^{1-\alpha} + R = rb + c - \delta k \ . \tag{5.5}$$

From (5.1) and (5.2) I have

$$n^{\chi-1} = (1-\alpha)k^{\alpha} n^{-\alpha} . \tag{5.6}$$

Equation (5.6) implies that marginal product of labor is equal to the marginal rate of substitution of work for consumption. Also, at the equilibrium, the marginal product of labor is equal to the real wage.

Equations (5.3) and (5.4) give:

$$k = n[\frac{\alpha}{r+\delta}]^{\frac{1}{1-\alpha}} . \tag{5.7}$$

Equations (5.7) into (5.6) give:

$$n = [(1-\alpha)(\frac{\alpha}{r+\delta})^{\frac{\alpha}{1-\alpha}}]^{\frac{1}{\chi-1}} .$$

The Euler equations are:

$$c = ((1+r))^{\frac{1}{\Omega}} + \frac{n^{\chi}}{\chi} - 1, \text{ and}$$

From (5.5):

$$b = \frac{Ak^{\alpha} n^{1-\alpha} + R - c - \delta k}{r} \quad \text{, where } \; i = \delta k \; .$$

Now, I have steady state values for consumption and bonds depending on the initial values and on the exogenous deterministic components. The steady state for λ is obtained directly from (5.1).

Given this steady state, I then log-linearize around the steady state. I define $\hat{\lambda}_t = \ln\left(\frac{\lambda_t}{\bar{\lambda}}\right)$, where $\bar{\lambda}$ is the steady state values and other derivatives are defined similarly. The log-linearized version of the FOCs are, thus:

$$\hat{\lambda}_t = -\theta \ln\left[\exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right], \tag{6.1}$$

$$-\theta \ln\left[\exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + (\chi - 1)\hat{n}_t = \hat{\lambda}_t + \ln(1-\alpha) + \alpha\hat{k}_t - \alpha\hat{n}_t + \hat{A}_t, \tag{6.2}$$

$$\hat{\lambda}_t = -\Omega \ln\left[1 + \exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + \ln(1+r) + \hat{\lambda}_{t+1}, \tag{6.3}$$

$$\begin{aligned} &\hat{\lambda}_t + \ln\left[1 + \Gamma\left(\exp(\hat{k}_{t+1}) - \exp(\hat{k}_t)\right)\right] = -\Omega \ln\left[1 + \exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + \hat{\lambda}_{t+1} \\ &+ \ln\left\{\alpha \exp\left(\hat{A}_{t+1}\right)\left(\exp\left(\hat{k}_{t+1}\right)\right)^{\alpha-1}\left(\exp\left(\hat{n}_{t+1}\right)\right)^{1-\alpha} + (1-\delta) + \Gamma\left(\exp\left(\hat{k}_{t+2}\right) - \exp\left(\hat{k}_{t+1}\right)\right)\right\}, \end{aligned} \tag{6.4}$$

$$\hat{b}_t = \ln\left[(1+r)\exp\left(\hat{b}_{t-1}\right) - \exp(\hat{y}_t) + \exp(\hat{c}_t) + \exp\left(\hat{i}_t\right) + \frac{\Gamma}{2}\left(\exp\left(\hat{k}_{t+1}\right) - \exp\left(\hat{k}_t\right)\right)^2\right] \text{, and} \tag{6.5}$$

$$\hat{V}_t = \hat{k}_{t+1}. \tag{6.6}$$

Note that I have introduced the $\hat{V}_t$ notation in equation (6.6). This allows me to have all items with either t or $t+1$ subscripts and reduce the system to an AR (1) process. Given this system of equations, I follow the methodology for solving the system outlined by Heer and Maussner (2005).

Using that methodology, this step follows the log-linear approximation for steady state FOCs. I write (6.1)-(6.6) in the following matrix notation:

$$C_u u_t = C_{x\lambda}\begin{bmatrix} x_t \\ \lambda_t \end{bmatrix} + C_z z_t \text{ , and} \tag{7.1}$$

$$D_{x\lambda} E_t \begin{bmatrix} x_{t+1} \\ \lambda_{t+1} \end{bmatrix} + F_{x\lambda}\begin{bmatrix} x_t \\ \lambda_t \end{bmatrix} = D_u E_t u_{t+1} + F_u u_t + D_z E_t z_{t+1} + F_z z_t \text{ .} \tag{7.2}$$

In the above two systems, the variables u_t, x_t, λ_t, and z_t are defined as follows:

$$u_t = \begin{bmatrix} \hat{c}_t \\ \hat{n}_t \end{bmatrix},$$

where u_t is the matrix for the control variables in the model. In the model, there are two control variables, consumption and labor hours. The notations $\hat{c}_t$,and $\hat{n}_t$ represent the percentage deviation of consumption and labor hours from the steady state respectively.

In addition, x_t, and λ_t represent the state and co-state variables, respectively, that are defined as follows:

$$x_t = \begin{bmatrix} \hat{k}_t \\ \hat{b}_{t-1} \end{bmatrix}$$

and

$$\lambda_t = \begin{bmatrix} \hat{\lambda}_t \\ \hat{V}_t \end{bmatrix}$$

where $\hat{k}_t$ and $\hat{b}_{t-1}$ represent the log-linearized state variables around the steady state. The co-state variables $\hat{\lambda}_t$,and $\hat{V}_t$ are log-linearized around the steady state. Furthermore, the matrix of shocks are represented by $z_t = \prod z_{t-1} + \varepsilon_t$, $\varepsilon_t \sim N(0,\Lambda)$, where Λ represents the values for the standard deviations.

The system given in (7.1) considers only the FOCs for c_t, and n_t. The C_u, $C_{x\lambda}$, and C_z matrices contain the coefficients for control variables, state and co-state variables, and shocks, respectively. The system given in (7.2) considers only the FOCs for k_{t+1}, b_t, and λ_t. The D_u, $D_{x\lambda}$, and D_z matrices contain the coefficients for control variables, state and co-state variables, and shocks, respectively, while $F_{x\lambda}$, F_u, and F_z contain the coefficients for state and co-state variables, control variables, and shocks, respectively.

The next step is to compute the policy functions as follows:

$$\hat{x}_{t+1} = L_{xx}\hat{x}_t + L_{xz}\hat{z}_t, \text{ and} \quad (8.1)$$

$$\begin{bmatrix} \hat{c}_t \\ \hat{n}_t \end{bmatrix} = L_{ux}\hat{x}_t + L_{uz}\hat{z}_t. \quad (8.2)$$

Equation (8.1) states that physical capital stocks at the subsequent period $\hat{k}_{t+1}$, and bonds b_t are functions of the physical capital stocks, productivity and oil shocks. In addition, Equation (8.2) states that consumption $\hat{c}_t$, and labor hours $\hat{n}_t$ are functions of the physical capital stocks and the series of the shocks specified in the model at time t.

More specifically, given equations (7.1) and (7.2), the Gauss program calculates the vectors L_{xx}, L_{xz}, L_{ux}, and L_{uz} to set the policy functions, where the series of the shocks follows $\hat{z}_t = \vartheta\hat{z}_{t-1} + \varepsilon_t$. Therefore, I set some starting values for state variables then iterate over these to get paths for endogenous variables given a sequence of shocks.

To implement the baseline model, I began with the Gauss program provided by Heer and Maussner (2005) and found that their program was designed for a closed economy model with only productivity shocks. Then, I made changes to allow for the model where the discount factor is not constant and with the capital adjustment cost is included. The program was further modified so that it could handle both productivity and oil revenue shocks. Finally, the model was solved numerically.

To solve the system numerically, I had to determine values for the parameters of the model. I used data drawn from reliable sources and then applied the Hodrick- Prescott (HP) filter to de-trend the data with proper specification for the annual data. Next, I calculated the cyclical component of the data. “The benefit of the Hodrick-Prescott decomposition is that it uses the same method to extract the trend from a set of variables. For example, many real business cycle models indicate that all variables will have the same stochastic trend. ” (Enders 2004: p. 224).

3.2. Calibration

In order to solve the model, I need to specify values for the model parameters. In this section, I discuss the calibration of the parameters, as well as the parameter values that I obtain from the literature. First, I calibrate the productivity shock A_t using the Solow residual:

$$\log A_t = \log y_t - (1-\alpha)\log n_t .$$

I omit the capital stock from the Solow residual equation for many reasons including data on capital stocks that are not available. Also, “capital stocks contribute very little to the cyclical fluctuations of output” (Backus et al., 1995). The share of capital in output is often between 0.3 and 0.36 (e.g. Mendoza, 1991; Blankenau et al., 2001; Backus et al., 1995). Following Mendoza (1991), I set $\alpha = 0.32$. Then, I used the residual of the AR (1) process for the Solow residual to calibrate the standard deviation for productivity shock, σ_1, as follows:

$$\ln A_t = \rho_1 \ln A_{t-1} + \varepsilon_t^1 .$$

The estimated AR (1) process for productivity yields:

$$\ln A_t = 0.63 \ln A_{t-1} .$$

The results indicate that σ_1=0.059.

Second, I calibrate ρ_2 and σ_2 for the oil shock R_t using the AR (1) process:

$$\ln R_t = \rho_2 \ln R_{t-1} + \varepsilon_t^2 .$$

The estimated AR (1) is:

$$\ln R_t = 0.65 \ln R_{t-1} .$$

The results indicate that oil revenue is persistent with a coefficient $\rho_2 = 0.65$ When the standard deviation is calibrated, σ_2=0.05. Specifically, this is the standard deviation of the residual in the above regression. Since data for physical capital stock are not available, it was not possible to calibrate the depreciation parameter δ. Following Kose and Riezman (2001), I set δ = 0.1; this value is often used by others in the literature.

Furthermore, I set the capital adjustment cost coefficient Γ to the desirable value to mimic the investment to output volatility. This approach is commonly used in the literature (Schmidt et al., 2005; Mendoza, 1991). Following Prescott (1982), the world interest rate of 0.04 is used. The remaining values for the model parameters follow Mendoza (1991).

The following table summarizes the values for the model parameters.

Table 1.2 The Parameter Values of the Model

θ	χ	Ω	α	Γ	r	δ	ρ_1	ρ_2	σ_1	σ_2
2	1.455	0.11	0.32	0.206	0.04	0.1	0.63	0.65	0.059	0.05

4.1. The Data

Annual data on gross domestic product (GDP), consumption, investment, and net exports from the period of 1970 to 2005 are obtained from the Saudi Arabian Ministry of Economy and

Planning (2005), *Achievement of the Development Plans Facts and Figures*. Due to unreliable data from the period of 1923 to 1969, this chapter uses post-1969 data.

The data are provided at constant prices. Following Kose (2001, 2002), I use an employment proxy since there are no data available for labor hours. Population data are drawn from the *International Financial Statistics (2006)* (IFS). Oil revenue and total government revenue data are from the Saudi Arabian Monetary Agency (SAMA 2006). Data on Saudi oil production, OPEC oil production, and non-OPEC oil production are drawn from British Petroleum Company (BP) (2006) reports. The world real oil prices are obtained from the Organization of Petroleum Exporting Countries (OPEC) publications.

5.1. Results

I evaluate the model's capability in capturing the macroeconomic stylized facts for the economy of Saudi Arabia. The data used to produce the volatility, correlations, and autocorrelation are filtered using the Hodrick Prescott procedure. Table 1-3 presents the volatility of the macroeconomic variables as measured by standard deviation. The correlations measure the co-movement while the autocorrelations measure the persistence of the variables.

Column (1) uses HP filtered data to characterize key features of the Saudi Arabia business cycle. To see the extent to which this model can match relevant features of the business cycle, the second moment of the model generated data are presented in the subsequent columns. The second column gives these items for the full model. To gauge the importance of various shocks, the third and fourth columns show moments of the model's data when only one shock is operative.

Table 1.3 Statistical Moments.

	Data (1)	Model with two shocks (2)	Model with only Oil shock (3)	Model with only productivity shock (4)
Volatilities				
std(y_t)	7.28	10.20	2.63	9.84
std(c_t)	9.0	13.95	3.33	13.54
std(i_t)	16.0	22.49	0.00	22.47
std(n_t)	6.63	11.29	0.00	11.27
std($\frac{tb_t}{y_t}$)	10.5	4.11	1.03	3.97
Serial correlations:				
corr(y_t, y_{t-1})	0.70	1.00	1.00	1.00
corr(c_t, c_{t-1})	0.6	0.90	0.39	0.94
corr(i_t, i_{t-1})	0.755	0.82	-	0.85
corr(n_t, n_{t-1})	0.628	0.96	-	1.00
corr($\frac{tb_t}{y_t}, \frac{tb_{t-1}}{y_{t-1}}$)	0.352	-1	-1	-1
Correlations with output				
corr(c_t, y_t)	0.17	0.81	0.98	0.81
corr(i_t, y_t)	0.64	0.48	-	0.49
corr(n_t, y_t)	-0.13	0.74	-	0.74
corr($\frac{tb_t}{y_t}, y_t$)	0.60	0.72	0.60	0.73

The model with two shocks produces a different volatility in magnitude compared to the first column; however, the model's volatility has the same ordinal ranking as the actual data for most variables. The volatility of investment is more than two times greater than that of output in both the actual data and in the model. The model with two shocks shows that consumption, investment, and labor hours are procyclical, while the actual data show that only consumption and investment are procyclical. The serial correlations from the actual data are persistent; this is consistent with the results from the full model. For example, the full model produces a value for investment of 0.82. In comparison, the actual data show 0.755.

For the model with only the oil shock, the volatility for consumption is higher than the volatility of output; this is consistent with the actual data. It is particularly interesting to note that the model with only the oil shock shows no volatility for either investment or labor hours.

This aspect of the model is associated with an arbitrage opportunity where the representative households have two channels to smooth consumption, either through capital stocks or trading in bonds. The decision by the representative household depends on relative return. If the marginal product of capital (MPK) is greater than r, then the representative household buys more capital and vice versa. With no arbitrage condition, such that MPK= r, a shock in oil revenue R_t does not change the capital stock or labor hours.[8] Therefore, in the model, the representative household smoothes consumption through international bond market operation. This is an unfavorable feature of the model and is addressed in subsequent chapters.

The model with only the oil shock produces the volatility values of 2.63, 3.33, and 1.03 for output, consumption, and trade balance ratio, respectively. This shows the same ordinal ranking of output and consumption as the actual data. The model with only the oil shock produces a value of 0.98 and 0.60 for the correlations between consumption and trade balance ratio with the output compared to 0.17 and 0.60 that result from the actual data. Thus, consumption and trade balance ratio are procyclical, which also matches the properties of the actual data.

The serial correlations from the model with only the oil shock produce the values 0.39 and 1.00 for consumption and output respectively. This is consistent with the results obtained from the actual data showing that consumption is less persistent than output. The serial correlations for output produced in all models is one and higher than that of consumption, which

[8] Since the capital stocks do not change, this implies that investment does not change.

matches with that of actual data. Further, while the model with only the oil shock underestimates the consumption persistence, other models overestimate the persistence of consumption. Additionally, the serial correlations for trade balance ratios produced in all models are negative compared to 0.352 that result from the actual data.

The model with only the productivity shock, column 4, shows the same ordinal rankings as volatilities from column 1. The model with only a productivity shock produces volatility values 9.84, 13.54, and 22.47 for output, consumption, and investment respectively, in comparison with 7.28, 9.0, and 16.0 that results from the actual data. Thus, the model with only a productivity shock produces most similar figures in terms of volatility magnitude to that of the actual data. Consumption, investment, and trade balance ratio are all procyclical which is consistent with the actual data.

To summarize the volatilities of both investment and labor hours appear to be primarily driven by the productivity shock. The small difference in the volatilities of investment and labor hours between columns 2 and 4 results from running two separate simulation exercises. The model with only the oil shock displays a relatively small volatility for output in comparison with the other models. All models display the exact ordinal ranking for volatilities for all variables. The net export ratio shows larger volatility in the actual data than what the models display.

Table 1-4 reveals the ratios of standard deviation. The moment ratios obtained from the actual data are 1.24, 2.2, and 0.91 for consumption, investment, and labor hours, respectively. For comparison, the values produced from the full model are 1.37, 2.2, and 1.11. In addition, the model with only an oil shock provides an even more concise approximation to the actual data for consumption.

The value of the ratio of consumption is the same for both the full model and the model with only the productivity shock. For the investment and labor ratios, the model with the productivity shock is similar to that of the actual data and is slightly higher than the values of the full model. The ratio of standard deviation for labor hours to that of output in the model with two shocks provides a reasonably close approximation to the actual data for this variable.

Table 1.4 Properties of Business Cycles in Saudi's Economy

	Standard Deviation		Ratio of Standard Deviation to that of {y}		
	y	*tb*	c	*i*	*n*
Actual Data	7.28	10.5	1.24	2.2	0.91
Model with two shocks	10.20	4.11	1.37	2.2	1.11
Model with only Oil shock	2.63	1.03	1.26	0	0
Model with only productivity shock	9.84	3.97	1.37	2.28	1.14

Data covers the period from 1970-2005. Statistics are based on Hodrick-Prescott-filtered data. Variables are y real output, *i* real fixed investment, c real consumption, *n* civilian employment, *tb* ratio of net exports to output. Statistics refer to logarithms. Source: *Achievements of the developments plans (2005). Data provided at constant prices (deflated by the publisher).*

Now, it is appropriate to judge the sensitivity of the different parameter values. Table 1-5 shows the simulation results when the calibrated standard deviations are doubled for the oil revenue and productivity. For the model volatilities to increase substantially, a large increase in the magnitude of the shock is required. In other words, the models are not very sensitive to changes in standard deviation. As expected, the size of standard deviation does not affect autocorrelations and cross correlations within the models.

Table 1.5 Sensitivity Analysis

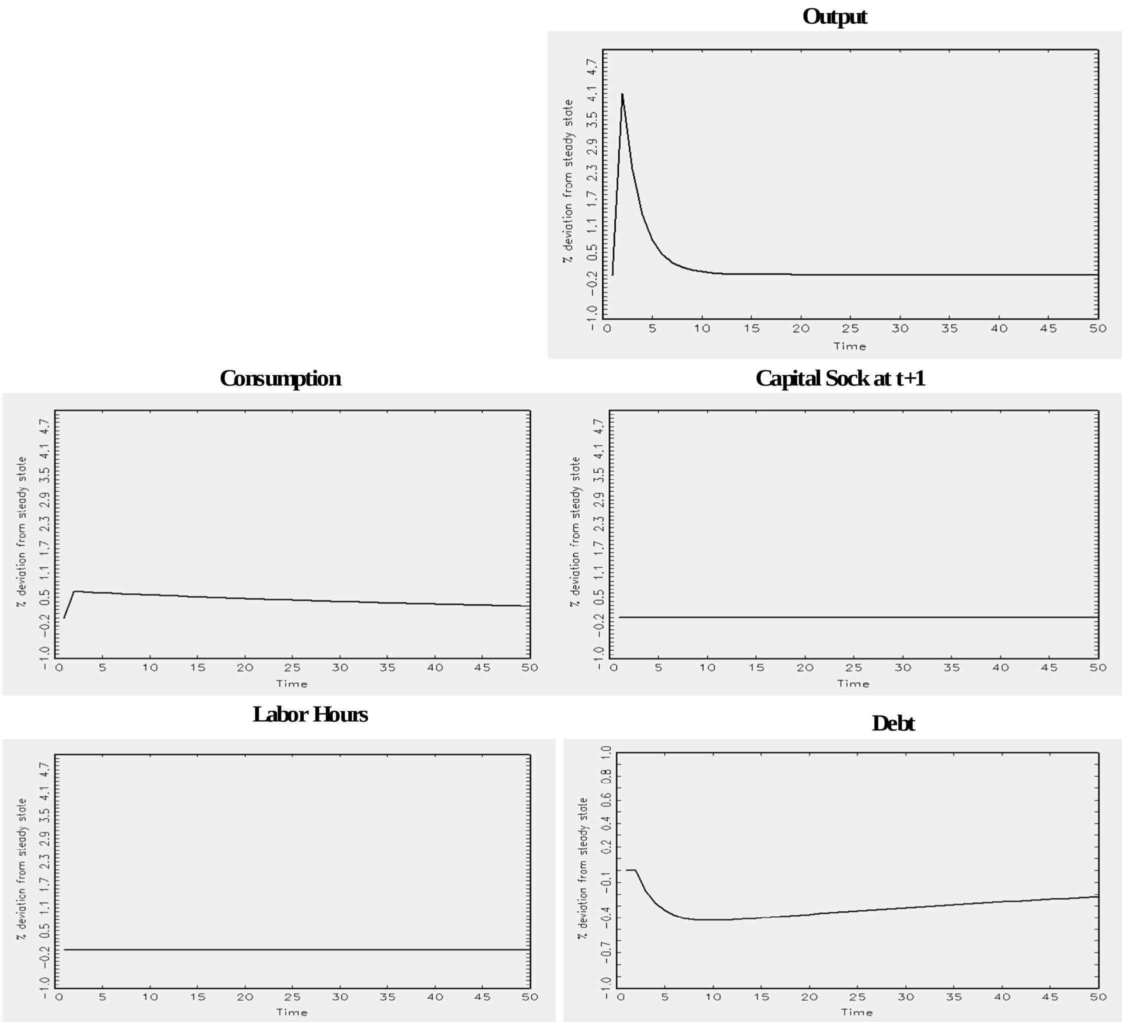
	Data	Model with two shocks	Model with only Oil shock	Model with only productivity shock
Volatilities				
std(y_t)	7.28	20.51	5.26	19.68
std(c_t)	9.0	28.16	6.55	27.15
std(i_t)	16.0	45.64	0.00	45.54
std(n_t)	6.63	22.64	0.00	22.51
std($\frac{tb_t}{y_t}$)	10.5	8.13	2.04	7.78

6.1. The Dynamic Impact of the Shocks

I use the Impulse Response Function (IRF) to examine the dynamic deviation of the economy from the steady state as a result of a particular shock. The traditional use of the IRF is to evaluate the model's capability to mimic real economic cycles and show its propagation mechanism. The aim is to examine the macroeconomic indicators in response to a temporary oil shock. This will allow us to assess the independent effect of a particular shock, holding all else constant. Since Saudi Arabia is an oil exporting country, I expect an economic boom to occur when international oil prices increase. Figure 1-7 reveals the response of the model's variables to a one standard deviation temporary oil shock. A sudden increase in the oil revenue due to a world oil price shock brings the economy to a boom cycle, up 3.7%. The oil shock has no effect after the fifth period. However, this shock has a relatively small effect on consumption that lasts for only two periods.

The IRF shows that capital stocks at time $t+1$ and labor hours are not affected by the oil shock. As indicated in the previous section, when solving the log-linearized system of equations, investment and labor hours were not found to be functions of oil shock. In accordance to the model, the representative household smoothes consumption through bonds. In a response to a one standard deviation oil shock, the representative household will save more as shown by the negative debt of 0.5%. The oil revenue shock effect on the debt starts to dissipate after seven periods.

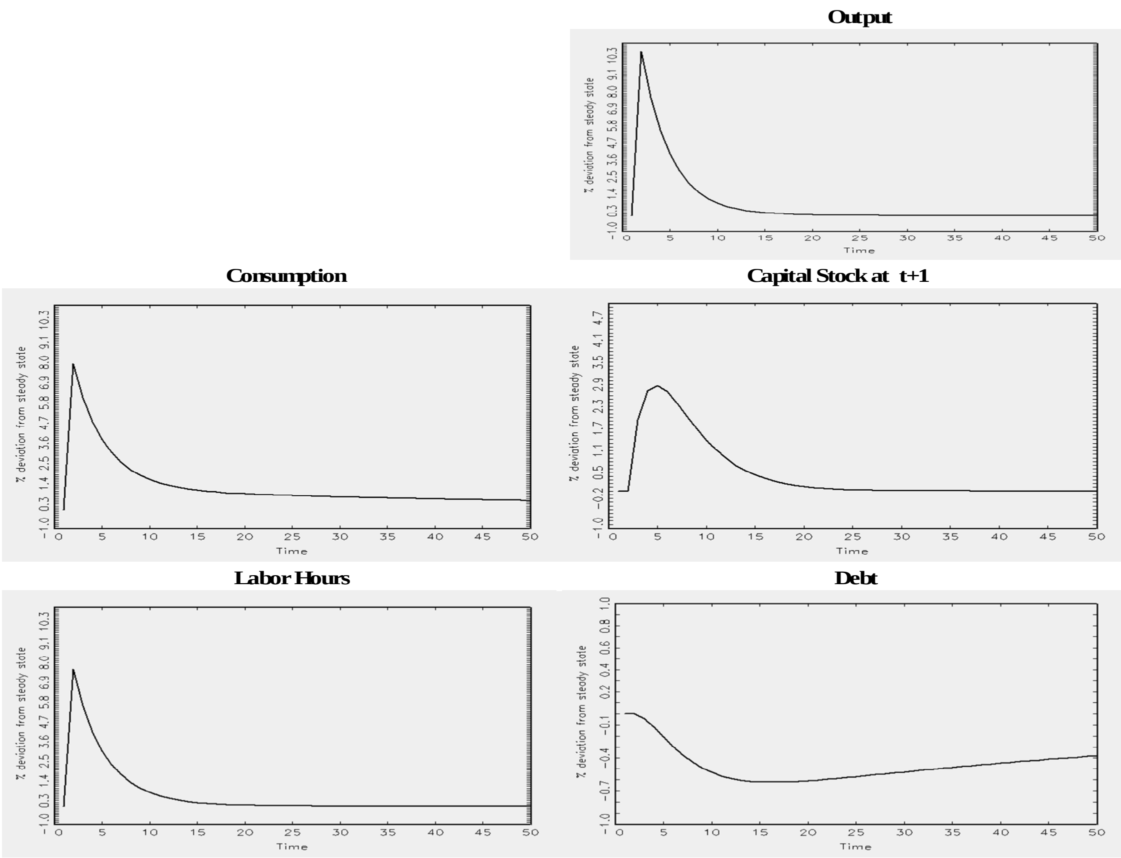
Figure 1.7 Impulse Response of a One Standard Deviation Shock in Oil



It is important to stress the role that the Solow residual plays in economic fluctuations (Charles, 1989). Figure 1-8 shows the response of the model variables to a one standard deviation temporary productivity shock. A sudden increase in the productivity brings the economy to a boom cycle, in which output is up 10.1 %.

A productivity shock in the economy leads to disequilibrium making the capital stock purchases more attractive because marginal productivity of capital is greater than r . The market mechanism works to arrive at the point where MPK= r . To allow for some incompleteness of the market, I included capital adjustment in the model (Mendoza, 1991).

Figure 1.8 Impulse Response of a One Standard Deviation Shock in Productivity



With high productivity, time spent on leisure is more expensive causing the demand for leisure to decrease. Thus, labor hours increase by about 7%. In turn, this increases the demand on consumption of goods and services, and capital stocks for the next period increases as well. In response to a one standard deviation temporary productivity shock, the representative household will increase its level of saving for 10 periods after the shock to smooth its consumption. This effect on saving reaches a maximum of 0.7% before beginning its convergence to the steady state. The effect of the productivity shock on output starts to die out after three periods, and it returns to the steady state after 15 periods. However, labor hours, and consumption tend to have short lived effects in response to a one standard deviation temporary productivity shock.

7.1. Conclusion

The objective of this chapter is to investigate the role of oil price shocks in explaining business cycles in Saudi Arabia using a dynamic stochastic general equilibrium approach. The model contributes to the literature by introducing the oil revenue for Saudi Arabia into the production function as a stochastic variable that follows an AR (1) process. The model with two shocks produces different values for volatility, but these values have the same ranking as that of the actual data for most variables. In addition, the actual data are close to the ratio of standard deviations to the output obtained from the model with two shocks.

The results indicate that productivity shocks are relatively more important to business cycles than the oil shocks. The model with only a productivity shock produces the most similar figures in term of volatility magnitude to that of the actual data.

Next, I use the Impulse Response Functions (IRF) to evaluate the capability of the model. The IRF shows no effect of an oil shock on the capital stocks and on labor hours, which is a feature of the model. When the log-linearized system of equations is solved numerically, investment and labor hours were not found to be functions of the oil shock. I recommend using different techniques to compare the model’s robustness. One method by which to do this is to have all decision variables as a function of the oil shock by inducing the stationarity to the model differently. Another method is to impose a bond adjustment cost. The aim of the next chapter is to incorporate these ideas and compare the results with those of the baseline model.

CHAPTER 2 - The Role of World Oil Price Shocks in Explaining Business Cycles in a Small Open Economy with Portfolio Adjustment Cost

1.1. Introduction

This chapter is an extension of the baseline model of chapter one. While the baseline model provides a Pareto Optimal solution, it also produces some unfavorable features that are associated with an arbitrage opportunity. Recall that the representative households can trade capital stocks and bonds in order to smooth consumption. The decision of how the household smoothes consumption depends on the relative return. For example, if the marginal product of capital (MPK) is greater than interest rate (r), then the representative household will purchase additional capital. With a no arbitrage condition such that MPK= r , a shock in oil revenue, R_t , does not change the capital stock or labor hours.[9] Stated differently, $r = A\alpha\left(\frac{L}{K}\right)^{1-\alpha}$ where both K and L do not change as a result of oil revenue shock since r does not change. Therefore, in the baseline model, the representative household smoothes consumption through international bond market operation. The problem is that if K is unchanged, then there is no way to explain employment variation, which is an important feature of business cycles. This is an unfavorable feature of the model and is addressed in this chapter.

Therefore, the objective of this chapter is to incorporate the portfolio adjustment cost so that the model produces volatility in both investment and labor hours when oil shocks are allowed. The advantage of adding the portfolio adjustment cost is that when the log-linearized system of equations are solved numerically, investment and labor hours will now be functions of the oil shock. Although the new model adds friction by incorporating the portfolio adjustment

[9] Since the capital stock does not change, this implies that investment does not change.

cost into the baseline line model, this alternative should produce similar dynamics (Schmitt-Grohe' and Uribe, 2003).

Recently, a number of studies (Bodenstein, 2006; Ghironi, 2006) have addressed alternative ways for inducing stationarity in real business cycle models for small open economies.[10] The First Welfare Theorem declares that Pareto Optimality derives the same solutions as the competitive equilibrium (Mas-Colell et al., 1995). Even when Mendoza (1991) allowed for some market imperfections by adding a capital adjustment cost, he showed that his model was still Pareto Optimal. Some studies have presented a variety of classical real business cycle models to investigate the role of the real world interest rate for a small open economy. For example, Mendoza (1991) found that the real world interest rate was not important in explaining business cycles in a small open economy for the case of Canada. Neumeyer and Perri (2001, 2005) and Blankenau et al. (2001) found that the real world interest rate was an important driving force of business cycles for a small open economy.

Neumeyer and Perri (2001, 2005) were the first authors to incorporate bond adjustment costs in their model. The authors investigate the role of interest rates in explaining business cycles for emerging economies using small open economy modeling. More specifically, they examine the role of interest rates in Argentina, Canada, Brazil, Korea, Mexico, and the Philippines. They calibrated the parameters of their model from data drawn from the Organization for Economic Co-operation and Development (OECD). The authors use quarterly data covering the period from 1983:01 to 2000:02 for Argentina and Canada. For the other countries, the data extend from 1994:01 to 2000:02.

[10] Unlike other approaches, Bodenstein (2006) indicates that inducing stationarity by endogenizing the discount factor always produces stationary and unique solutions.

They write the domestic interest rate for a particular country as a function of the U.S. interest rate and a scalar that represents the risk associated with lending to domestic borrowers. Also in their model, they presume that a transaction technology must be paid by firms before production begins. There are three sub-periods within each period of the model. In the first sub-period, the firms borrow to pay the rent for factors of production. Next, the firm must pay for labor and capital in the second sub-period. In the last sub-period, firms use their surplus output to repay the debt they incurred in the first sub-period so that the market clearance conditions hold. For the parameter of the portfolio adjustment cost, the authors assign similar values for all countries. Finally, the authors find that the volatility of consumption was greater than output and that omitting country risk lowered the volatility of output for Argentina by 27%. In this research, I incorporate the bond adjustment cost equation introduced by Neumeyer and Perri (2001, 2005) so that the model will now produce some volatility for both investment and labor hours.

The remainder of this chapter is organized as follows: Section 2 illustrates the derivation of the theoretical model and the calibration of the alternative DSGE model. Section 3 provides an outline of the data and sources. Section 4 documents the stylized facts of business cycles for Saudi Arabia. Section 5 discusses impulse response functions and includes an analysis of the results. Section 6 shows the results of the sensitivity analysis. Concluding remarks, policy recommendations, and limitations are given in Section 7.

2.1. Theoretical Framework:

This alternative model adds friction to our baseline model. More specifically, this model includes portfolio adjustment cost. Therefore, the economy consists of a large number of infinitely lived households. The technology used for production follows a Cobb Douglas form:

$$y_t = A_t k_t^{\alpha} n_t^{1-\alpha} + R_t \ .$$

The y_t represents total output. A_t, k_t, and n_t are productivity shocks, physical capital, and labor hours, respectively; together, they represent the non-oil GDP. R_t is oil revenue and is treated as a stochastic exogenous endowment in the model.

In this model, both productivity and oil revenue shocks follow an AR(1) process:

$$\ln A_t = \rho_1 \ln A_{t-1} + \varepsilon_t^1$$

and

$$\ln R_t = \rho_2 \ln R_{t-1} + \varepsilon_t^2$$

where $0 < \rho_1 < 1$, and $0 < \rho_2 < 1$, $\varepsilon_t^1 \sim NII\,(0,\sigma_1^2), \varepsilon_t^1 \in (0,1)$, and $\varepsilon_t^2 \sim NII\,(0,\sigma_2^2)$, $\varepsilon_t^2 \in (0,1)$. The coefficients of the AR(1) process for both shocks, ρ_1 and ρ_2, are restricted to be less than unity in absolute value.

The capital accumulation equation is

$$k_{t+1} = i_t + (1-\delta)k_t$$

where k_{t+1} represents the physical capital stock at time $t+1$, and i_t is the current investment. Net physical is $(1-\delta)k_t$, and δ represents the depreciation rate such that $\delta \in (0,1)$.

The representative household is able to trade in bonds in international market. Hence, the net trade equation is:

$$NT = b_t - (1+r_{t-1})b_{t-1}$$

where NT represents the net trade in bonds, b_t indicates bonds in the current period, and r_t is the rate of return on bonds. I rule out the Ponzi scheme to prohibit infinite borrowing (Sargent and Ljungqvist, 2004):

$$\lim_{i\to\infty} E_t \frac{b_{t+i}}{\prod_{t=1}^{i}(1+r_t)} \le 0 .$$

In addition, I eliminate the individual impact on the discount rate by endogenizing the discount factor with no internalization. Following the formulation from chapter one, the discount factor is a function of consumption and labor hours.

Preferences are written as follows:

$$\nu_{t+1} = \beta(\tilde{c}_t, \tilde{n}_t)\nu_t \qquad (1.1)$$

$$t \ge 0 \text{ where } \nu_0 = 1$$

where $\tilde{c}_t$ is the average per capita consumption, and $\tilde{n}_t$ is labor hours; both are exogenous to the representative agent. The functional form of the discount factor follows:

$$\beta(\tilde{c}_t, \tilde{n}_t) = [1 + \tilde{c}_t - \tilde{n}_t^{\chi}/\chi]^{-\Omega} .$$

Using the Lagrangean multiplier, the social planner maximizes the expected lifetime utility subject to the resource constraint in the economy.

$$L = E_t \sum_{t=0}^{\infty} \nu_t \left(\begin{array}{l} \left[\frac{[c_t - n_t^{\chi}/\chi]^{1-\theta} - 1}{1-\theta} \right] + \\ \lambda_t \left(A_t k_t^{\alpha} n_t^{1-\alpha} + R_t + b_t - (1+r_{t-1})b_{t-1} - c_t - k_{t+1} + (1-\delta)k_t - \frac{\Gamma}{2}(k_{t+1} - k_t)^2 - \frac{\tau}{2}(b_t - \bar{b})^2 \right) \end{array} \right),$$

where Γ represents the parameter of capital adjustment cost and is $\Gamma(0) = \Gamma'(0) = 0$ by assumption (Schmitt-Grohe and Uribe, 2003). The new feature in this model is the portfolio adjustment cost equation where τ represents the parameter of portfolio adjustment cost. The τ parameter is " a constant determining the size of the bond holding costs, and $\bar{b}$ is the steady state level of bonds-to-GDP ratio" (Neumeyer and Perri, 2005).

The FOCs for c_t, n_t, b_t, k_{t+1}, and λ_t, respectively, are:

$$\lambda_t = [c_t - n_t^{\chi}/\chi]^{-\theta} \ , \tag{2.1}$$

$$[c_t - n_t^{\chi}/\chi]^{-\theta} n_t^{\chi-1} = \lambda_t (1-\alpha) A_t k_t^{\alpha} n_t^{-\alpha} \ , \tag{2.2}$$

$$\nu_t \left[1-\tau(b_t - \bar{b})\right]\lambda_t = \nu_{t+1}(1+r)E_t\lambda_{t+1} \ , \tag{2.3}$$

$$\lambda_t[1+\Gamma(k_{t+1}-k_t)]\nu_t = \nu_{t+1}E_t\lambda_{t+1}\left[\alpha A_{t+1}k_{t+1}^{\alpha-1}n_{t+1}^{1-\alpha} + (1-\delta) + \Gamma(k_{t+2}-k_{t+1})\right] \text{,and} \tag{2.4}$$

$$b_t = (1+r_{t-1})b_{t-1} + c_t + k_{t+1} - (1-\delta)k_t + \frac{\Gamma}{2}(k_{t+1}-k_t)^2 - A_t k_t^{\alpha} n_t^{1-\alpha} - R_t + \frac{\tau}{2}(b_t - \bar{b})^2 . \tag{2.5}$$

Using the functional form for (1.1) in (2.3) and (2.4) so that the FOCs for c_t, n_t, b_t, k_{t+1}, and λ_t become, respectively:

$$\lambda_t = [c_t - n_t^{\chi}/\chi]^{-\theta} \ , \tag{3.1}$$

$$[c_t - n_t^{\chi}/\chi]^{-\theta} n_t^{\chi-1} = \lambda_t (1-\alpha) A_t k_t^{\alpha} n_t^{-\alpha} , \tag{3.2}$$

$$\lambda_t \left[1-\tau(b_t - \bar{b})\right] = [1+\tilde{c}_t - \tilde{n}^{\chi}{}_t/\chi]^{-\Omega}(1+r)E_t\lambda_{t+1} \ , \tag{3.3}$$

$$\lambda_t[1+\Gamma(k_{t+1}-k_t)] = [1+\tilde{c}_t - \tilde{n}_t^{\chi}/\chi]^{-\Omega}E_t\lambda_{t+1}\left[\alpha A_{t+1}k_{t+1}^{\alpha-1}n_{t+1}^{1-\alpha} + (1-\delta) + \Gamma(k_{t+2}-k_{t+1})\right] \text{,and} \tag{3.4}$$

$$b_t = (1+r_{t-1})b_{t-1} + c_t + k_{t+1} - (1-\delta)k_t + \frac{\Gamma}{2}(k_{t+1}-k_t)^2 - A_t k_t^{\alpha} n_t^{1-\alpha} - R_t + \frac{\tau}{2}(b_t - \bar{b})^2 . \tag{3.5}$$

This system is different from the baseline model in two aspects. First, the representative agent can borrow an additional unit to increase the current consumption. In the following period, the representative agent pays back the debt plus some interest rate, r, that is dependent on bond holdings. Thus K depends on total revenue. With an oil shock, the economy saves more using bonds so that r increases because bond holdings go up. Since r is different then $\alpha\left(\frac{L}{K}\right)^{1-\alpha}$ must adjust to a new equilibrium. The second difference is that the budget constraint in equation (3.5) includes bond adjustment cost. Equation (3.5) shows that when the representative agent borrows an additional unit and creates more debt so that b_t increases.

Solving this system by log-linearization around the non-stochastic steady state requires first solving for the steady state. At the steady state, $\tilde{c}_t = c_t$ and $\tilde{n}_t = n_t$ implying that, in equilibrium, agent average per capita consumption and labor hours are the same. Furthermore, the bonds at time t ,along the balance growth path, are equal to the average bonds in the economy. Hence, FOCs at steady state become:

$$\lambda = [c - n^{\chi}/\chi]^{-\theta}, \tag{4.1}$$

$$[c - n^{\chi}/\chi]^{-\theta} n^{\chi-1} = \lambda(1-\alpha)k^{\alpha} n^{-\alpha}, \tag{4.2}$$

$$1 = [1 + c - n^{\chi}/\chi]^{-\Omega}(1+r) , \tag{4.3}$$

$$1 = [1 + c - n^{\chi}/\chi]^{-\Omega}\left[\alpha k^{\alpha-1} n^{1-\alpha} + (1-\delta)\right] \text{,and} \tag{4.4}$$

$$k^{\alpha} n^{1-\alpha} + R = rb + c - \delta k . \tag{4.5}$$

It is important to note that the baseline model and the current one share the same steady state conditions so the steady state solution is identical. However, the log-linearized system of equations is not identical in both models because they differ when away from the steady state. As in the baseline model, the steady state solution is as follows:

From (4.1) and (4.2):

$$n^{\chi-1} = (1-\alpha)k^{\alpha} n^{-\alpha}. \tag{4.6}$$

This implies that the marginal product of labor is equal to the marginal rate of substitution of work for consumption. Also at the equilibrium, the marginal product of labor is equal to real wage. Equations (4.3) and (4.4) give:

$$k = n[\frac{\alpha}{r+\delta}]^{\frac{1}{1-\alpha}} \tag{4.7}$$

Plugging equation (4.7) into (4.6) give:

$$n = [(1-\alpha)(\frac{\alpha}{r+\delta})^{\frac{\alpha}{1-\alpha}}]^{\frac{1}{\chi-1}}$$

Now the Euler equations are:

$$c = ((1+r))^{\frac{1}{\Omega}} + \frac{n^{\chi}}{\chi} - 1$$

and, from (4.5)

$$b = \frac{Ak^{\alpha}n^{1-\alpha} + R - c - \delta k}{r} \tag{4.8}$$

where $i = \delta k$. Now, steady state values exist for consumption and bonds depending on the initial values of the exogenous deterministic components. The steady state for λ is obtained directly from (4.1).

Next, I log-linearize around the given steady state. Define $\hat{\lambda}_t = \ln\left(\frac{\lambda_t}{\bar{\lambda}}\right)$,where $\bar{\lambda}$ is the steady state values, and other derivatives are defined similarly. The log-linearized version of the FOCs are thus:

$$\hat{\lambda}_t = -\theta \ln\left[\exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right], \tag{5.1}$$

$$-\theta \ln\left[\exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + (\chi - 1)\hat{n}_t = \hat{\lambda}_t + \ln(1-\alpha) + \alpha\hat{k}_t - \alpha\hat{n}_t + \hat{A}_t, \tag{5.2}$$

$$\hat{\lambda}_t + \ln\left[1 - \tau(\exp(\hat{b}_t) - \ln(\bar{b}))\right] = -\Omega \ln\left[1 + \exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + \ln(1+r) + \hat{\lambda}_{t+1}, \tag{5.3}$$

$$\begin{aligned} &\hat{\lambda}_t + \ln\left[1 + \Gamma\left(\exp(\hat{k}_{t+1}) - \exp(\hat{k}_t)\right)\right] = -\Omega \ln\left[1 + \exp(\hat{c}_t) - \chi^{-1}\left(\exp(\hat{n}_t)\right)^{\chi}\right] + \hat{\lambda}_{t+1} \\ &+ \ln\left\{\alpha \exp\left(\hat{A}_{t+1}\right)\left(\exp\left(\hat{k}_{t+1}\right)\right)^{\alpha-1}\left(\exp\left(\hat{n}_{t+1}\right)\right)^{1-\alpha} + (1-\delta) + \Gamma\left(\exp\left(\hat{k}_{t+2}\right) - \exp\left(\hat{k}_{t+1}\right)\right)\right\} \end{aligned}, \tag{5.4}$$

$$\hat{b}_t = \ln\left[(1+r)\exp\left(\hat{b}_{t-1}\right) - \exp(\hat{y}_t) + \exp(\hat{c}_t) + \exp\left(\hat{i}_t\right) + \frac{\Gamma}{2}\left(\exp\left(\hat{k}_{t+1}\right) - \exp\left(\hat{k}_t\right)\right)^2 + \frac{\tau}{2}\left(\exp(b_t) - \ln(\bar{b})\right)^2\right], \text{and} \tag{5.5}$$

$$\hat{V}_t = \hat{k}_{t+1}. \tag{5.6}$$

The $\hat{V}_t$ notation is introduced in equation (5.6) so that all items with either t or $t+1$ subscripts will reduce the system to an AR (1) process. Given this system of equations, I follow the methodology for solving the system outlined by Heer and Maussner (2005).[11]

Unlike the baseline model, the log-linearized system of equations shown above now contains the bond adjustment cost. This means that when the system is solved numerically, investment and labor hours will now be a function of the oil shock. In this model, r depends on the number of bond holdings so that any change in bond holdings affects the interest rate. With the new level of bond holdings, r varies and that requires K to change to return to the equilibrium where r =MPK.

2.2. Calibration

The parameter of the portfolio adjustment cost, τ, is incorporated so that this model generates a similar volatility in the trade balance ratio to output as the baseline model. The value chosen for τ is equal to 0.000745. Like Neumeyer and Perri (2001, 2005), the chosen value for the parameter of bond adjustment cost is smaller than the parameter value of capital adjustment cost. The value for $\bar{b}$ is calculated from the steady state equation (4.8). The remaining parameter values of this model are similar to those assigned for the baseline model.[12]

3.1. The Data

Data were obtained from the Saudi Arabian Ministry of Economy and Planning, *Achievement of the Development Plans Facts and Figures (2005)*. Annual data include gross domestic product (GDP), consumption, investment, and net exports from the period of 1970 to

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[11] In the first chapter, I discussed the algorithm used to solve a dynamic general equilibrium model.
[12] Later in the chapter, I provide sensitivity analysis to find how the results of the model change when assigning different parameter values.

2005. Reliability issues suggest that only post-1969 data be used. The data are provided at constant prices. Following Kose (2001, 2002) and Backus et al. (1995), I use civilian employment data as a proxy since there are no data available for labor hours.

4.1. Results

Comparing the statistical moments of the theoretical model with those of the data enables us to evaluate the capability of our model to explain business cycles. The data used to produce the volatility, correlations, and autocorrelation are filtered using the Hodrick Prescott (HP) procedure. Table 2-1 presents the volatility of the macroeconomic variables as measured by standard deviation. The correlations measure the co-movement while the autocorrelations measure the persistence of the variables.

Column (1) uses HP filtered data to characterize key features of the Saudi Arabia business cycle. To see the extent to which this model can match relevant features of the business cycle, the second moment of the model generated data are presented in subsequent columns. The second column shows the second moments for the full model. To gauge the importance of various shocks, the third and fourth columns show moments of the model's data when only one shock is allowed.

The model with two shocks, Model 2, produces a different volatility in magnitude compared to the first column; however, the model's volatility has the same ordinal ranking as the actual data for most variables. The volatility of investment is more than two times greater than that of output in both the actual data and in the model. The model with two shocks shows that consumption, investment, and labor hours are procyclical; yet the actual data show that only consumption and investment are procyclical. The serial correlations from the actual data are persistent, and this is consistent with the results from the full model. For example, the full model produces a value for investment of 0.83. In comparison, the actual data show 0.755.

Table 2.1 Statistical Moments

	Data (1)	Model with two shocks (2)	Model with only Oil shock (3)	Model with only productivity shock (4)
Volatilities				
std(y_t)	7.28	10.27	2.65	9.94
std(c_t)	9.0	14.27	3.42	13.94
std(i_t)	16.0	22.71	0.82	22.69
std(n_t)	6.63	11.37	0.29	11.38
std($\frac{tb_t}{y_t}$)	10.5	4.14	1.04	4.01
Serial correlations:				
corr(y_t, y_{t-1})	0.70	1.00	1.00	1.00
corr(c_t, c_{t-1})	0.6	0.91	0.48	0.94
corr(i_t, i_{t-1})	0.755	0.83	0.65	0.86
corr(n_t, n_{t-1})	0.628	0.97	0.17	1.00
corr($\frac{tb_t}{y_t}, \frac{tb_{t-1}}{y_{t-1}}$)	0.352	-1.00	-1.00	-1.00
Correlations with output				
corr(c_t, y_t)	0.17	0.82	0.98	0.82
corr(i_t, y_t)	0.64	0.49	0.96	0.49
corr(n_t, y_t)	-0.13	0.74	1.00	0.74
corr($\frac{tb_t}{y_t}, y_t$)	0.60	0.73	0.62	0.74

For the model with only the oil shock, the volatility for consumption is higher than the volatility of output; this is consistent with the actual data. As discussed above, this model produces volatility for both investment and labor hours whereas the baseline model shows zero volatility from oil price shocks. The volatility for investment and labor hours produced are relatively small in this model, which is attributable to the relative unimportance of oil shocks to productivity shocks in Saudi Arabia.[13]

The model with only the oil shock produces volatility values of 2.65, 3.42, 0.82, 0.29, and 1.04 for output, consumption, investment, labor hours, and trade balance ratio, respectively. This shows the same ordinal ranking of output and consumption as the actual data. Model 3 produces a value of 0.98 and 0.96 for the correlations between consumption and investment with output which compare to 0.17 and 0.64 from the actual data. Thus, consumption and investment are procyclical.

Model 3 produces serial correlation values of 0.48 and 1.00 for consumption and output, respectively. This is consistent with the results obtained from the actual data that show consumption is less persistent than output. The serial correlation for output produced in each model is higher than that of consumption, which matches the actual data. Further, Model 3 underestimates consumption, investment, and labor hour persistence. The persistence of consumption, investment, and labor hours are overestimated in the other two models.

The model with only the productivity shock, Model 4, shows the same ordinal rankings as volatilities from the first column. Model 4 produces volatility values 9.94, 13.94, and 22.69 for output, consumption, and investment, respectively, in comparison with 7.28, 9.0, and 16.0 that result from the actual data. Therefore, the model with only a productivity shock produces the most similar figures in terms of volatility magnitude to that of the actual data. Consumption, investment, and the trade balance ratio are all procyclical which is consistent with the actual data.

[13] This matter is further investigated later in this chapter when I conduct sensitivity analysis and is empirically investigated in the next chapter.

Model 3 displays a relatively small volatility for output in comparison with the other models. All models display the exact same ordinal ranking of volatilities for all variables. The net export ratio shows more volatility in the actual data than what the models display.

Table 2-2 reveals the ratios of standard deviation. The moment ratios obtained from the actual data are 1.24, 2.2, and 0.91 for consumption, investment, and labor hours, respectively. In comparison, the values produced from the full model are 1.39, 2.2, and 1.11.

Table 2.2 Properties of Business Cycles in Saudi's Economy

	Standard Deviation		Ratio of Standard Deviation to that of {y}		
	y	*tb*	*c*	*i*	*n*
Actual Data	7.28	10.5	1.24	2.2	0.91
Model with two shocks	10.27	4.14	1.39	2.2	1.11
Model with only Oil shock	2.65	1.04	1.29	0.31	0.11
Model with only productivity shock	9.94	4.01	1.40	2.28	1.14

Data covers the period from 1970-2005. Statistics are based on Hodrick-Prescott-filtered data. Variables are y real output, i real fixed investment, c real consumption, n civilian employment, tb ratio of net exports to output. Statistics refer to logarithms. Source: *Achievements of the developments plans (2005)*. *Data provided at constant prices (deflated by the publisher).*

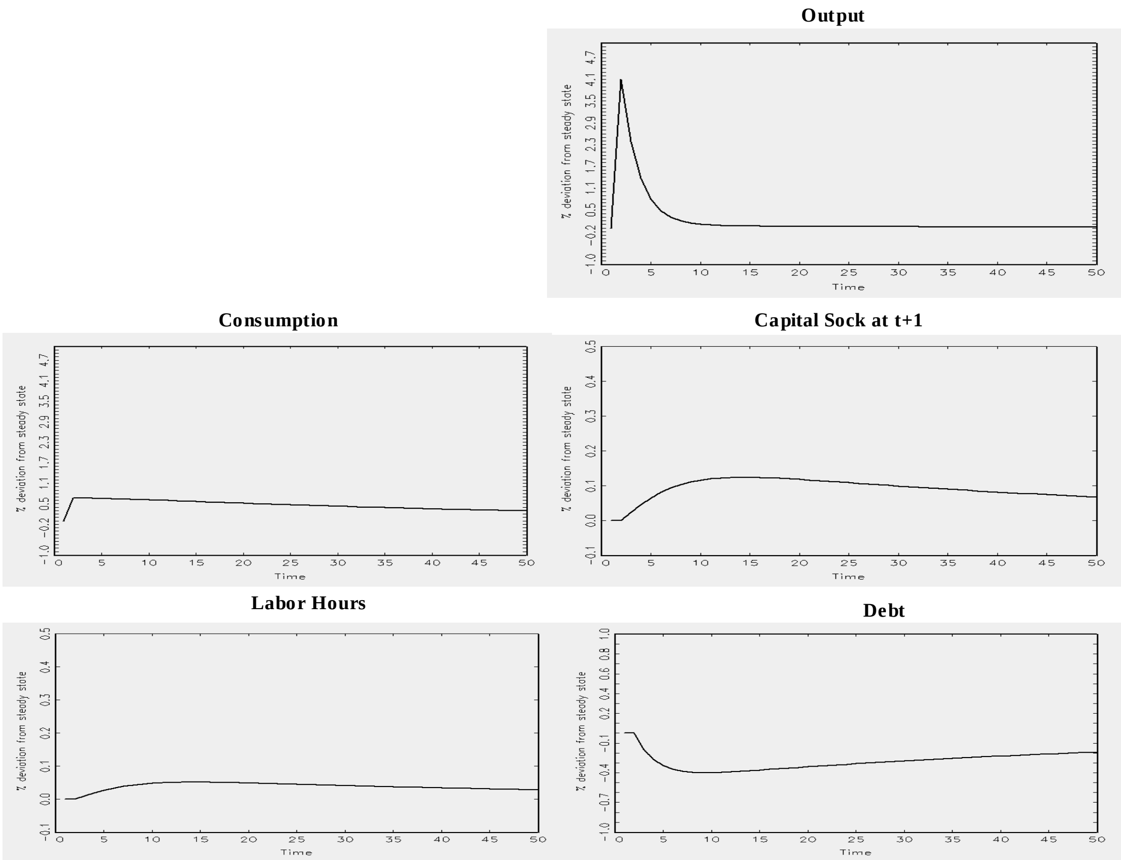
The value of the ratio of consumption is almost the same for both the full model and the model with only the productivity shock. For the investment and labor ratios, the model with the productivity shock is similar to that of the actual data and is slightly higher than the values of the full model. The ratio of standard deviation for labor hours to that of output in the model with two shocks provides a reasonably close approximation to the actual data for this variable.

5.1. The Dynamic Impact of the Shocks

The Impulse Response Function (IRF) is used to examine the dynamic deviation of the economy from the steady state as a result of a particular shock. The aim is to examine the macroeconomic indicators in response to a transitory oil shock. This will allow us to assess the independent effect of a particular shock, *ceteris paribus*. Since Saudi Arabia is an oil exporting country, I expect an economic boom to occur when international oil prices increase. Figure 2-1 reveals the response of the model's variables to a one standard deviation temporary oil shock.

A sudden increase in the oil revenue due to a world oil price shock increases output to a maximum of 4%. The oil shock has no effect after the eighth period. However, this shock has a relatively small effect on consumption that lasts for only two periods before it begins to die-out.

Figure 2.1 Impulse Response of a One Standard Deviation Shock in Oil



The IRF shows that a transitory oil shock increases the capital stock at time $t+1$. The effect of an oil shock on the capital stock at time $t+1$ lasts for ten periods before it starts to die out. The effect of a temporary oil shock on labor hours is positive but small. The relatively small effect of oil shocks on both capital stocks and labor hours could be attributed to a lack of substitution of capital stocks and labor hours in the oil sector and those used elsewhere. Additionally, the oil sector is more of a resource endowment to the economy.

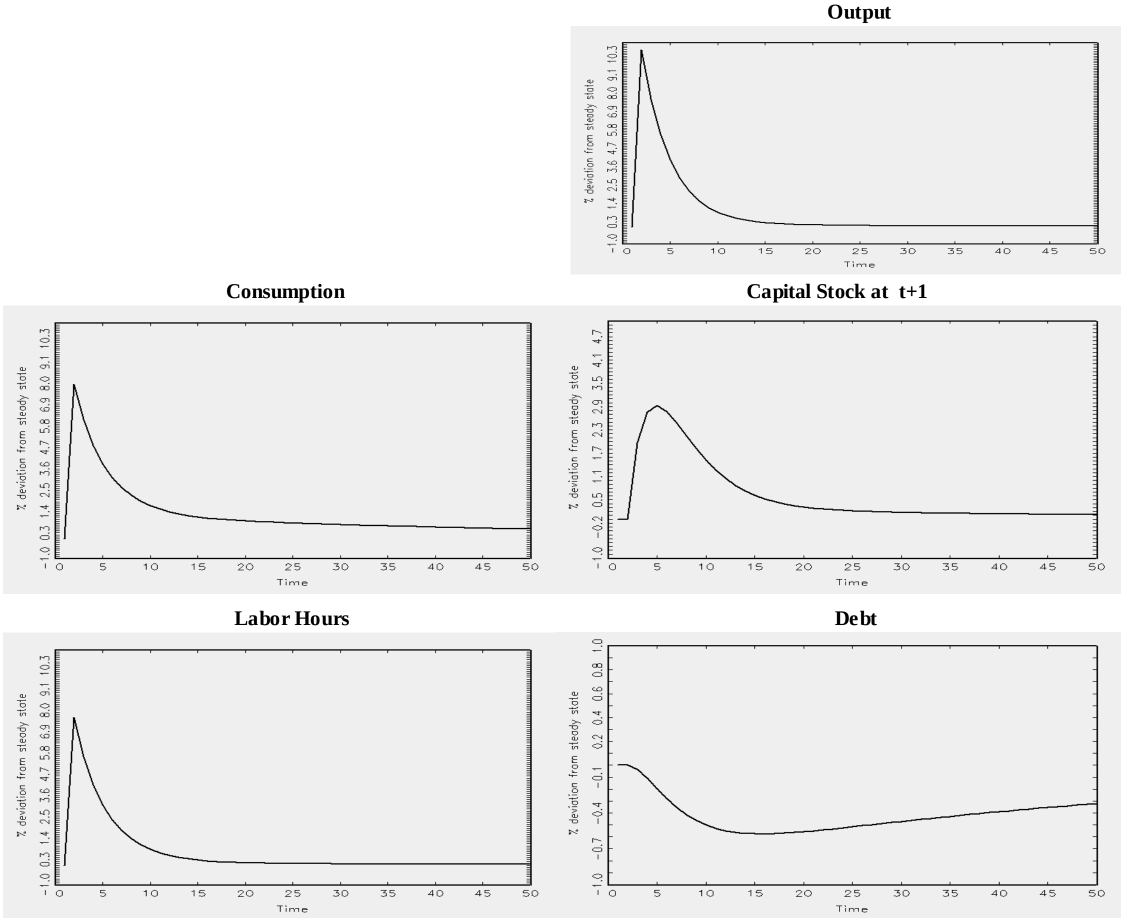
In this model, the agent smoothes consumption through international bond market operations and capital stocks. In response to a one standard deviation oil shock, the representative household will accumulate more saving as shown by the negative debt of 0.5% in the fifth period. The effect of the oil revenue shock on the debt dissipates after seven periods.

It is important to investigate the role that the Solow residual plays in economic fluctuations (Charles, 1989). Figure 2-2 shows the response of the variables to a one standard deviation transitory productivity shock. A sudden increase in productivity brings the economy to a booming cycle in which output is up 10.1 %.

A productivity shock in the economy leads to disequilibrium, making the capital stock purchases more attractive since MPK $> r$. The market mechanism works to arrive at the point where MPK= r. To allow for some incompleteness of the market, I include a capital adjustment cost in the model (Mendoza, 1991).

With high productivity, time spent on leisure is more expensive causing the demand for work to increase. Thus, labor hours increase by about 7%. In turn, this increases the demand for the consumption of goods and services, and this demand reaches a maximum in the third period prior to dying out.

Figure 2.2 Impulse Response of a One Standard Deviation Shock in Productivity



In addition, demand for capital stocks and international bonds increase for the purpose of consumption smoothing. In response to a one standard deviation temporary productivity shock, the representative household will increase its level of saving for 10 periods after the shock to smooth its consumption. This effect on saving reaches a maximum of 0.7% before beginning its convergence to the steady state. The effect of the productivity shock on output starts to die out after three periods and returns to the steady state after 15 periods. The IRFs show that the productivity shock on output is shorter lived than consumption or capital stock at time t+1.

6.1. Sensitivity Analysis

It is appropriate to judge the sensitivity of the different parameter values; thus, different parameter values for the model are assigned in this section. This helps to determine if the model produces different volatilities in response to alternative parameter values than that of the theoretical model. In his quote below, Kydland (1992) stresses the importance of sensitivity analysis:

> If all parameters could be accurately calibrated, then in principle only one computational experiment would be needed. In practice, however, the researcher will not have access to that much information. Consequently, some additional experiments, with different parameter values in a reasonable range, may be useful. These experiments may tell us either of two things. One possibility is that the answer is not sensitive to different values of a given parameter, in which case its measurement is not urgent. Alternatively, if the answer is indeed sensitive to values of an imprecisely measured parameter, then efforts directed towards its measurement could have considerable payoff (pp.477-478).

Table 2-3 shows the simulation results when the calibrated standard deviations are doubled for oil revenue and productivity. For the model volatility to increase substantially, a large increase in the magnitude of the shock is required. For example, doubling the standard deviation when both shocks are operative, the model produces 20.53, 28.69, 46.17, 22.71, and 8.22 compared to 10.27, 14.27, 22.71, 11.37, and 4.14 under the calibrated standard deviations for output, consumption, investment, labor hours, and the trade balance ratio to output, respectively.

When only one shock is operative, the statistical moment of the models doubled when doubling the calibrated standard deviation for the operative shock. Thus, the model is not very sensitive to changes in standard deviation. As expected, the size of standard deviation does not affect autocorrelations and cross correlations within the models.

Table 2.3 Simulation results when calibrated standard deviations are doubled for both shocks

	Data	Model with two shocks	Model with only Oil shock	Model with only productivity shock
Volatilities				
std(y_t)	7.28	20.53	5.33	19.80
std(c_t)	9.0	28.69	6.87	27.66
std(i_t)	16.0	46.17	1.66	45.98
std(n_t)	6.63	22.71	0.58	22.67
Std($\frac{tb_t}{y_t}$)	10.5	8.22	2.08	7.85

Table 2-4 reveals the simulation results under different parameter values of the intertemporal elasticity of substitution for labor supply, θ. The results are similar for varied values of the elasticity of substitution. The results show that there is no significant change in either the ordinal ranking or magnitude of the macroeconomic variables when different values for θ are assigned.

With either higher or lower values of θ assigned, the model will still produce the same statistical moments. The slight difference between the statistical moments results from running separate simulations. For example, with two shocks and a lower interval of intertemporal elasticity of labor, θ, the statistical moments are 10.27, 14.67, 22.64,11.35, and 4.14 compared to 10.27, 14.27, 22.71, 11.37, and 10.5 under the calibrated θ for output, consumption, investment, labor hours, and the trade balance ratio, respectively. When only the oil shock is operative at the upper interval of θ, the statistical moments are 2.66, 3.72, 0.98, 0.36, and 1.05 compared to 2.65, 3.42, 0.82, 0.29, and 1.04 when θ =2 for output, consumption, investment, labor hours, and the trade balance ratio, respectively.

Table 2.4 **Simulation results with** $\theta \pm 1$

Volatilities	Data	Model with two shocks		Model with only Oil shock		Model with only productivity shock	
		Lower interval	**Upper interval**	**Lower interval**	**Upper interval**	**Lower interval**	**Upper interval**
std(y_t)	7.28	10.27	10.26	2.64	2.66	9.90	9.97
std(c_t)	9.0	14.67	14.22	3.25	3.72	14.23	13.86
std(i_t)	16.0	22.64	22.69	0.60	0.98	22.66	22.80
std(n_t)	6.63	11.35	11.34	0.19	0.36	11.33	11.43
Std($\frac{tb_t}{y_t}$)	10.5	4.15	4.14	1.04	1.05	4.00	4.02

Table 2-5 shows the simulation results when different values for the capital share, α, is assigned. It is important to note that there is a tradeoff between the share of capital and that of labor.[14] With two shocks, the results indicate that with $\alpha = 0.3$ value, the investment volatility increases from 22.71 to 26.09, while the model still retains the same ordinal ranking.

Furthermore, the model with only an oil shock shows that despite different values of capital share α, the conclusion of the model does not change compared to what the results suggest when α is equal to 0.32. That is to say, the volatility for investment and labor hours produced by the model continue to be relatively small to that produced by the model with productivity shock. For example, the model produces the standard deviations of 1.18 and 0.45 for investment and labor hours, respectively when the share of capital α is increased to 0.36. Similarly, when productivity is the only shock, different values of physical capital share produce a marginal change in the values while it retains the ordinal volatility ranking of the variables. For example, the investment continued to be more volatile than consumption, while the latter is more volatile than output.

[14] By definition, both shares of capital and labor sum to one; and thus when the share of physical capital increases, then the share of labor must decrease.

Table 2.5 **Simulation results for different values of** α

Volatilities	Data	Model with two shocks		Model with only Oil shock		Model with only productivity shock	
		$\alpha = 0.3$	$\alpha = 0.36$	$\alpha = 0.3$	$\alpha = 0.36$	$\alpha = 0.3$	$\alpha = 0.36$
std(y_t)	7.28	10.57	9.63	2.66	2.7	10.22	9.26
std(c_t)	9.0	13.78	15.43	3.19	4.15	13.41	14.97
std(i_t)	16.0	26.09	16.69	0.71	1.18	26.08	16.66
std(n_t)	6.63	11.71	10.63	0.24	0.45	11.70	10.61
Std($\frac{tb_t}{y_t}$)	10.5	4.0	4.36	0.97	1.19	3.86	4.18

Table 2-6 reveals the simulation results under different values of the elasticity of the discount factor, Ω.The purpose of assigning different values for Ω is to see how the results respond to different rates of convergence to the long balance growth path.

Table 2.6 **Simulation results with** $\Omega \pm 0.066$

Volatilities	Data	Model with two shocks		Model with only Oil shock		Model with only productivity shock	
		Lower interval	Upper interval	Lower interval	Upper interval	Lower interval	Upper interval
std(y_t)	7.28	10.24	10.27	2.66	2.66	9.94	9.92
std(c_t)	9.0	7.50	17.14	1.77	4.16	7.34	16.50
std(i_t)	16.0	22.72	22.67	0.78	0.84	22.75	22.69
std(n_t)	6.63	11.33	11.36	0.27	0.29	11.38	11.36
Std($\frac{tb_t}{y_t}$)	10.5	29.63	4.89	20.63	1.24	21.38	4.71

The results indicate that different values for Ω affect mainly the volatilities for consumption and the trade balance ratio. With a higher value of Ω, the consumption volatility increases. The volatility of the trade balance ratio increases when Ω deviates from the value of 1.455.

To summarize, the results of the model do not change significantly under different values of the elasticity of substitution. Also, the conclusions of the different models under different values of capital share, with two shocks, and with a single shock do not change. Assigning different values for α produces different values in magnitude, while the models retain the same volatility ranking. The sensitivity analysis also indicates that assigning different values for Ω primarily affects the consumption and trade balance ratio. From the above experiments, different parameter values did not show any robust results and this leaves fewer suspicions about the "imprecisely measured parameter" in the future research agenda.

7.1. Conclusion

This chapter incorporates a portfolio adjustment cost so that the model produces volatility in both investment and labor hours when oil shocks are allowed. This model shows that investment and labor hours are functions of the oil shock when the portfolio adjustment cost equation is considered. While this model incorporates the portfolio adjustment cost, it continues to produce the same dynamics as the baseline model.

Next, I use the Impulse Response Functions (IRF) to evaluate the capability of the model. The IRF shows that a sudden transitory productivity shock has a larger effect on the macroeconomic indicators than an oil shock.

This research also finds that the model does not change significantly under different values of elasticity of substitution. In addition, assigning different values for α produces different values in magnitude, while the models retain the same volatility ranking. The sensitivity analysis also indicates that assigning different values for Ω only affects consumption and the trade balance ratio.

The theoretical model predicts that productivity could be the driving force of business cycles in Saudi Arabia. This finding is interesting and consistent with other studies on oil importing countries, such as Schmidt and Zimmermann (2005). The model with only the productivity shock continues to produce the most similar figures to that of the actual data, in terms of volatility magnitude. Thus, the theoretical model suggests that the role of oil price shocks in explaining real business cycles in Saudi Arabia should be downplayed compared to the role of productivity shocks.

The findings of the theoretical model could be further investigated. Thus, the next chapter explores empirically how real world oil price and productivity shocks affect output, consumption, investment, labor hours, and trade balance ratio for Saudi Arabia.

CHAPTER 3 - The Effect of World Oil Price Shocks on the Macroeconomic Variables: The Case of Saudi Arabia and its Primary Trade Partners

1.1. Introduction

The oil sector's role in the economy of Saudi Arabia has been decreasing through time. However, the oil sector's contribution since the 1970s has always been above 28% of total Gross Domestic Product (GDP). Even though the oil sector plays a prominent role in the Saudi economy, the role of oil price shocks versus other shocks in generating business cycles could be trivial. For example, the majority of Saudi jobs are in the non-oil sector, and in many cases, the economy has grown as oil-prices have decreased. Additionally, the share of non-oil GDP is currently more than two-thirds of total GDP and has more than doubled in the last 30 years. This chapter examines the relative importance of oil price shocks versus productivity shocks in explaining the economic fluctuation of Saudi Arabia and its primary trade partners.

There are few studies that examine the effect of real world oil price shocks on macroeconomic performance for both developed and developing countries. In addition, some studies, such as Aleisa and Dibooglu (2002) and Dibooglu and Aleisa (2004) omit significant oil price shocks in the 1970s and focus on the role of oil-prices on the real exchange rate and inflation in Saudi Arabia from 1980-2000. This research deviates from related literature in four specific aspects. First, this study considers a longer time horizon and covers the period from 1970 to 2005. Thus, it accounts for the significant real world oil price shocks of 1974 and 1979. Since the reasonable duration of business cycles assumed in most literature for developing countries is five years (Barro and Sala-i-Martin, 2004), it is therefore appropriate to capture this time dimension using annual data for Saudi Arabia. Second, the role of world oil price shocks on the disaggregated macroeconomic variables of Saudi Arabia is investigated as well as its major trade partners. Specifically, this study investigates the role of oil prices shocks on output, consumption, investment, labor hours, and trade balance ratio to output. Third, this study examines the role of real world oil price shocks versus productivity shocks. Fourth, this study documents the stylized facts of business cycles of primary trade partners with Saudi Arabia and examines the aspects of the international business cycle. Since 2000, oil prices have been rising; however there are no relevant studies to examine the potential of oil prices shocks transmission to the Saudi Arabian economy. This study intends to fill this gap.

The objective of this chapter is to empirically investigate how real world oil price and productivity shocks affect output, consumption, investment, labor hours, and the trade balance output ratio for Saudi Arabia. This chapter complements the theoretical model of chapter one. In addition, this study builds a foundation for future studies in examining the impact of real world oil price shocks on the economies of the most significant trade partners of Saudi Arabia.

To achieve this objective, I employ the Granger Causality test to examine the validity of the assumption that world oil prices are exogenous to the Saudi economy. Next, I examine the role of world oil prices versus productivity shocks in explaining the variation in output, consumption, investment, labor hours, and trade balance ratio to output using Forecasting Error Variance Decomposition (FEVD) for Saudi Arabia and its primary trade partners. Third, I display the Impulse Response Function (IRF) to examine the response of macroeconomic variables to transitory and permanent shocks of oil prices and productivity for Saudi Arabia. Finally, I compare aspects of the results between Saudi Arabia and its primary trade partners. In conclusion, I present the implications of these findings.

The chapter is organized as follows: Section 1 examines the economic performance of the Saudi Arabian economy throughout the changes and developments of real world oil prices during the last three decades. Section 2 presents a literature review of the relevant studies to the subject. Section 3 examines the assumption that real world oil prices are determined exogenously to the Saudi economy. Section 4 discusses the Vector Autoregressive methodology and restrictions used in this chapter. Section 5 gives an outline of the data sources utilized in the chapter. Section 6 contains the empirical findings from variance decomposition and impulse response functions to evaluate the bilateral short and long run relationship between real world oil prices and real GDP, investment, labor hours, consumption, and trade balance ratio to the output for Saudi Arabia. Section 7 also addresses the relative importance of the shocks in explaining the variation of the main macroeconomic variables of Saudi Arabia's primary trade partners and examines the effect of transitory real world oil price shocks on their economic activities. Section 8 contains the properties of business cycles of Saudi Arabia and its primary trade partners. Concluding remarks and policy recommendations are given in Section 9.

1.2. Economic Performance

The level of world oil price effects on total oil revenue has influenced the economic development of Saudi Arabia over the last three decades. For example, high oil revenue enables policymakers to finance government expenditures on development projects. Since 1970, Saudi Arabian policymakers have adopted new comprehensive economic plans every five years. The primary goals of these plans are to keep economic diversification and to decrease the economic reliance on oil. Thus, it is essential to conduct empirical analyses regarding the economic performance of Saudi Arabia.

1.2.1. Consumption

The final consumption of goods and services has gone through different stages, while it continues to be the largest component of the total national expenditure of Saudi Arabia. Table 3-1 shows that in 1970 the total consumption contributed only 30% of the total national expenditure. However, this percentage shows a drastic increase, reaching 91% by 1985. This increase is associated with a large increase in private consumption relative to government consumption.

Table 3.1 The Structure of Final Consumption (Constant Prices)

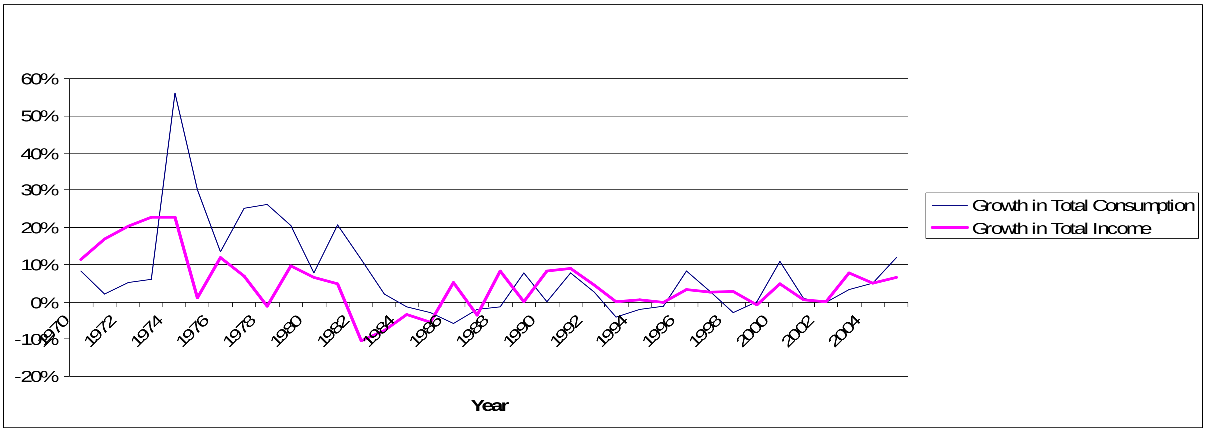
Year	% Government[15] Consumption in GDP	% Private Consumption in GDP	% Total Consumption in GDP
1970	13	17	30
1975	18	15	33
1980	25	29	54
1985	39	52	91
1990	30	45	75
1995	23	44	67
2000	29	42	71
2005	33	39	72

Source: Ministry of Economy and Planning, Saudi Arabia, 2006.

Since 1977, the government consumption expenditures have never exceeded that of private expenditures. Figure 3-1 shows that the growth rate of total consumption was greater than that of total income from 1974 to 1985. In addition, the non-correspondence in the movement between growth in consumption and that of total income could be attributed to consumption smoothing by the agents within the economy.

[15] This excludes government expenditure on fixed capital formation.

Figure 3.1 Growth Rates of Real Total Consumption and Real GDP



Source: Ministry of Economy and Planning, Saudi Arabia, 2006.

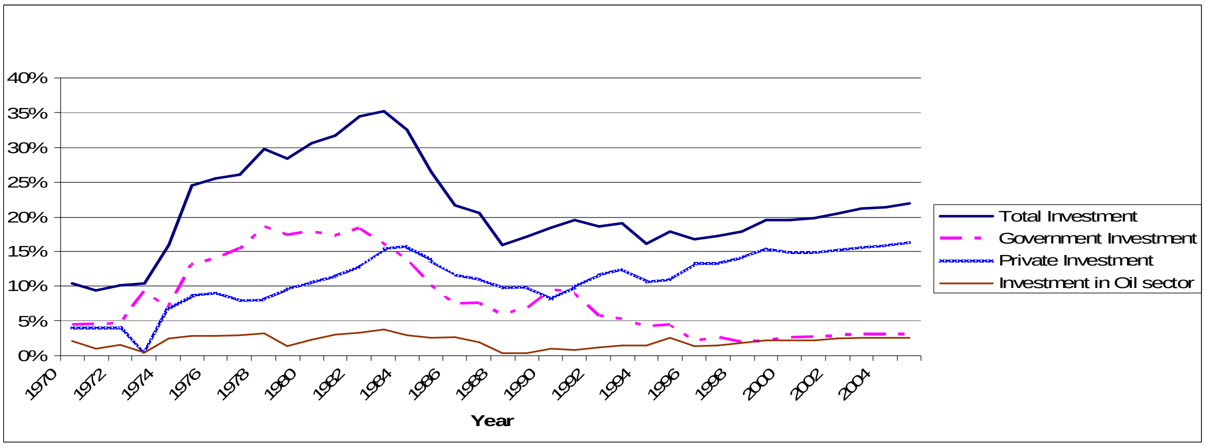
Specifically, consumption habits could be an essential aspect in explaining the non-parallel movement between the growth rates of total real consumption and real GDP. From the 1970s until the early 1980s consumption was relatively more important than investment because the level of industrialization was in its early stages (Alabeed and Ateeah, 1994). It should be noted that when the economy experienced a recession during the early 1980s, the total consumption was still increasing. After the mid-1980s, the growth rate of total consumption began to move more closely with the growth of real GDP. This change was due to policymakers' efforts to change the structure of expenditure on GDP in favor of total investment expenditure, especially those in the private sector. At the same time, policymakers have increased the efficiency of government expenditures and have increased the efficiency of managing economic resources (Ministry of Economy and Planning, 2004).

1.2.2 Investment

By definition, total investment consists of both non-oil and oil investment. The total non-oil investment consists of private and government investment components. The ratio of government non-oil investment to total investment shows a decreasing trend. Figure 3-2 shows that the share of government investment was relatively high in the 1970s. This can be attributed to high oil revenue that was invested in the fixed capital formation; consequently, Saudi Arabia's infrastructure and its development have been effected by oil revenue. In 1982, a decrease in oil revenue caused a decreased share of government investment to total investment. Although the ratio of government investment decreased, the total investment continued to grow until 1984 due to increased private investment. The share of total investment to real GDP increased through time to reach a maximum of 35% in 1982. Then, the share of total investment showed a drastic decline following the completion of key economic projects. After 1984, the shares of investment by government and private sectors declined, and the share of private investment continued to be higher than that of government.

Figure 3-2 shows that the share of oil investment is moderate and has always been much lower than non-oil investment shares.

Figure 3.2 Share of Investment of Total Real GDP by Category



Source: Saudi Arabian Monetary Agency (SAMA), Saudi Arabia, 2006.

Table 3-2 shows the structure of Gross Fixed Capital Formation (GFCF). It is important to note the clear increase in the role of the private sector in the economy from this table. More specifically, the share of private investment to total investment nearly doubled from 38% in 1970 to 74% in 2005. However, the role of government investment in the economy has been decreasing through time. The ratio of government oil and non-oil investment to total investment declined from 62% in 1970 to 26% in 2005.

The role of the private sector and its contribution to total GDP increased from 33% in 1970 to about 51% in 1999. The number of privately operated factories increased from 199 in 1970 to 3123 in 1999, while the number of private sector companies increased from 923 to 9302 for the same period.

Table 3.2 The structure of Gross Fixed Capital Formation.

Year	Oil Sector	Non-Oil Sector		Total Non-Oil Sectors	Total
		Government	Private		
1970	20%	42%	38%	80%	100%
1975	12%	53%	35%	88%	100%
1980	8%	58%	34%	92%	100%
1985	10%	38%	52%	90%	100%
1990	5%	51%	44%	95%	100%
1995	14%	25%	61%	86%	100%
2000	11%	13%	75%	88%	100%
2005	12%	14%	74%	88%	100%

Source: Ministry of Economy and Planning, Saudi Arabia, 2006.

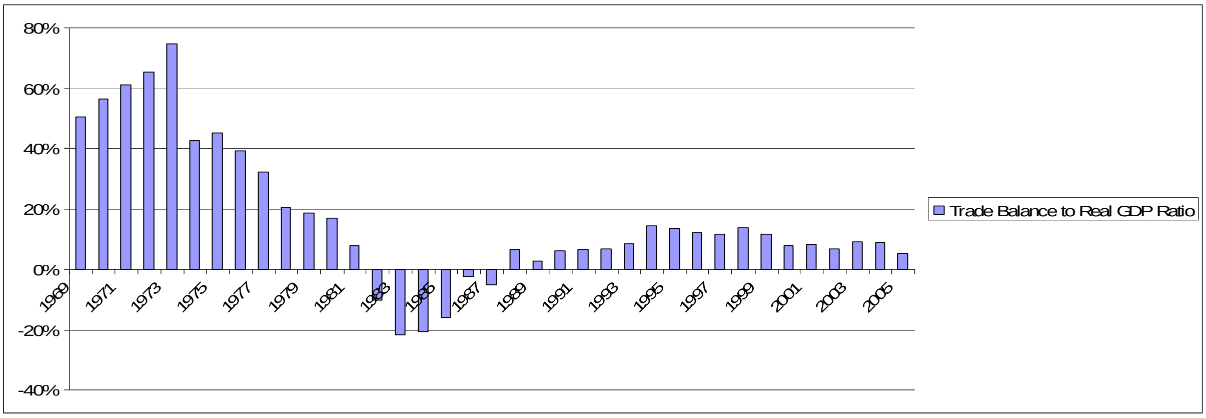
The private sector accounted for 87% of total employment in 2004 compared with 83% in 1991 (Ministry of Economy and Planning, 2005). The development of non-oil private sector has been the primary objective of Saudi government policies and is consistent with its emphasis on reducing the economic reliance on the oil sector. Since Saudi Arabia is a small open economy that interacts with other countries, its international trade is worth investigating.

1.2.3 Trade Balance

The trade balance is the difference between value of exports and imports. The trade balance relative to real GDP for Saudi Arabia has shown an opposite trend to that of the consumption and investment ratios to real GDP. Recall that from 1970 to 1985, the consumption ratio to real GDP shows an increasing pattern. The investment ratio to real GDP also has an increasing pattern from 1970 to 1983. However, Figure 3-3 shows that trade balance ratio to real GDP has a decreasing pattern until 1985.

Saudi Arabia experienced a slight trade deficit from 1981 to 1985 because of a sharp decline in the volume of exports associated with a relatively high level of imports. However in 1989, the volume of exports began to increase relative to imports. Figure 3-3 shows that the trade balance ratio at the beginning of the century is much smaller than that of the 1970s even though both eras had relatively high real oil prices. This gives evidence that the world oil prices are important but do not have a dominant role in determining the trade balance ratio of Saudi Arabia.

Figure 3.3 Trade Balance to Real GDP Ratio



Source: Ministry of Economic and Planning (2006).

Saudi Arabia is heavily engaged in international trade. A large portion of its trade occurs with developed countries, since developed countries import large amounts of crude oil to operate their economies. In 2004, oil exports were about 85% of total exports, while the ratio of oil exports to real GDP was 33% for the same year. The trade balance ratio to real GDP shows only a slight surplus.

As the economy of Saudi Arabia is integrated with the world economy, a recession or boom cycle in a developed country may have an effect on developing countries like Saudi Arabia. To examine this theory, it is important to compare the stylized facts of business cycles in Saudi Arabia with the stylized facts of its trade partners.

Primary Trade Partners:

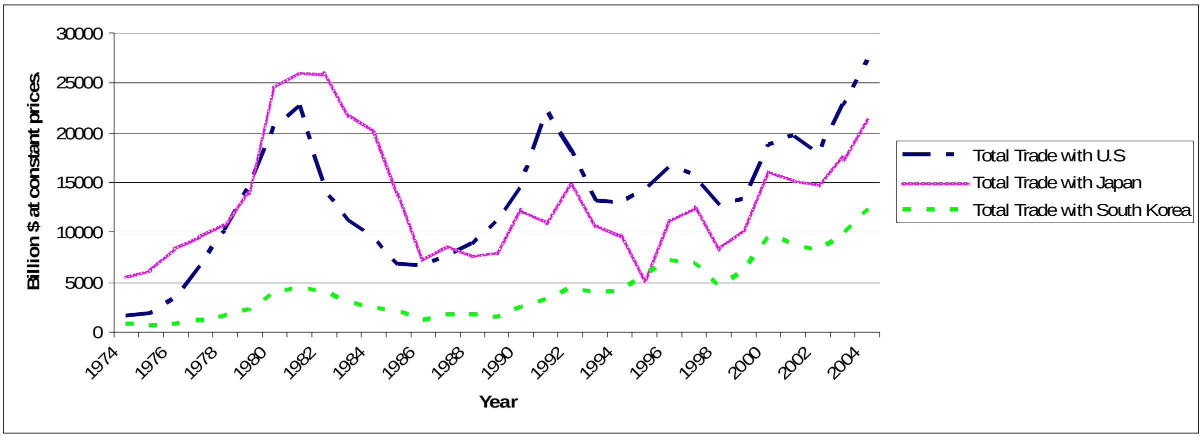
The largest trading partners of Saudi Arabia are the United States, Japan, and South Korea, respectively in 2005. A long time-series of data on total trade for Saudi Arabia with trade partners is not attainable from a single source. Thus, the data is drawn from several publications of the Direction of Trade Statistics (DOTS).

Figure 3-4 shows that the total trade with primary trade partners has fluctuated over the last three decades. In 1976, the total trade between the U.S. and Saudi Arabia grew by 82%; while the U.S. real GDP grew by 4.3% for the same period compared to 1975 (Penn World Table, 2007).

The volume of total trade between the U.S. and Saudi Arabia grew rapidly throughout the 1970s, including a growth rate of 98% in 1977 compared to 1976. The U.S. economy grew at a rate of 3.2% during the same year. However, in 1993, the total trade between the U.S. and Saudi Arabia dropped by 27%, and Saudi Arabia experienced zero economic growth. In 2000, both the

U.S. and Saudi economies grew at rate of 2.4 % and 5%, respectively, in comparison with 1999, and their total trade transactions grew at rate of 42%.

Figure 3.4 Total Trade with Primary Trade Partners



Source: Direction of trade statistics, several publications (DOTS). (1981, 1993, 2000, 2002, 2005)

The Japanese economy experienced negative growth of 1.2% beginning in 1998 and continued with negative growth until 2003. However, there is mixed evidence in the trend of total trade with Saudi Arabia as shown in Figure 3-4.

In 1998, the total trade between Saudi Arabia and South Korea dropped by 31%, a period where that the latter experienced a negative growth of 6.4%. Then, the South Korean economy experienced a recovery from the Asian crises. South Korea experienced a positive growth rate of 6.1%, while the total trade transactions with Saudi grew by 22% for the same period. The importance of these countries to the Saudi economy can be seen through calculating the dependency ratio as follows: [16]

$$D_t = \frac{X_{st} + M_{st}}{X_{wt} + M_{wt}}$$

[16] This formula is used by Alam's (2007) study. The incentive for using the dependency ratio formula is that it gives information about the level of reliability or engagement in trade between particular econmies.

where, D_t represents the trade dependency ratio of Saudi Arabia. X_{st} is Saudi's exports to trade partners, and M_{st} is Saudi's imports from this trade partner. X_{wt} and M_{wt} represent Saudi's total world exports and Saudi's total world imports, respectively.

Table 3-3 reveals that the trade dependency ratios of the Saudi Arabian economy could be contingent on the business cycles. Table 3-3 provides motivation to compare the stylized facts of business cycles between primary trade partner countries and Saudi Arabia. The dependency ratio indicates that the Saudi Arabian economy was relatively more dependent on trading with Japan in the mid-1970 to mid-1980s. However, the dependency ratio of Saudi Arabia with the U.S surpassed that of Japan in the mid-1980s. Meanwhile, the dependency ratio on South Korea has steadily increased since 1974, even though the ratio is still less than the U.S. and Japan.

Table 3.3 Dependency Ratio of Saudi Arabia

Year	United States	Japan	South Korea
1974	5%	16%	2%
1980	16%	19%	3%
1986	17%	16%	3%
1992	20%	18%	5%
1998	19%	12%	7%
2004	17%	13%	8%

Source: Direction of Trade Statistics (DOTS), IMF, and authors calculations.

In the next section, I briefly present the most recent papers relevant to the subject matter. The review presents the contribution by several authors for both developed and developing countries.

2.1. Literature Review

There are a large number of studies examining the role of different shocks in explaining macroeconomic fluctuation for different countries using Vector Autoregressive (VAR). These studies incorporate the examination of a variety of shocks including monetary policy shocks, oil price shocks, productivity shocks, and fiscal policy shocks on the movement of real exchange rates and economic growth in different countries. This section reviews relevant studies that utilized similar VAR methodologies, that incorporate oil prices as an exogenous external shock, and that focus on less developed countries.

Aleisa and Dibooglu (2002) investigate the role of real world oil price shocks in explaining exchange rate movements in Saudi Arabia. The authors use a simple Vector Autoregressive (VAR) framework. The objective of their paper is to examine to what extent world price shocks are able to explain the exchange rate movements in Saudi Arabia. This study uses a monthly data set from 1980 to 2000. The findings of this paper do not support the importance of world oil price shocks in explaining the exchange rate movements in Saudi Arabia.

In addition, Aleisa and Dibooglu (2004) investigate the role of terms of trade shocks in explaining the fluctuations in aggregate output, the exchange rate, and the price level using a VAR. This study uses quarterly data from 1980 to 2000. Since quarterly data for output is not available for Saudi Arabia, the authors use a proxy of oil production in Saudi Arabia. The authors also use real oil prices as a proxy for the terms of trade, as they assume that the price of Saudi Arabian imports is the numeraire. This study found the terms of trade shocks explain a larger proportion of the variation of exchange rate than those for output and inflation.

Berument and Ceylan (2005) examine the role of oil price shocks on the economic growth of some Middle East and North African countries (MENA).[17] The authors use a simple VAR model where the growth rate of GDP does not enter the specification of the real world oil prices. The study uses annual data from 1960 to 2003. Due to data constraints, the data range used in the study differs across countries with respect to years. The data in this study are obtained from International Financial Statistics (IFS). The findings of this study indicate that a transitory real world oil price shock has a statistically significant impact on the economic growth of Algeria, Iran, Iraq, Jordan, Kuwait, Oman, Qatar, Syria, and Tunisia. Further, the authors find that real world oil price shocks have an instantaneous positive effect on economic growth for all countries, regardless of whether the country is a net oil-exporter or a net oil-importer.

Olomola and Adejmo (2006) investigate the role of real world oil price shocks in explaining macroeconomic fluctuations for the country of Nigeria. The authors examine the contribution of real world oil price shocks to account for the variability in the real exchange rate, output, money supply, and inflation. The authors use quarterly data that cover the time span from 1970 to 2004. The authors utilize the Consumer Price Index (CPI) as a proxy for inflation. They measure the real world oil prices by using the domestic price of crude oil deflated by CPI. The authors use the VAR method and employ forecasting error variance decomposition to conduct an analysis of a unit shock spread to the variables in the system. The findings of this study indicate that real world oil price shocks carry an insignificant effect on the macroeconomic activities as measured by real GDP. The results also indicate that real world oil price shocks explain a significant part of real exchange rate variability.

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[17] The countries included in their study are Algeria, Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, U.A.E, Yemen, Djibouti, Egypt, Jordan, Lebanon, Morocco, Syria, and Tunisia.

Ayadi (2005) investigates primarily the relationship between real world oil prices and industrial production in Nigeria. The study uses quarterly data that covers the period from 1980 to 2004. This study uses a VAR where the author assigns forecasting error variance decomposition to examine the contribution of the oil shock to the variables in the system. Ayadi examines the contribution of real world oil price shocks on real exchange rate, discount rate (using interest rate as a proxy), industrial production, money supply, and inflation. The findings of forecasting variance decomposition indicate that the contribution of real world oil price shocks to the variation in inflation, discount rate, real exchange rate, and industrial production are 0.84 ,0.58, 0.30, 1.33 of the variables, respectively.

3.1 Causality Test

A simplifying assumption often made in the literature is worth discussing. It is commonly believed that oil prices are determined by the political environment and not primarily controlled by a profit-maximizing firm. In particular, the role of Saudi Arabia as the largest global oil producer is not dominant. This argument can be supported in a variety of tests. The Granger Causality test is one method which supports the assumption that the world oil price is exogenous to the Saudi economy. The null hypothesis claims that Saudi production of oil does not Granger Cause real world oil price changes.

An assumption underlying the standard estimation procedures is that the time series are stationary, in the sense that the mean and variance are independent of time. However, many economic time series are not stationary and change over time (Nelson and Plosser, 1982). Non-stationarity is usually removed by taking first differences. I use time-series statistical tools to test for the stationarity of the data.

Stationarity and Unit Root Test

The Augmented Dickey-Fuller (ADF) unit root test was applied to the two-time series variables of Saudi's oil production Q_s and real world oil prices P_w. Table 3-4 reports the results of the ADF of unit root tests and the results for Phillips-Perron controlling for serial correlations. Based on the reported results in Table 3-4, the null hypothesis of a unit root cannot be rejected for the levels of each variable. The test of the ADF for oil production of Saudi Arabia at its level shows that both the ADF statistic values are -2.16 and -2.1 without and with trend, respectively. These are less in absolute values than their corresponding critical values at the 5% significance level. In addition, for both variables real world oil prices and Saudi's oil production are not stationary when controlling for the serial correlation because the PP statistics values are less in absolute values than the critical values. To achieve stationarity, I differenced both Saudi's oil production and real world oil price time-series data. The results show evidence that each time-series is integrated of order one; that is, each series is I (1). In the other words, both variables are stationary at the first difference where ADF and PP statistics are greater in their absolute values than their corresponding critical values.

Table 3.4 ADF and PP Tests for Stationarity of the Time Series

Variable	Level				First difference			
	ADF		PP		ADF		PP	
	Without trend (-2.94)	With trend (-3.54)	Without trend (-2.94)	With trend (-3.54)	Without trend (-2.94)	With trend (-3.54)	Without trend (-2.94)	With trend (-3.54)
Q_S	-2.16	-2.1	-2.43	-2.37	-4.75	-4.67	-4.74	-4.65
P_w	-1.86	-1.98	-1.95	-1.98	-5.04	-4.95	-5.04	-4.95

The 5% critical values are given in parentheses

Next, the procedure for Granger Causality follows Gujarati (2003). First, I regress the oil prices only on all lagged oil price terms as follows:

$$\Delta P_w = \sum_{i=1}^{n} \varphi_i \Delta P_{t-i}$$

where ΔP indicates the differenced variable of real world oil prices that is a function of its lagged variable, and φ_i represents those coefficients of the lagged real world oil prices. Table 3-5 reports the values for Akaike information criterion (AIC) and Schwarz information criterion (SIC) for choosing the proper lagged variables. Both AIC and SIC are reliable criteria to choose the appropriate number of lagged variables, while SIC penalize more for adding more regressors to the model (Griffiths, et al., 1993).

Table 3.5 The criteria for choosing the lag length for real world oil price

Number of lags	AIC	SIC
1	4.13	4.18
2	4.23	4.32
3	4.32	4.46
4	3.98*	4.173*
5	4.029	4.263
6	4.138	4.421
7	4.26	4.59
8	4.38	4.76

* indicates the lowest value.

The residual obtained from this regression is called the restricted residual sum of squares ($RSS_{restricted}$). The lowest values for both AIC and SIC are associated with number of lags equal to four. The regression results including the lagged values for the differenced Saudi oil production series is shown in Table 3-6, which reports the criteria values of AIC and SIC. Both criteria suggest that the number of lags should equal one.

Table 3.6 The criteria for choosing the lag length for Saudi's oil production

Number of lags	AIC	SIC
1	3.93*	4.17*
2	4.00	4.28
3	4.03	4.35
4	3.96	4.33
5	3.96	4.38
6	4.06	4.53
7	4.09	4.62
8	3.96	4.53

* indicates the lowest value.

Therefore, the unrestricted residual ($RSS_{unrestricted}$) can be obtained for the following estimated regression:

$$\Delta P_t = \sum_{i=1}^{4} \varphi_i \Delta P_{t-i} + \varpi \Delta Q_{t-1}$$

where φ_i represents the coefficient for the four lagged variables for real world oil price, and ϖ is the coefficient for the lagged variable for the Saudi oil production. Again the intent is to test the null hypothesis, $H_0 : \varpi = 0$, meaning the lagged Q term does not belong to the specification. Hence, to test this hypothesis, I use the F-test as follows:

$$F_{estimated} = \frac{(RSS_{restricted} - RSS_{unrestricted})/J}{RSS_{unrestricted} /(T - k)} = 3.45$$

where J represents the number of lagged Q terms. The k term is the number of estimated coefficients in the unrestricted model, and T represents the number of observations. Therefore, in this model the critical F-value is 4.18 for (1 and 29 degrees of freedom). The results from the Granger Causality test show that the estimated F-value is smaller than the critical F-value at the 5% level. Therefore, the null hypothesis is not rejected. This result suggests that there is no direction of causality from Saudi production of oil to real world oil price. Thus, real world oil prices can reasonably be modeled exogenously to the Saudi economy.

4.1. Methodology

The role of real world oil price shocks in explaining macroeconomic fluctuation in Saudi Arabia is dynamic rather than static. According to Sims (1980), the VAR approach is useful to study the relationship among economic variables (Enders, 2004). Thus, this chapter uses Vector Autoregressive (VAR) to capture the dynamic relationship among the variables of interest. More specifically, this study uses a methodology of Structural Vector Autoregressive (SVAR) similar to that by Cushman and Zha (1997). This chapter accounts for two shocks, real world oil price and productivity shocks. In addition, the method involves imposing restrictions on VAR residual supported by economic theory. It is reasonable to claim that a real world oil price can affect Saudi macroeconomic variables. However, the size of the Saudi Arabian economy is relatively small compared to the rest of the world so cannot significantly affect real world oil prices. Thus, the block recursive model used in this chapter says that real world oil price is determined by its own lags. Also, none of the lagged macroeconomic variables of Saudi Arabia enter the real world oil price specification. Real world oil price shocks, through their transmission to the Saudi government revenue, could affect the productivity within the economy. As the global economy observes the price shock in the oil market, it creates incentives for technology transfers to the Saudi economy. Consequently, the lagged real world oil prices enter the specification for productivity. However, the lagged macroeconomic variables of Saudi Arabia do not enter the productivity specification. In addition, an increase in productivity through technology transfers increases labor productivity and earnings.

The model, using matrix notations, can be written:

$$D(L)x(t)=\varepsilon(t) \tag{1.1}$$

where $x(t)$ is a 3×1 vector of observations; $D(L)$ is the 3×3 matrix polynomial in the lag operator L; and $\varepsilon(t)$ is the 3×1 vector of structural shocks. Thus, the specification of the model is as follows:

$$x(t)=\begin{bmatrix}P_t\\Z_t\\EV_t\end{bmatrix}, D(L)=\begin{bmatrix}D_{11}(L) & 0 & 0\\D_{21}(L) & D_{22}(L) & 0\\D_{31}(L) & D_{32}(L) & D_{33}(L)\end{bmatrix}, \varepsilon(t)=\begin{bmatrix}\varepsilon_1(t)\\\varepsilon_2(t)\\\varepsilon_3(t)\end{bmatrix} \tag{1.2}$$

where P_t represents real world oil prices. Z_t represents the productivity and EV_t represents the endogenous variable of interest, that is, real output, consumption, investment, trade balance ratio, or labor hours. $D(0)$ is assumed to be non-singular, and $\varepsilon(t)$ is uncorrelated with past $x(t-h)$ for $h>0$.

The restrictions are $D_{12}(L)$=0 and $D_{13}(L)$=0, so that the block exogeneity restrictions imply the first block P_t is exogenous to the second Z_t and third EV_t blocks. To choose the lag order for identified VAR, the Schwarz information criterion is the basis for choosing the proper number of lags.

5.1. The Data

Annual data on gross domestic product (GDP), consumption, investment, exports, and imports from the period of 1970 to 2005 at constant values are from Saudi Arabian Ministry of Economy and Planning (2005), *Achievement of the Development Plans Facts and Figures*. Due to unreliable data from the period of 1923 to 1969, this chapter uses post-1969 data. Following Kose (2001, 2002), I use an employment proxy since there are no data available for labor hours. The data on exports and imports with Saudi Arabia's largest trade partners are drawn from several publications of the *Direction of Trade Statistics* (DOTS), IMF, 1981, 1993, 2000, 2002, and 2005 issues. The data of Saudi oil production are drawn from British Petroleum Company (BP, 2006) reports. The world real oil prices are obtained from the OPEC publications. The quarterly data of gross domestic product (GDP), consumption, investment, exports, and imports from the period of 1970:01 to 2004:04 for primary trade partners are obtained from *International Financial Statistics* IFS (2005). The civilian employment data for Saudi's primary trade partners are drawn from *Organization for Economic Co-operation and Development Main Indicators* OECD (2007). Civilian employment data for South Korea are available only for post-1982:02. I used the Solow residual as a measure of the productivity, Z as follows:

$$\log Z = \log y - (1-\alpha)\log L$$

where y and L are real output and labor hours, respectively. The capital stock from the Solow residual equation is omitted for many reasons, including that data on capital stocks are not available (Backus et al., 1995). The α parameter is set to 0.32 because the share of labor in output is often between 0.3 and 0.4 (e.g. Mendoza, 1991; Blankenau et al., 2001).

6.1. Empirical Results:

The Hodrick Prescott filter (HP) is used to de-trend the variables series in this study. The lag length is chosen based on Schwarz information criterion and summarized in Table 3-7:

Table 3.7 Lag Criteria Selection

Country	Lag length
Saudi Arabia	1
United States	5
Japan	5
South Korea	5

I estimate the VAR after imposing restrictions: $D_{12}(L)$=0, $D_{13}(L)$=0, and $D_{23}(L)=0$. The dynamic effect of real world oil prices and productivity shocks can be analyzed by variance decomposition and impulse response functions (IRF). Table 3-8 reveals the variance decomposition of the main macroeconomic variables in the case where there are two shocks, real world oil price and productivity shocks. The forecast error variance decomposition tells us the variation of the variable due to external shocks, where the external shocks in this chapter are real world oil prices and productivity. Thus, variance decomposition examines the relevance of the shocks. The results suggest that productivity shocks explain a large proportion of the variation in the output scaled to 62.2% in the first period; while real world oil price shock explains 12.5%. The role of real world oil price shock in the variation of the output decreased by half in the long run. Yet a productivity shock continues to explain a large variation of the output in the longer time horizon. The result is consistent with the theory that when the real world oil price shock occurs, it creates incentives for technology transfers to the Saudi economy. The productivity increases, as a result of technology transfers, imply that the technology parameter enters the production function directly as follows:

$$Y_t = Z_t K_t^{\alpha} L_t^{1-\alpha}$$

where Y_t represents output. Z_t is a productivity index, K_t is physical capital, and L_t is the time the representative agent spends working. α is the capital share such that $0<\alpha<1$.

Furthermore, Table 3-8 shows that real world oil price and productivity shocks explain 29.5% and 0.46%, respectively, of the consumption variation in the first period. The role of productivity shock largely increases in the first five periods. This is consistent with the fact that agents become optimistic about the future economy in the case of a real world oil price shock. This apparently carries an effect on the agent's productivity later. The real world oil price shock will appear to be a permanent shock to the expected lifetime income, so this increases consumption instantaneously. This result is consistent with consumption smoothing.

Table 3.8 Variance Decomposition of the Main Macroeconomic variables for Saudi Arabia

Horizon	***Output***		***Consumption***		***Investment***		***Trade balance Ratio***		***Labor hours***	
	Oil Shock	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*
1	12.5	62.2	29.5	0.46	28.9	8.47	15.94	8.3	0.379	46.89
2	8.4	70.61	38.4	6.39	34.18	33.8	26.17	7.3	0.29	36.7
3	7.1	74.99	40.2	14.11	29.42	48.02	30.04	6.73	0.294	31.672
4	6.66	75.99	38.95	18.5	25.8	53.9	30.6	6.8	0.29	30.48
5	6.46	75.31	37.7	19.7	24.96	54.93	30.42	6.8	0.283	31.03
6	6.36	74.4	37.32	19.5	25.56	54.2	30.35	6.85	0.278	31.86
7	6.3	73.71	37.43	19.3	26.15	53.65	30.4	6.85	0.276	32.41
8	6.3	73.43	37.54	19.4	26.4	53.6	30.4	6.85	0.276	32.6
9	6.3	73.4	37.53	19.6	26.3	53.7	30.4	6.85	0.276	32.68
Long run	6.3	73.4	37.48	19.6	26.3	53.8	30.4	6.85	0.276	32.66

In addition, the real world oil price shock explains 28.9% of the variation in investment in the first period; while productivity explains only 8.47%. The role of productivity shocks in explaining the variation in investment increases through time so that it is relatively more important than real world oil price shocks in the long run. With higher expected lifetime income, the agent consumes and invests more. The increase in investment causes the capital stock to rise. The increase in the capital stock indirectly causes the productivity to increase. The real world oil price shock explains a relatively larger proportion in the variation of trade balance ratio to output than the productivity shock in the first period. In the long run, the results show that 30.4% and 6.85% of the variation in trade balance ratio is explained by real world oil price and productivity shocks, respectively. The role of real world oil price shock seems to be trivial to labor hours. A plausible explanation of this result comes from the fact that the oil sector is capital intensive rather than labor intensive.

Impulse Response Function:

The Impulse Response Functions (IRF) examine the macroeconomic variables' response to a single transitory shock in real world oil prices and productivity, respectively. Figure 3-5 shows the response of macroeconomic variables to a single temporary shock in real world oil prices. A sudden increase in the real world oil price has a statistically significant impact on the real output only in the first period, while it has no statistically significant impacts thereafter. This is consistent with the theoretical model that suggests that real price shocks are quantitatively unimportant to the volatility to the overall economy. A temporary one standard deviation increases in real oil price shock increases consumption significantly by 3.1%. However, the effect of this transitory shock on consumption begins to die out in the second period. This shock is statistically insignificant after the third period.

In addition, a one standard deviation shock in real world oil price increases the investment by 4.1%. The effect of this shock begins to die out after the second period, becoming statistically insignificant. It should be noted that a sudden world oil price shock leads to an immediate increase in both consumption and investment; this is consistent with the fact that economic agents become more optimistic about achieving a higher expected permanent income.

The effect of the real world oil price shock on labor hours is not statistically different from zero. A one standard deviation shock in real world oil prices leads to an immediate decrease in the trade balance ratio in the first period. This shock is negative and statistically significant. The effect of the shock trade balance ratio begins to die out after the second period. This clearly shows that an increase in the real world oil price does not necessarily lead to an increase in the trade balance ratio. The immediate effect of the real world oil price shock on trade balance ratio is sensible given a rise in the transport cost of the imported goods by Saudi Arabia.

Figure 3.5 Effect of Single Transitory Real World Oil Price Shock on the Macroeconomic Variables for Saudi Arabia.

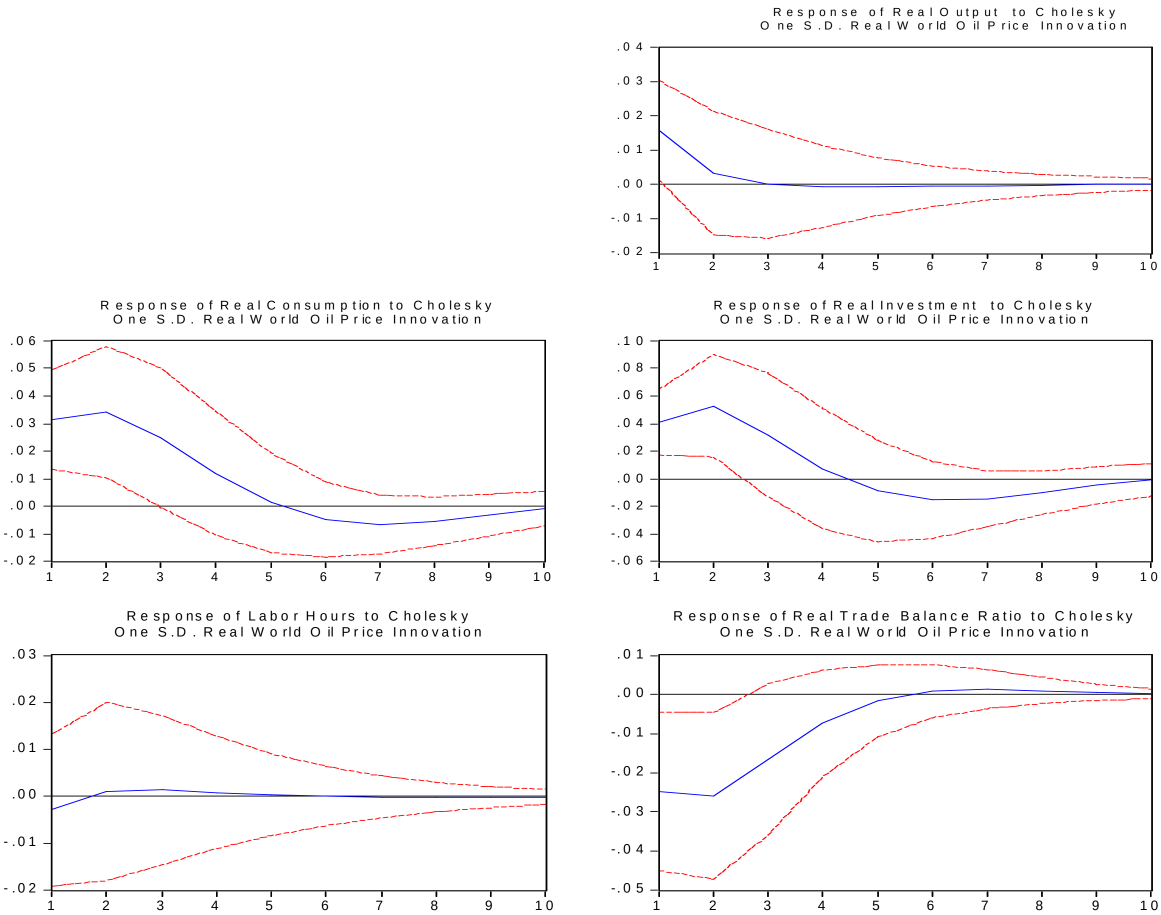
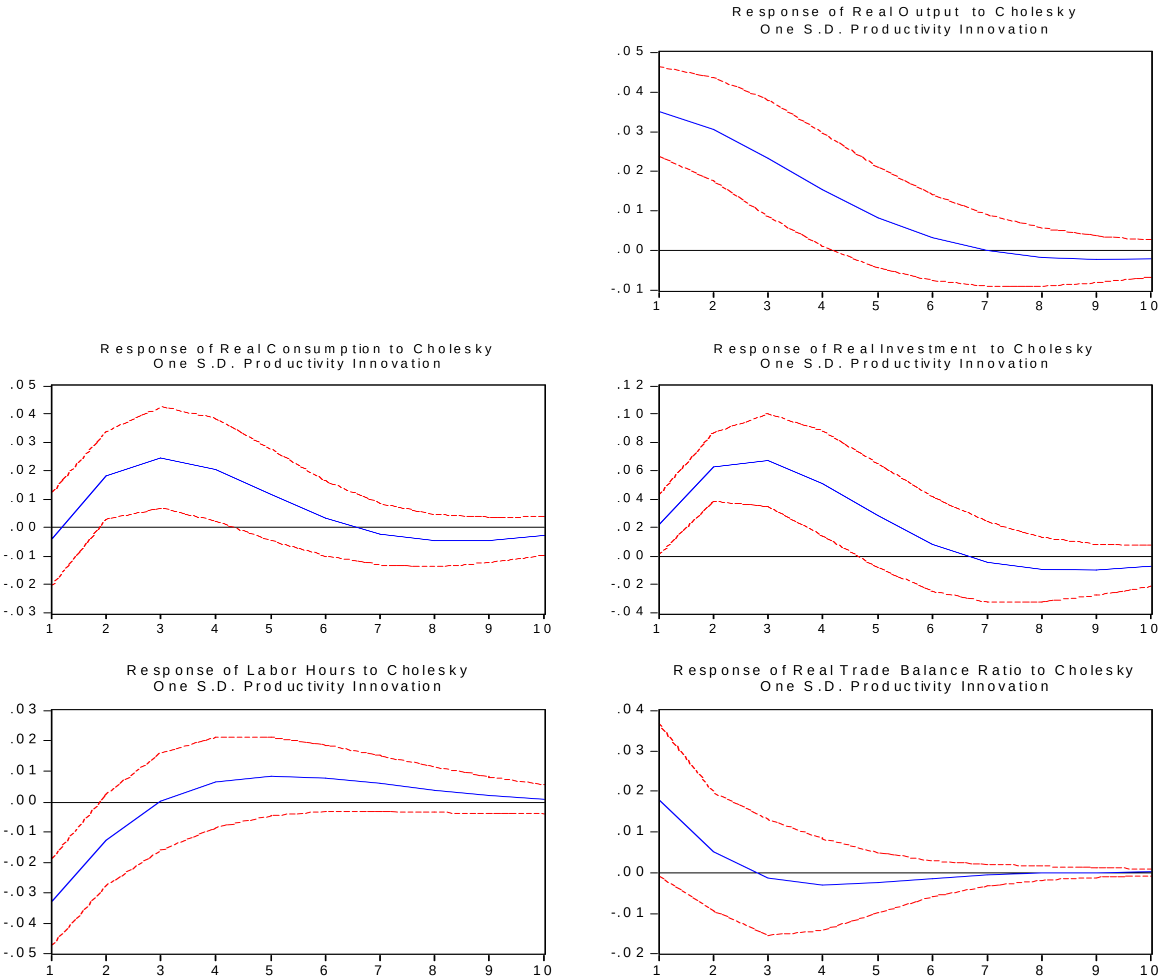


Figure 3-6 presents the impact of a transitory productivity shock. A sudden one standard deviation shock in the productivity puts the economy into a booming cycle, up 3.5%. The IRF obtained from the data shows that the role of the productivity shock on the overall economy of Saudi Arabia is statistically significant. Interestingly, the immediate effect of the productivity shock on output exceeds that from real world oil price shock, and its effect lasts much longer than a real world oil price shock. This is consistent with what our theoretical model suggests.

Figure 3.6 Effect of Single Transitory Productivity Shock on the Macroeconomic Variables of Saudi Arabia

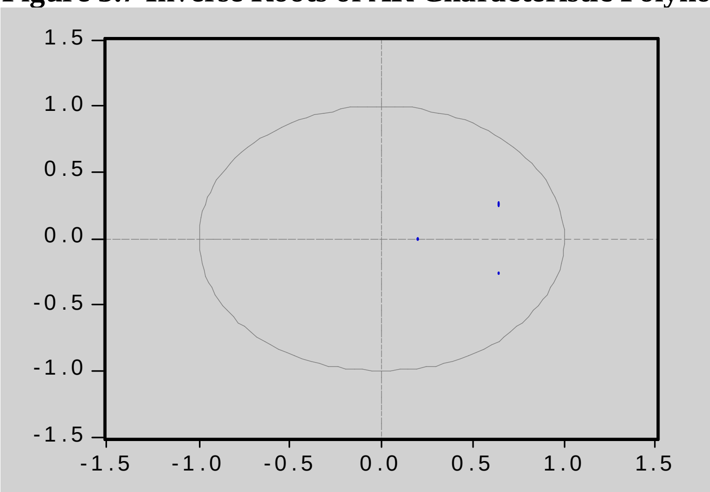


The following quote is useful in understanding the dynamic impact of a transitory productivity shock in Saudi Arabia:

> "A more persistent increase in productivity would tend to raise wealth more significantly by raising future output……incentive to increase investment would plausibly be reduced and his incentive to increase consumption would be increased. There would be also less incentive to work harder today because the wealth effect is stronger and intertemporal substitution effect is reduced." (Charles 1989:pp.56)

The results of the IRF indicate that the wealth effect is dominant for the case of Saudi Arabia, at least in the short run. Thus, with a productivity shock, investment increases by 2.1%. The effect of productivity shocks on investment begins to die out after the third period, and after the fifth period the effect is insignificant. A one standard deviation shock in the productivity is significant only during the second and fourth periods for consumption. This transitory shock causes "less incentive to work harder today", and thus labor hours decrease by 3.1%. However, this effect of the shock is insignificant after the second period. A temporary one standard deviation productivity shock increases the trade balance ratio by 1.9% in the first period; in other periods, the effect of the shock is not statistically different from zero.

Figure 3.7 Inverse Roots of AR Characteristic Polynomial

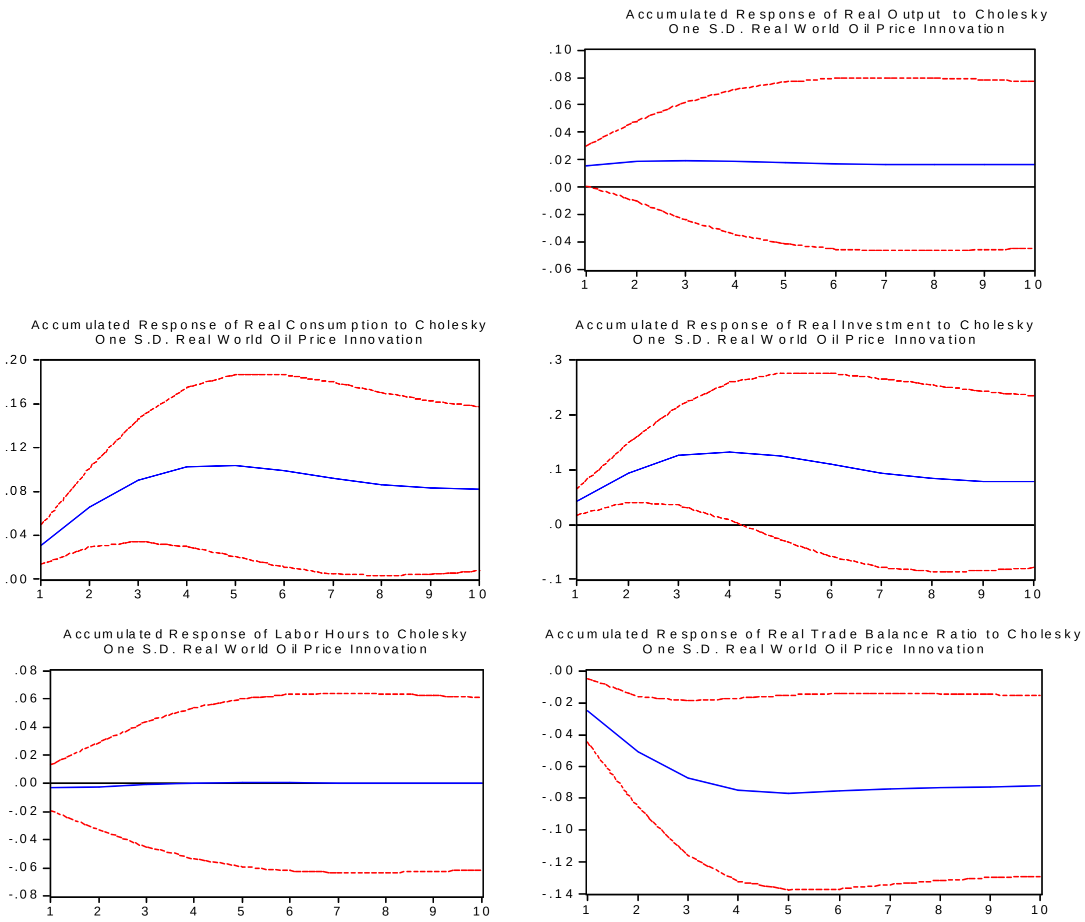


Theoretically, the IRF is obtained from a VAR system. To ensure the stability of a VAR system, one way is to note the die out aspect in the IRFs. Another method to confirm this aspect is to find if all roots have a modulus less than one and lie inside of the unit circle. Figure 3-7 shows that all units lie inside the circle, and thus I claim the stability of the VAR system. If the unit roots happen to be outside the unit circle, then I claim that the VAR system is unstable.

Accumulated Impulse Response Function:

The accumulated response function allows the examination of the long run relationship between variables. Two variables are said to have a long run relationship when their relation does not die out in the long time horizon. Figure 3-8 presents the effect of permanent real world price shocks on the main macroeconomic indicators of Saudi Arabia. The accumulated response function shows that there is no statistically significant long run relationship between real world oil prices and real output.

Figure 3.8 Effect of Permanent Real World Oil Price Shock on the Macroeconomic Variables of Saudi Arabia

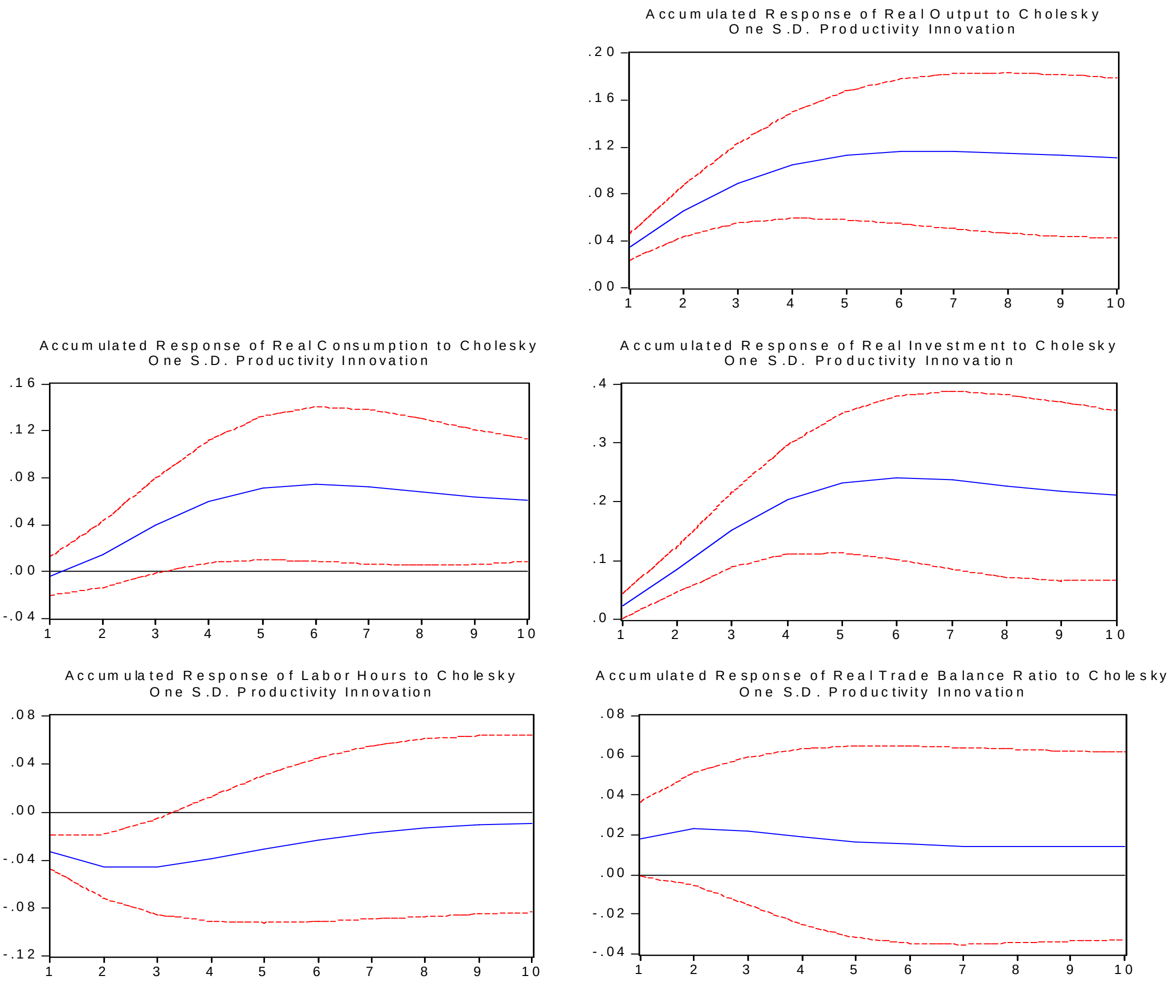


The evidence from the accumulated response function suggests the existence of a statistically significant relationship between real world oil prices and both consumption and trade balance ratio. The relationship between real world oil prices and investment is statistically significant until the fourth period. In addition, the accumulated response function does not support the existence of a long run relationship between real world oil price and labor hours which is somewhat consistent with the findings of the theoretical model in that the effect of oil price shocks is positive but very small. It is also important to examine a single permanent productivity shock to verify the relative importance of the productivity shock to that of a real world oil price shock.

Figure 3-9 shows the existence of a bilateral long run relationship between the productivity shock and real output. The accumulated IRF supports a strong statistically significant long run relationship between productivity and real output in Saudi Arabia. This is an important finding for two reasons. First, this is consistent with the predictions of our theoretical model in that productivity is a driving force of business cycles in Saudi Arabia. Second, it suggests that policymakers interested in increasing output in Saudi Arabia should be concerned with increasing productivity through adopting new technologies to increase economic prosperity. For example, the policymakers should continue diversifying economic resources and reducing their reliance on oil.

Furthermore, the evidence from the accumulated IRF supports the existence of a statistically significant bilateral long run relationship between productivity and consumption, beginning from the third period. The evidence also supports a strong statistically significant long run relationship between productivity and investment in Saudi Arabia. Not surprisingly, productivity has a long run relationship with investment due to the importance of the effect of new capital on productivity. This is consistent with the fact that most of the investment in Saudi Arabia comes from the non-oil sector. The effect of a permanent productivity shock on labor hours is insignificant after the third period. The accumulated IRF does not support a bilateral long run relationship between productivity and the trade balance ratio.

Figure 3.9 Effect of Permanent Productivity Shock on the Macroeconomic Variables of Saudi Arabia



Saudi Arabia, along with the rest of the world, is heavily engaged in international trade. A large portion of its trade transactions occur with the United States, Japan, and South Korea. Thus, empirically examining real world oil price shocks versus productivity shocks is worthwhile. Therefore, variance decomposition is used to examine the relative importance of the shocks to these economies.

7.1. Primary Trade Partners

Trade data show that Japan ranked as the top trade partner for Saudi Arabia until the mid-1980s, while the United States ranked second. In 1985, the total trade between United States and Saudi Arabia began to grow rapidly. South Korea ranks as the third primary trade partner for Saudi Arabia. This section examines the impact of real world oil price versus productivity shocks on the main macroeconomic variables for those countries.

United States:

The economy of United States is the largest in the world. The United States engages in trade with many countries, including Saudi Arabia. The United States mainly imports crude oil from Saudi Arabia to operate its industries. It is commonly believed that high real world oil prices negatively impact the U.S. economy, at least in the short run. There are many studies discussing the causes of U.S. macroeconomic fluctuations (Hansen and Prescott, 1993; Hamilton, 1983; Kilian, 2006; and Kim and Loungani, 1992). However, this section focuses on the relevance of a real world oil price shock versus a productivity shock to the U.S. economy. This enables us to compare the effect of real world oil price shocks on the U.S. with that of Saudi Arabia.

Table 3-9 reveals that the variance decomposition of the main macroeconomic indicators for the United States in the case where there are two shocks, real world oil price and productivity shocks. The results show that productivity shocks are relatively more important than real world oil price shocks for almost all U.S. macroeconomic indicators. In the first period, productivity shock explains 90.82% of the variation in output, while real world oil price shock explains only 0.81%.

Table 3.9 Variance Decomposition of the Main Macroeconomic variables for United States

Horizon	*Output*		*Consumption*		*Investment*		*Trade balance Ratio*		*Labor hours*	
	Oil Shock	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*
1	0.81	90.82	0.16	21.75	0.42	44.1	2.55	0.00008	0.39	44.23
4	2.81	91.54	1.24	14.6	2.85	58.5	8.498	4.34	0.65	77.97
8	14.12	81.21	11.8	10.71	15.74	44.19	13.6	7.1	16.031	65.5
16	17.1	78.6	13.91	10.86	17.3	44.9	12.73	15.05	19.3	59.15
24	17.93	77.6	14.04	11.07	17.48	44.1	11.7	17.2	19.9	55.49
Long run	18.45	77.1	14.1	11.131	17.54	43.96	11.4	17.8	19.48	52.5

The role of a real world oil price shock increases largely in the long run, and it explains 18.45% of the variation. In the first period horizon, productivity shocks are relatively more important in explaining the variation in consumption and investment, explaining 21.75% and 44.1% of the variation respectively. In the long time horizon, the real world price shock explains 14.1 and 17.54 percents of the variation in consumption and investment respectively. In the long run, the real world oil price shock explains a greater proportion of the variation in consumption than productivity shock. The variation of trade balance ratio explained by productivity shock increases from nearly zero in the first period to 17.8% in the long run. In the first period, 0.39% of the variation in labor hours is explained by real world oil price shocks, while 44.23% of the variation is explained by productivity shocks. The variation in labor hours explained by productivity shocks increases in the long run to 52.5%, while the variation explained by real world oil price shocks increases to 19.48%.

Japan:

Japan is one of the most developed countries in the world. Japan was the leading trade partner of Saudi Arabia until the mid 1980s. Japan mainly imports crude oil from Saudi Arabia.

Table 3-10 shows that a real world oil price shock is relatively less important than a productivity shock in explaining the variation in output, consumption, and investment. This holds for both the short and long run. However, real world oil price shock explains 10.6% of the variation in the trade balance ratio in the first period, while productivity shock accounts for only 0.35%. The productivity shock explains a greater proportion of the variation in labor hours than real world oil price shock in both the short and long run.

Table 3.10 Variance Decomposition of the Main Macroeconomic variables for Japan

Horizon	***Output***		***Consumption***		***Investment***		***Trade balance Ratio***		***Labor hours***	
	Oil Shock	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*
1	1.59	95.97	0.97	69.22	2.021	68.07	10.6	0.35	5.32	15.3
4	2.3	94.93	1.99	69.22	1.39	65.86	8.1	9.78	4.02	34.2
8	1.87	91.75	2.54	69.09	3.85	66.33	13.2	15.46	3.7	36.1
16	1.91	90.77	2.8	67.82	5.21	66.56	16.6	18.82	4.1	35.1
24	1.95	90.9	2.93	68.0	5.43	66.63	17.2	19.4	4.23	32.4
Long run	1.97	90.8	2.98	68.1	5.371	67.3	17.3	19.5	4.29	32.2

South Korea:

South Korea is considered the primary trade partner in the group of East Asian Tiger Countries (EATC). During the early 1960s, South Korea had an economy that was comparable to underdeveloped countries in Africa. However, in the last three decades, the South Korean economy has been rapidly growing. This is due to government promotion of importing raw materials and advanced technology. In 1998, statistics show a negative growth of 6.6%, which is attributed to the famous Asian crisis. However, economic growth has returned since then and was 3.3% and 6.2% in 2001 and 2002, respectively (World Facts, 2007).

Table 3-11 presents the variance decomposition of the main macroeconomic variables for South Korea. The results indicate that a real world oil price shock explains 0.01% of the variation in output in the short run and about 1.41% in the longer time horizon. The productivity shock explains 93.23% and 80.6% of the variation in the output in the short run and long run, respectively. In addition, a productivity shock explains 44.9% of the variation in consumption in the first time horizon, while the real world oil price shock explains only 4.53%. The productivity shock continues to be more important than the real world oil price shock in explaining the variation in consumption in the long run. For investment variation, a real world oil price shock explains 1.23% in the first period, while productivity explains 40.12%. The variation in investment, as explained by the real world oil price shock, increases in the longer time horizon. However, the productivity shock continues to explain a greater proportion of the variation.

Table 3.11 Variance Decomposition of the Main Macroeconomic variables for South Korea

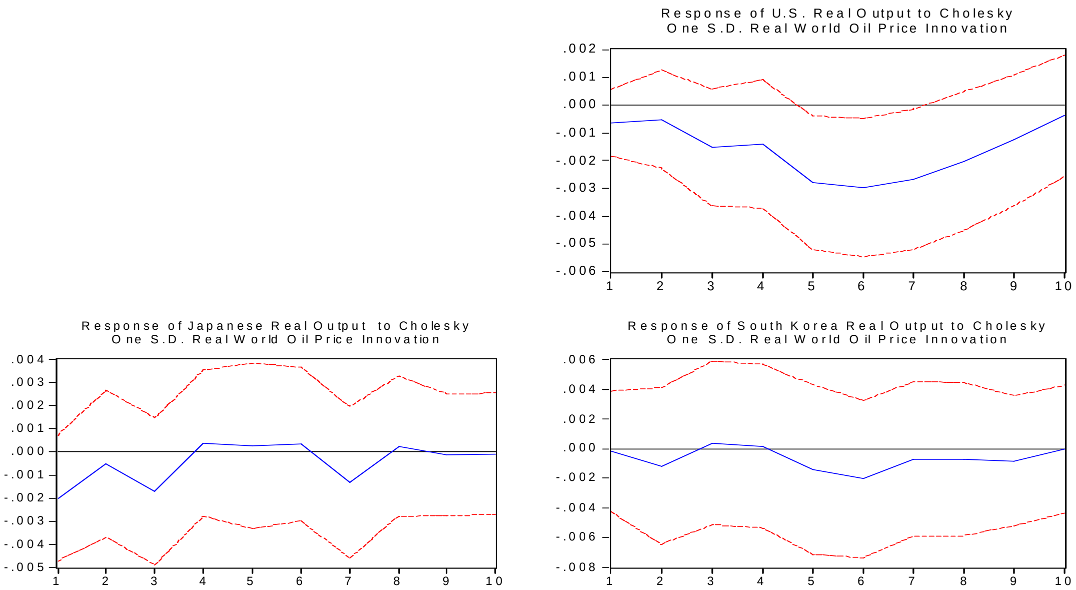
Horizon	*Output*		*Consumption*		*Investment*		*Trade balance Ratio*		*Labor hours*	
	Oil Shock	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*	*Oil Shock*	*Productivity Shock*
1	0.01	93.23	4.53	44.9	1.23	40.12	2.8	8.1	2.0	54.5
4	0.3	93.88	13.64	39.8	7.74	33.2	22.7	8.8	4.5	61.1
8	1.04	92.4	14.44	39.79	6.8	37.3	25.5	8.6	4.2	64.0
16	1.46	87.2	15.4	40.1	5.87	40.1	24.72	10.14	4.3	65.9
24	1.45	84.3	15.34	41.12	5.19	41.2	24.6	10.31	4.1	66.48
Long run	1.41	80.6	15.2	41.63	4.5	41.42	24.5	10.4	3.95	66.34

The real world oil price shock explains a smaller percentage of the variation in the trade balance ratio than the productivity shock does in the short run. In the long run, however, the real oil price shock explains a greater percentage of the variation in the trade balance ratio than does the productivity shock. The variation in labor hours is largely explained by productivity by 54.5% and 66.34% in the first period and long time horizon, respectively.

The Effect of a Transitory Real World Oil Price Shock on the Economic Activities of Primary Trade Partners:

To drive the analysis of the IRF findings, it is important to identify the economic position of each country. Saudi Arabia is considered to be an oil exporting country, while its primary trade partners are commonly known as net oil importing countries. Thus, I would expect the real world oil price shock to carry an immediate negative effect on the primary trade partners, while carrying a positive effect on the Saudi economy. Figure 3-10 reveals that a one standard deviation transitory shock of real world oil prices does not have an immediate significant effect in the U.S. overall economy; however, this effect has a statistically significant negative effect between the fifth and seventh periods.

Figure 3.10 The Effect of Transitory Real world Oil Price Shock on the Real Output of Major Trade Partners of Saudi Arabia



Additionally, the immediate effect of the real world oil price shock on Japan and South Korea is not statistically significant. This does not necessarily mean that the real world oil price shock does not carry adverse effects on these economies. However, the economies of some oil importing countries could enter into a recession cycle if the increase in the real world oil prices surpasses a certain *threshold level*. In addition, some oil importing counties have better success in absorbing the high real oil prices by increasing the prices of their exported goods.

The variance decomposition shows the relevance of the productivity shocks in explaining greater variation in the real output than the real world oil price shock for Saudi Arabia. This also holds for their primary trading partners in both the short and long term. The real world oil price shocks explain a greater proportion of the variation in consumption than productivity shocks in the long run for both Saudi Arabia and the United States; the opposite is true for Japan and South Korea.

The productivity shock is dominant in explaining the variation in investment for Saudi Arabia and its primary trade partners in the long term. The real world oil price shock is relatively more important in explaining the variation in trade balance ratio for Saudi Arabia in both the short and long run. Of the three primary trading partners, the effect of the real world oil price shocks on the United States is the most comparable to that of Saudi Arabia.

Oil importing countries often express concern about the effects of sharp increases in the real world oil prices. That is to say, these countries believe an increase in the real world oil prices has adverse effects on their economies. The results of this chapter show that the fears of oil importing countries appear to be overstated. However, there might be adverse effects that this study did not capture. For example, the empirical real world oil price shock could have led to an adverse effect on the economies of primary trade partners of Saudi Arabia if it exceeded a certain threshold level. Another possibility could be that the relationship between real world oil prices and the economic activities is non-linear.

8.1. The Stylized Facts

Studying the properties of business cycles in Saudi Arabia and its trade partners is essential for finding potential similarities and differences between the features of these different economies. Table 3-12 shows the properties of business cycles from 1970 to 2005 for Saudi Arabia. It illustrates the properties for the United States and Japan from 1970:01 to 2004:04. It reports the properties of business cycles for South Korea from 1982:02 to 2004:04. The reason for not considering the same time range is due to the unavailability of the data for some countries. The findings of these stylized facts for Japan and the United States are consistent with those properties reported by Backus, et al. (1995).[18] The data used to produce the volatility, correlations, and autocorrelation are filtered using the Hodrick Prescott procedure.

Table 3-12 presents the volatility of the main macroeconomic variables as measured by standard deviation. The correlations measure the co-movement, while the autocorrelations measure the persistence of the variables. That is to say, the consumption volatility for all Saudi's trade partners is less than the volatility in output. However, the consumption volatility for Saudi Arabia is higher than the volatility in output. The relatively greater consumption volatility is attributed to a rapid rate of economic development which occurred in Saudi Arabia in the decade of 1970s relative to those of its primary trade partners. The volatility of the trade balance ratio to output is much higher for Saudi than for most of its trade partners. Investment is more volatile

[18] I perform similar steps to that of Backus, et al. (1995) using their data range that covers the period from 1970:01 to 1990:02 to arrive at their exact numbers. Then, I perform the same steps again with a different time range and countries to report the numbers in Table 7-1.

than output, while employment is less volatile than output for Saudi Arabia and its trade partners. In addition, the persistence of output for Saudi Arabia and the United States are high, while it is relatively low for Japan. When I omit the 1970s from the time series data for Japan, the persistence for the output increases to 0.80.

Table 3.12 Properties of Business Cycles for Saudi Arabia and its Primary Trade Partners

	Standard Deviation %		Ratio of Standard Deviation to that of {y}			Autocorrelation	Correlation with Output			
	y	*tb*	*c*	*i*	*n*	*y*	*c*	*i*	*tb*	*n*
Saudi Arabia	7.28	10.5	1.24	2.2	0.91	0.70	0.17	0.64	0.60	-0.13
United States	1.58	0.44	0.62	2.73	0.85	0.86	0.85	0.93	-0.44	0.66
Japan	3.83	0.79	0.99	1.37	0.38	0.029	0.96	0.87	-0.07	0.13
South Korea	8.03	3.29	0.57	1.46	0.48	-0.31	0.85	0.93	-0.44	0.66

For Saudi Arabia, Data covers the period from 1970-2005. Statistics are based on Hodrick-Prescott-filtered data. Variables are y real output, *i* real fixed investment, c real consumption, N civilian employment, TB ratio of net exports to output. Statistics refer to logarithms. Source: *Achievements of the developments plans (2005). Data provided at constant prices {deflated by the publisher}.* The data for primary trade partners are obtained from International Financial Statistics (IFS) 2005. The civilian employment data is obtained from the OECD's Main Economic Indicators. The data for Korean civilian employment only available for post-1982:03.

The result of the autocorrelation for South Korea is puzzling. The cross correlation with output shows that both consumption and investment are procyclical. Trade balance ratio appears to be procyclical for Saudi Arabia, while it is countercyclical for its largest trade partners. Employment is countercyclical for Saudi Arabia, while it is procyclical for its trade partners

9.1. Conclusion

This study examines empirically the role of real world oil price shocks in explaining the main macroeconomic fluctuations of Saudi Arabia and its primary trade partners. This study complements the theoretical model in the previous chapters. In addition, this study builds a foundation for future studies in examining the impact of real world oil price shocks on the economies of the primary trade partners of Saudi Arabia.

The findings of this study are somewhat consistent with previous studies and are encouraging for potential future work. This research finds that a productivity shock contributes largely to business cycles of Saudi Arabia and its trade partners. The real world oil price shock explains more of the variation in the consumption and investment in the short run for Saudi Arabia, while the contribution of the productivity shock becomes dominant for investment in the long run. Using accumulated impulse response functions, this study does not support the conclusion that there are bilateral relationships between real world oil prices and the real output of Saudi Arabia. Conversely, the accumulated impulse response function supports a strong, statistically significant long run relationship between productivity and real output in Saudi Arabia. This finding is consistent with our theoretical model in the previous chapters.

Moreover, I would expect that the relative importance of productivity shock found in this research could be due to the effort by the policymakers of Saudi Arabia in diversifying the economic resources. That is to say, the role of oil shocks could have diminished the relative importance of productivity shocks in explaining business cycles. The results suggest that policymakers of Saudi Arabia should focus on increasing and adapting new technologies to increase the productivity in the economy. These increases in productivity can also be achieved by putting more resources into education. Such policies are likely to increase the prosperity level of the Saudi economy in the long run.

The transitory shock of real world oil prices does not have a significant impact on the overall economic activities of the primary trade partners of Saudi Arabia. The results of this chapter show that the fears of oil importing countries appear to be overstated. However, there might be adverse effects that this study did not capture. For example, the empirical real world oil price shock could have led to an adverse effect on the economies of primary trade partners of Saudi Arabia if it exceeded a certain threshold level. Another possibility could be that the relationship between real world oil prices and the economic activities is non-linear.

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