University of Essex

# Multi-Sectoral Productivities and Interlinkages:

# The Case of Oman


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## Abstract

Countries that derive the bulk of their revenue from a single natural resource are vulnerable to uncertainties such as how long that revenue would continue, resource price volatility, and changes in demand, or even substitution. Their future economic sustainability and growth, therefore, depend on the identification of new revenue streams in the short- or long-term.

The Sultanate of Oman represents a useful case study of this process as it now seeks to reduce five decades-worth of dependency on Mining and Quarrying (M&Q) sector income and create a more diversified economy.

The overall objective of this study is to contribute to the discussions of how this transformation and diversification can take place. The specific aim of this thesis is to use input factor analysis and multi-sectoral linkages analysis to identify the non-M&Q tradable sectors with large productivity and productivity growth performances, strong multi-sectoral interplay and structural linkages to other sectors within Oman's economy, during the period 1998–2016.

The results showed that the M&Q boom, and specifically the government expenditure funded by the M&Q revenue, has been the main driver of development and expansion of the non-M&Q sectors in the Oman's economy.

The input factors analysis showed that output growth in Oman's economy has been heavily driven by capital investment and labour accumulations, and less by technology. The agriculture and fisheries, manufacturing and financial intermediation sectors were the tradable sectors that showed the highest technology contribution.

The multi-sectoral linkages analysis showed that the M&Q sector was working almost in isolation from other sectors, whereas the non-M&Q tradable sectors were the sectors with the strongest linkages in the economy, especially the manufacturing sector.

The thesis concluded that Oman’s future economic growth is dependent on a policy of reallocating current M&Q income towards the main non-M&Q tradable and productive sectors.

## Declarations

I declare that the material contained in this thesis has not been used or published before. This thesis is my own work, and it has not been submitted for another degree or at another university.

Shabir M. Abdullah

## Acknowledgments

I am indebted to my advisor Professor Christian Ghiglino, for all his support and encouragement. My thanks also go to Professor Sheri Markose, my panel chairperson, and Lorna Woollcott, our department's graduate administrator, for all their understanding and guidance.

I would like to acknowledge the support that I received from the National Center of Statistical Information (NCSI) staff in gathering data on Oman.

Finally, without the blessing and encouragement of my dearest mother, my life partners, my kids, my sisters and brothers, and my colleagues, I would have not achieved this milestone.

Many thanks to all of you, and big love.

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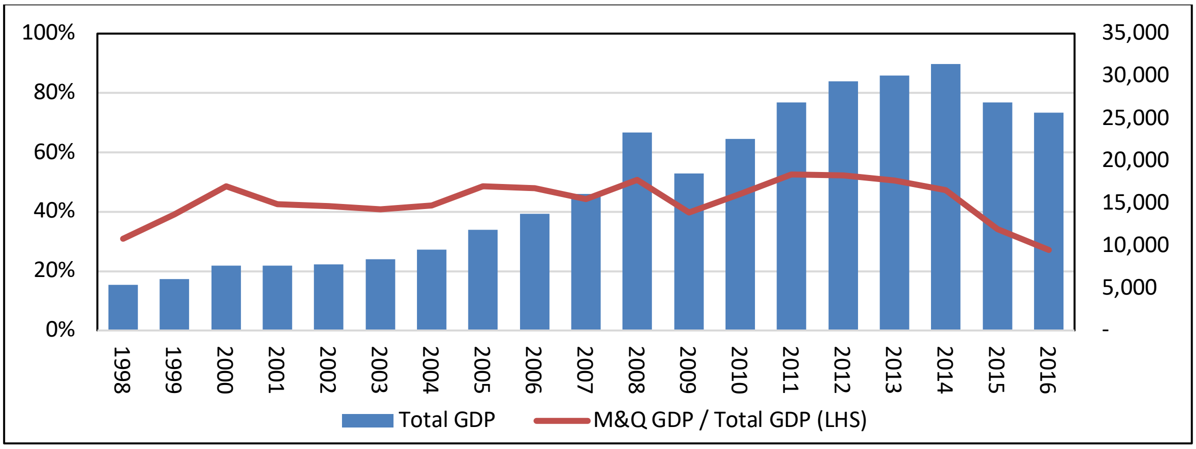
# Chapter 1: Introduction

## 1.1 Statement of the Problem

Mining & Quarrying (M&Q) resources, which in Sultanate of Oman (Oman) mainly comprise oil and gas, were discovered in commercial quantities in the country in 1962. Their production and exports started in 1967, and over the last two decades Oman has been producing almost a million barrels of oil per day (Al Yousef, 1997). Given an average price of $53.0 for a barrel of oil during the period 1998 to 2016,[1] this level of production has been the key factor behind Oman's Gross Domestic Product (GDP)[2] increasing from OMR[3] 5.4 billion in 1998 to OMR 25.7 billion in 2016, with the M&Q sector's GDP share accounting for an average of 43.5% of total GDP during the same period, as shown in Figure (1.1).

*Figure 1. 1: Oman's Total GDP OMR (Mn) and the Component of this derived from the M&Q Sector, During the Period 1998–2016*

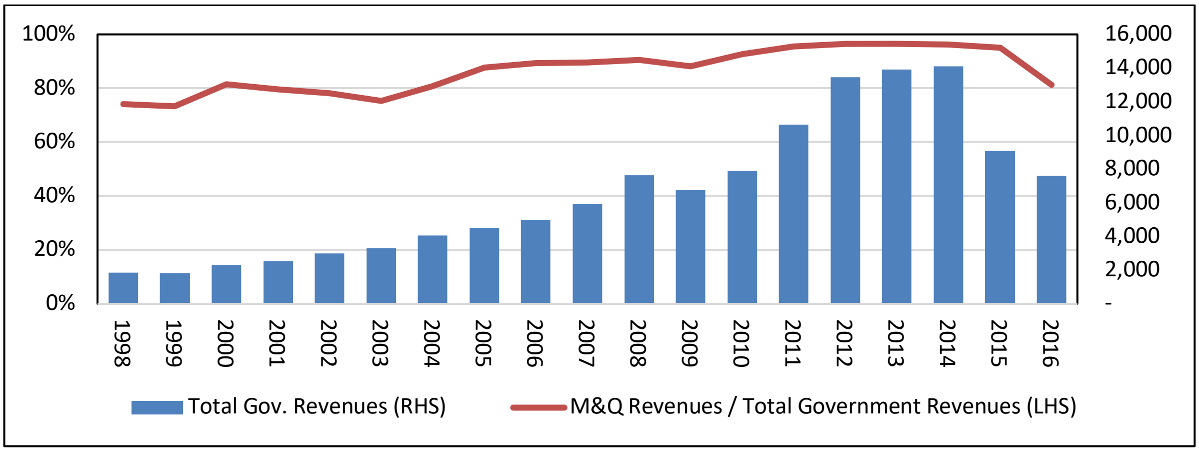



*Source: Compiled by Author using National Center of Statistical Information (NCSI) Data*

[1] Being the period of our research (1998–2016).
[2] At current prices (also called nominal prices).
[3] Being Oman's currency (Omani Rial (OMR)).

The same effect was evident in the public finances, with the government's total revenues increasing almost four-fold from OMR 1.9 billion to OMR 7.6 billion,[4] during the same period, with the M&Q sector's revenue share accounting for 86.8%, on average of the government's total revenues, during the same period, as shown in Figure (1.2).

*Figure 1. 2: Oman's Total Government's Revenues OMR (Mn) and the Component of this derived from the M&Q Sector, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

As a result, when oil prices declined by 45.0% in 2015, the size of the whole of the country's economy declined in parallel. This parallelism is illustrated in Figure (1.3), which shows total GDP, and M&Q sector's GDP, becoming negative to the tune of 14.6% and 38.3%, respectively, in 2015; and total revenues accruing to public finances decreasing by 35.7% at the same time.[5]

Over the course of the period since the discovery and export of M&Q products, it seems that the government of Oman could not optimally capitalize on the M&Q sector's increasing

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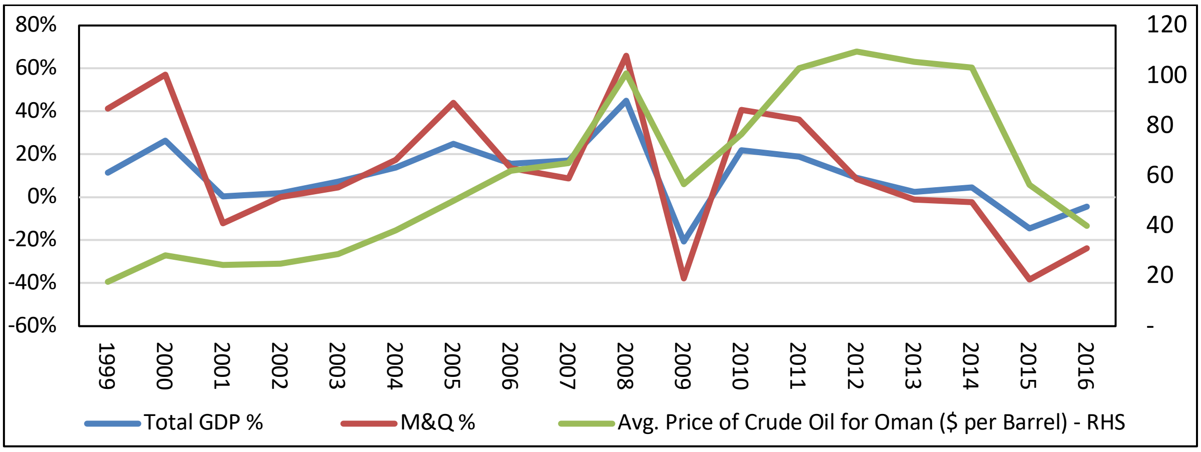
[4] Reaching a peak of seven times in 2014, as shown in Figure (1.2).
[5] As shown in Figure (1.2).

revenue to create a healthy diversified[6] economy and secure a long-term fiscal position that was less dependent on the M&Q sector, thus protecting the country from fluctuations in the price of M&Q sector's product and the consequences of the ultimate depletion of that sector's resources.

*Figure 1. 3: Impact of Fluctuations in the Price of M&Q Sector Product on Oman's GDP and the M&Q Sector's GDP*




*Source: Compiled by Author using NCSI Data*

## 1.2 Case Selection

Oman has been chosen for this research because the rapid economic development it has experienced over the last five decades, which has been mainly depended on the vast income generated through its M&Q sector's resources. With those waning, the country's future sustainability and growth is dependent on the capacity of the non-M&Q sectors to expand and add further value to the economy. The urgent need to realize the potential of the private sector is reflected in the Omani government's own development vision, which has two main elements.

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[6] The Development Council in Oman defines diversification as a reduction in dependence on income from the M&Q sector through an increase in the outputs of other sectors of the economy. The Development Council stated, "Since oil is the main source of Oman's national income, the decline of oil revenue will inevitably be reflected in reductions in the gross national product unless measures are taken in the Development Plan to increase the value-added in other sectors of the economy." (Oman Development Council, 1976).

First, diversification of the economic base away from the M&Q sector, allowing the other sectors in the economy to take more significant roles. Second, increasing the role of the private sector as an engine of future economic growth. The Omani government sees encouraging the private sector as vital to the future creation of employment opportunities and opportunities for economic development and diversification.

In this context, this research reviews and analyses Oman's multi-sectoral input factors, their productivities and growth, and their interplay and structural linkages within the economy. Understanding this is centrally important if Oman's non-M&Q sectors are to grow in the future.

The findings of this study on the Omani economy's multi-sectoral productivities and their interlinkages, including the interdependencies between the M&Q sector and other sectors of the economy, have important policy implications, not only for Oman, but also for other countries that rely mainly on mineral resources as their main source of revenue.

## 1.3 Motives and Objectives of this Research

In Oman, strategic planning and policy making for the country's economic development is undertaken by the government through Five-Year Plans (FYPs). The first of these was produced in 1976. The core objective of each development strategy has been to diversify Oman's economy so as to reduce its dependency on the M&Q sector. Every recent FYP has had a very clear roadmap to promote economic diversification, with a defined implementation plan and identification of the associated challenges. As we will see, however, although a lot of progress has been made in economic measures during the period since the discovery of M&Q products, the economy remains highly dependent on the M&Q sector and the planned economic diversification has not fully materialized in its true sense.

The main objectives of this research are to:

1) Provide an overall contribution to the discussions about Oman's structural transformation and development experience.
2) Analyse the role of the M&Q sector's income on Oman's economic output, and hence on the economy's development and transformation, as well as the M&Q sector's impact on other sectors within the economy.
3) Measure and analyse how Oman's multi-sectoral input factors contributed to each sector's output, and hence, on the economy's overall output.
4) Using different economic models, estimate Oman's multi-sectoral productivities and their growth performances on national, M&Q and other[7] multi-sectoral levels.
5) Measure and analyse Oman's multi-sectoral direct and indirect backward and forward linkages.
6) Measure and analyse Oman's multi-sectoral relationships with respect to their demand, supply and prices.
7) Analyse Oman's multi-sectoral network production structure.
8) Using different economic models, measure and analyse the direct and indirect impacts arising from demand shocks, taxes and subsidies and the hypothetical extraction of these sectors from the economy.
9) Finally, identify the most dominant, productive, and high performing non-M&Q tradable sectors in Oman's economy for future sustainability and economic growth.

## 1.4 Research Questions

Through the above research objectives, this study will answer the following key questions:

[7] Beside the national level, we will analyse in total 14 different sectors in the economy, including the M&Q sector.

1) How important has been the role of the M&Q sector in the economic transformation and development of Oman, and how has that sector affected other sectors' contributions towards the economy?
2) Which main input factors, on national, M&Q sector, and other sectoral levels, have contributed to economic output (GDP) and its growth, and what has been the role of technology?
3) Which are the main productive and dominant non-M&Q tradable sectors in the economy? Should those be prioritized for further allocation of resources to support their expansion, and overall economic diversification and sustainable growth?
4) What future policies could be adopted by the government of Oman to increase the output of the economy beyond the M&Q sector?.

## 1.5 Significance of this Research

Despite the importance of the M&Q sector in nations, such as Oman, that are dependent on the exploitation of their natural resources, not much research has been performed on the impact of M&Q sector on the overall microeconomic dynamics and interlinkage effects on other sectors of the economy.

To the author's knowledge, there has been no previous attempt to use a range of economic models to measure and analyse the contributions of multi-sectoral input factors on Oman's economy, their Total Factor Productivities (TFP) and growth, their direct and indirect backward and forward linkages and multiplier effects, their network structures, and the effects arising from their demand shocks, from taxes and subsidies, and from their hypothetical extractions from the economy.

In addition, most of the previous work seeking to estimate TFP has used fixed coefficients of labour and capital stock shares, whereas this research measures and uses the actual averages for the period in question to estimate TFP and TFP growth on a national and individual sectoral levels. In addition, the study for estimating TFP and TFP growth uses data mainly from a single source (the National Center for Statistics and Information, NCSI), which results in better overall estimations.

This research is therefore of interest because it will:

1) Build capacity in economic policy analysis in Oman, since the existing literature is scarce, except that which has been published by the government through media articles by individuals and through associations such us the International Monetary Fund (IMF) and the World Bank (WB).
2) Support the public policy makers in Oman in identifying and highlighting the main non-M&Q tradable sectors in the economy that could be prioritized for support to underpin future economic sustainability and growth. Further, since these sectors are mainly being dependent on private sector activity, the research also supports the Omani government's policy of increasing the role of the private sector in Oman's economy.
3) Offering insights relevant to other Gulf Cooperation Council (GCC)[8] countries which, like Oman, are largely dependent on the M&Q sector and have relatively small manufacturing sectors, a small populations, high output growth at times of favourable terms of trade, and similar economic and political structures. Insights may also be relevant to other countries dependent on the M&Q sector exports and could provide a good reference for future academic studies in this field.

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[8] Bahrain, Kuwait, Oman, Qatar, the Kingdom of Saudi Arabia (KSA), and the United Arab Emirates (UAE).

## 1.6 Outline of the Research

Following this introductory Chapter (1), Chapter (2) reviews, analyses and summarizes Oman's economic structural composition and overall development experience since the discovery of the M&Q products in 1962 and their export since 1967. This is performed to provide the necessary historical background in respect to the development of the economy. Next, the chapter focuses on the period of our research (1998–2016), mainly using time series data from the NCSI about government revenue, expenditure, consumption and savings trends in Oman, and their overall effects on the economy. The chapter also outlines Oman's multi-sectoral composition and their growth trends during the period, with respect to their capital investments, workforce, exports, gross-outputs, intermediate consumptions, and outputs (GDPs).

Thereafter, Chapters (3) to (6), use different economic models to identify the main non-M&Q tradable sectors with large productivity and positive productivity growth performances, strong multi-sectoral interplay and structural (direct and indirect) linkages to other sectors. This is performed to support the government of Oman to allocate additional resources to support the expansion of those sectors, and thereby achieve greater economic diversification and more sustainable growth.

Chapter (3) estimates and analyses the input factors contributions to output growth on both national and multi-sectoral levels during the period 1998–2016, using an empirical growth accounting exercise that decomposes the growth rate of aggregate output (GDP) into contributions of capital stock, labour, and TFP. This is performed to identify the main non-M&Q tradable sectors in Oman's economy with positive productivity (TFP) growth during the period.

Chapter (4) measures and analyses the multi-sectoral interlinkages in Oman's economy for the year 2005, with respect to their direct and indirect forward and backward linkages, their final demand and total output, final demand and total supply, value-added ratios and prices, and impacts arising from their demand shocks and the hypothetical extractions of these sectors from the economy. This is performed to identify the most dominant sectors in the economy. The chapter also compares Oman's multi-sectoral linkages to a developed country's (the USA's) multi-sectoral linkages for the same year. This is achieved through applying different empirical models within the Input-Output (IO) framework. In order to examine the multi-sectoral linkages, the chapter also examines the possible impact of the so-called Dutch disease on Oman's economy, in the form of the windfall gains from the M&Q sector during the period 1998–2016.

Chapter (5), on the same lines as Chapter (3), measures and analyses TFP and TFP growth at national and multi-sectoral levels during the period 1998–2016, but instead of using the aggregate growth accounting framework that was used in Chapter (3), uses a theoretical framework with a Cobb-Douglas production function where intermediate inputs are incorporated. The chapter also compares and analyses the results obtained from both the frameworks. Moreover, on the same lines as the Chapters (4), this chapter measures and analyses the multi-sectoral interlinkages in Oman's economy for the year 2005, but with respect to their production network structure and output-multipliers, and also measures multi-sectoral TFP performances. The chapter also compares Oman's multi-sectoral linkages and TFP performances, with the USA's multi-sectoral interlinkages and TFP performances for the same year. This is achieved by applying different empirical models within the IO framework.

As discussed in detail in each of the Chapters (2) to (5), the analyses find that, if Oman is to attain overall economic diversification and sustainable growth, it is important for the government of Oman to reduce dependency on the M&Q sector, and to adopt a policy of reallocation of resources and/or deploying further resources to support the expansion of the main productive and dominant non-M&Q tradable sectors within the economy. Building on these overall findings, Chapter (6) conducts counter-factual exercises to analyse the effects on Oman economy's aggregate gross-output when reallocation of resources are enforced by the government within the sectors by applying taxes on input factors of the non-productive M&Q sector and forwarding these proceeds to input factors of another sector (in our case the productive manufacturing sector), (i.e., a policy of subsidizing one sector from proceeds raised from another). Moreover, the chapter also analyses the effects of a fixed level of resource support provided by the government to a particular sector on the economy's output (GDP) and gross-output. This is achieved using Ghosh models within the IO framework.

Finally, Chapter (7) summarizes the major findings of this thesis, their significance and future policy implications and recommendations.

# Chapter 2: Oman's Economic Review

The overall objective of this chapter is to review and analyse Oman's overall history of economic development, and especially how the structure of the economy has changed over the period since the discovery of Mining & Quarrying (M&Q) resources and the commencement of exports of M&Q products. This will be achieved mainly by reviewing the history of oil production, the fluctuations in its price in international markets and the associated direct effects on government revenue, and multi-sectoral capital investments, labour distributions, export contributions, gross-outputs, intermediate consumptions, and finally, outputs (Gross Domestic Products, GDPs).

This chapter will answer the following major questions:

1) What are the main outcomes of Oman's overall development experience?
2) How important has been the role of M&Q sector in transforming Oman's economy and how has that sector affected other sectors' contributions towards the economy?
3) What efforts needed to be considered by Oman's government to reduce its dependency on the M&Q sector and to diversify its economy, for future economic growth?.

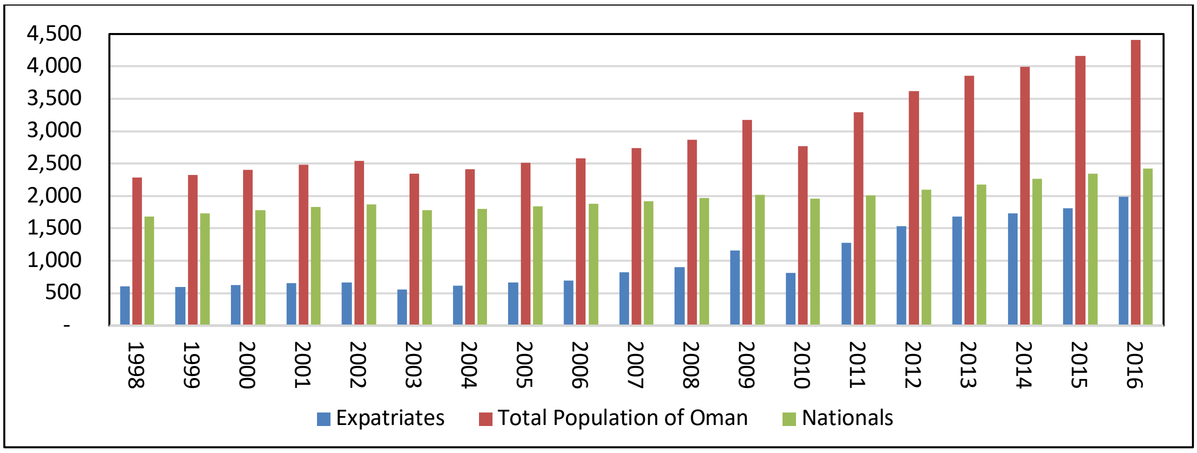
## 2.1 Geography

The Sultanate of Oman (Oman) is located in the south-eastern quarter of the Arabian Peninsula and covers a total land area of 309,500 square kilometres, with a coastline that extends 1,700 kilometres. Oman has borders with Saudi Arabia and the United Arab Emirates in the west and with the Republic of Yemen in the south. To the east, Oman faces the Arabian Sea and Gulf of Oman, while to the north, it overlooks the Strait of Hormuz. Oman's capital city is Muscat, and the country is divided into eight administrative regions. Oman's vast land area is 82% comprised of sand and gravel desert, another 15% is mountainous, and thus the coastal plains represent only 3% of the country (Al Yousef, 1997). The official language is Arabic, but English is widely used in Oman. Oman's currency is the Omani Rial (OMR), divisible into 1000 Baizas, and pegged to the US dollar at the rate of 1 OMR equals 2.6 US dollars without any foreign exchange restrictions on convertibility.

## 2.2 Population

According to the first official census, carried out in 1993, Oman's population stood at 2.02 million, of which 73.5% were Omanis and the rest expatriates. In 2016, the population was estimated to be 4.55 million, out of which 54.3% were Omanis.[9] As shown in Figure (2.1), during the period 1998–2016 the population almost doubled (193.0%), with an average growth rate of 3.9% per annum. On average, expatriate population growth rate amounted to 8.2% per annum, whereas the population growth among Omani nationals was lower, at 2.1% per annum. Thus, population increase in Oman has been mainly due to the growth in the number of expatriates, which can be attributed to the rapid economic development in the country during this period.

*Figure 2. 1: Oman's Total Population Composition, (000'), During the Period 1998–2016*



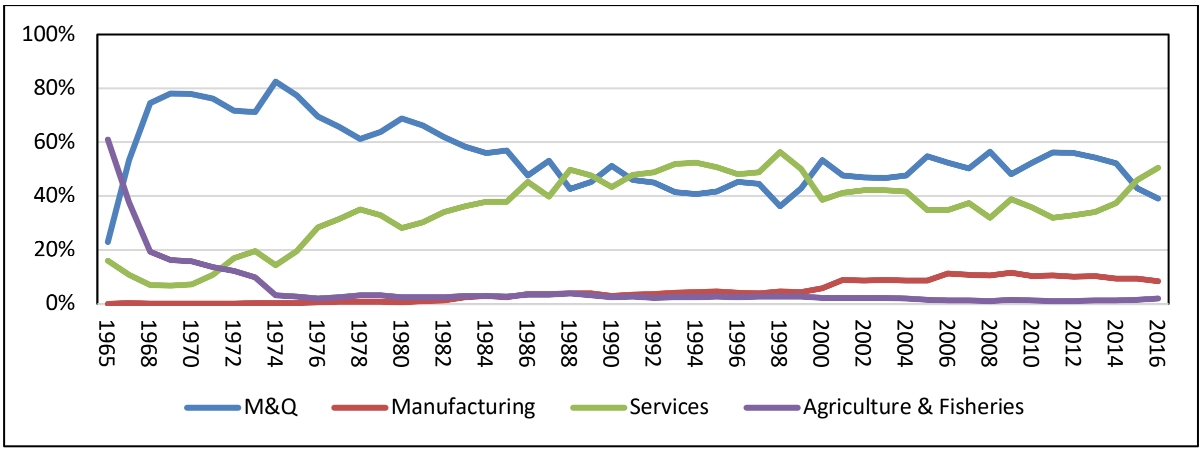

*Source: Compiled by Author using NCSI Data*

[9] With 35.0% being below 15 years of age and 59.0% in the age group of 15–64 years.

## 2.3 Oil and Economic Growth

Before oil started to be commercially exploited and exported in 1967, Oman was a typical low-income agricultural and fisheries country. In 1965, the agriculture and fisheries sectors contributed 61% of the country's GDP, whilst M&Q sector contributed 23% and 16% was derived from the services sector (World Bank, 1987). After the discovery of oil, and the start of the oil export boom, however, the economy went through a significant structural transformation. As shown in Figure (2.2), in 2016, the agriculture and fisheries, M&Q, services, and manufacturing sectors contributed 1.6%, 40.1%, 49.4% and 8.9% to Oman's GDP, respectively. The large increase in the share of GDP held by services was mainly due to high demand for services by the private and government, as will be further discussed in section 2.8. The M&Q sector revenues and their effect on government income, had a direct effect on the services sector through government expenditure and demand for services, beside the M&Q sector's own demand for services for its own sustainability. M&Q sector thus played a major role in the expansion of the economy, both directly and indirectly; directly through the increase in crude oil production and exportation, and indirectly through the impact of its revenues on other sectors of the economy.

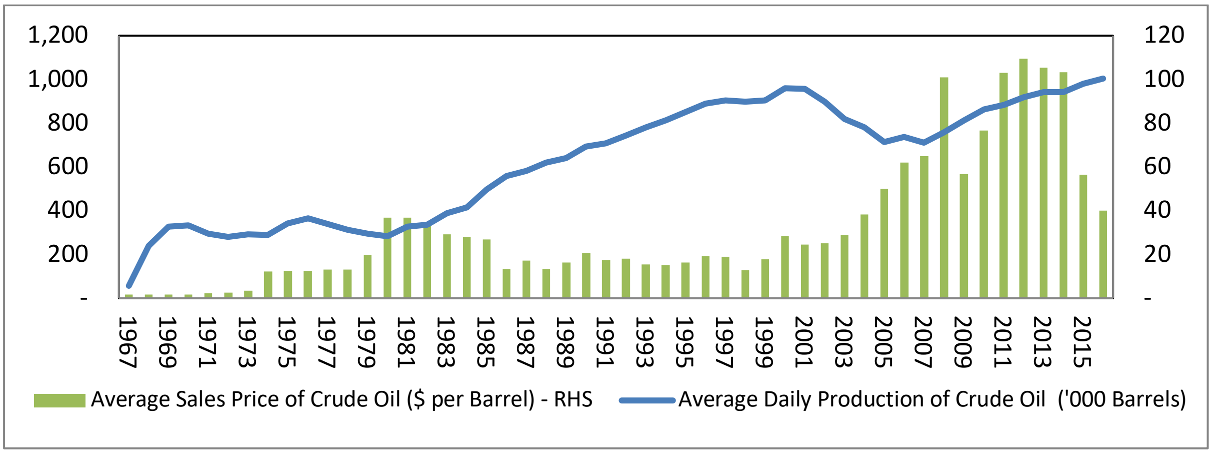
*Figure 2. 2: Oman's Multi-Sectoral Shares in GDP, During the Period 1965–2016*




*Source: Compiled by Author using WB Data*

Figure (2.3) shows the average daily crude oil production increased from 57 thousand barrels per day in 1967 to 904 thousand barrels in 1997, with an average oil price of $15.9/barrel during this period. This was instrumental in Oman's GDP increasing from OMR 170 million to OMR 7.1 billion,[10] for the same period. From 1998 to 2016, however, oil production was almost a million barrels per day, with oil prices averaging $58.1/barrel, rising to a peak of $110/barrel in 2012. As a result, GDP increased by almost fivefold during the period, reaching OMR 25.7 billion in 2016, with the highest GDP of OMR 31.5 billion being achieved in 2014.[11] A similar affect took place on Gross National Income (GNI), which increased significantly during the period, with the average growth of 5.4% per annum, reaching a maximum of OMR 8.2 thousand in the year 2011, as shown in Figure (2.4).

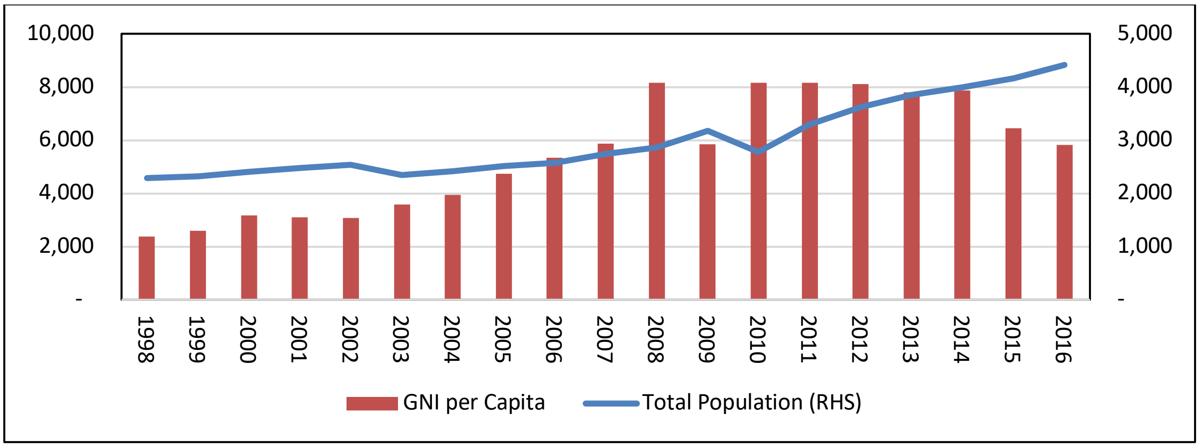
*Figure 2. 3: Oman's Average Daily Production of Crude Oil, and Average Crude Oil Price, During the Period 1967–2016*




*Source: Compiled by Author using WBDI and NCSI Data*

[10] At current prices.
[11] Refer to Figure (1.1).

*Figure 2. 4: Oman's GDP per Capita and Total Population, (000'), During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data.*

## 2.4 Government Revenue and Expenditure Trends

Record levels of revenue poured into the government of Oman, mainly as a result of the M&Q resources export in the period 1998–2016. Specifically, government revenues increased almost fourfold from OMR 1.9 billion to OMR 7.6 billion in the same period, with the highest revenue occurring in the year 2014. M&Q sector revenue has been the main source of government income as the government fiscal policy favoured low taxation,[12] low customs duties and few fees, in order to stimulate the growth of the non-M&Q sectors and to promote economic development. As shown in Figure (2.5), the government's budgetary reliance on revenues from the export of M&Q sector's products was significant, constituting 70.6% and 61.0% of total government revenues during the years 1998 and 2016, respectively. Although revenues from other sectors did increase marginally during the period, the M&Q sector continued to be the dominant source of government revenue.

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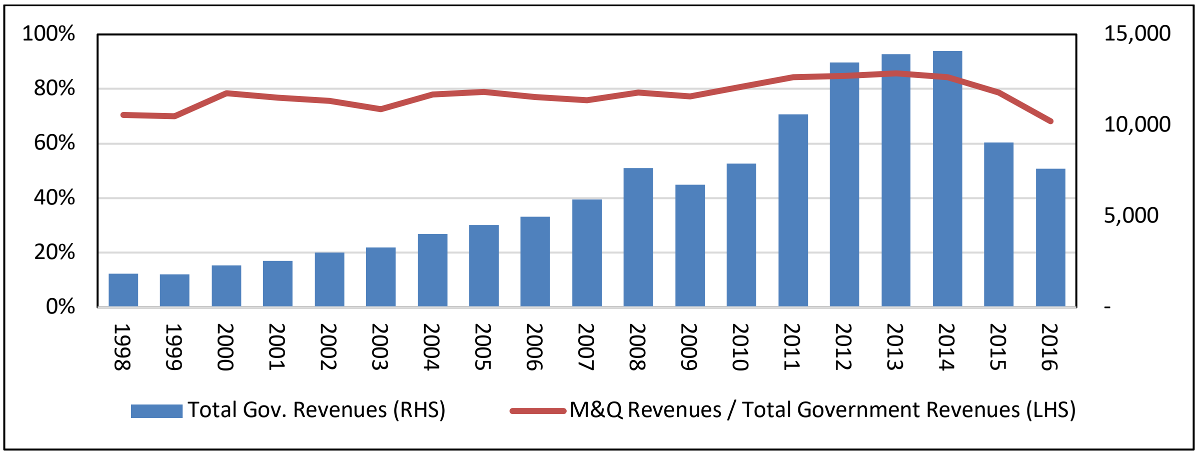
[12] Maximum taxation during the period has been 15% on corporates' net profits.

*Figure 2. 5: Oman's Government Total Revenue OMR (Mn), and the Component of this derived from the M&Q Sector, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data.*

As with government revenues, government expenditure also increased at a substantial rate. Indeed, fiscal expenditure has occasionally outstripped total government revenues during the 1998–2016 period, as shown in Figure (2.6). Government current expenditure to total government revenues stood at 95.3% and 120.1% in 1998 and 2016, respectively. Capital investment expenditure, meanwhile, averaged around a quarter of the government's total revenues during the period as a whole.

Current expenditure as a proportion of total expenditure stood at 79.2% and 72.6% in 1998 and 2016, respectively, as shown in Figure (2.7). Capital investment expenditure increased marginally as a proportion of total expenditure during the period from 1998 to 2016, from 20.0% to 22.2%.

This large and continuous increase in the government's current expenditure caused the share of government consumption in aggregate output (GDP) to increase from 26.3% in 1998 to 29.3% in 2016, as shown in Figure (2.8). Moreover, the national savings rate in Oman has also been influenced by the exports boom in M&Q sector products, increasing at times of increased oil revenue and decreasing at times of decreased oil revenue. The savings rate marginally increased from 11.9% in 1998 to 13.8% in 2016, with a maximum savings rate of 44.6% being reached in the year 2008. The fluctuation in the national savings rate against the oil prices reflects the inability of the economy to absorb the M&Q product prices windfalls.

*Figure 2. 6:Oman's Government Current and Capital Investment Expenditure Components in relation to Total Government Revenue OMR (Mn), During the Period 1998–2016*

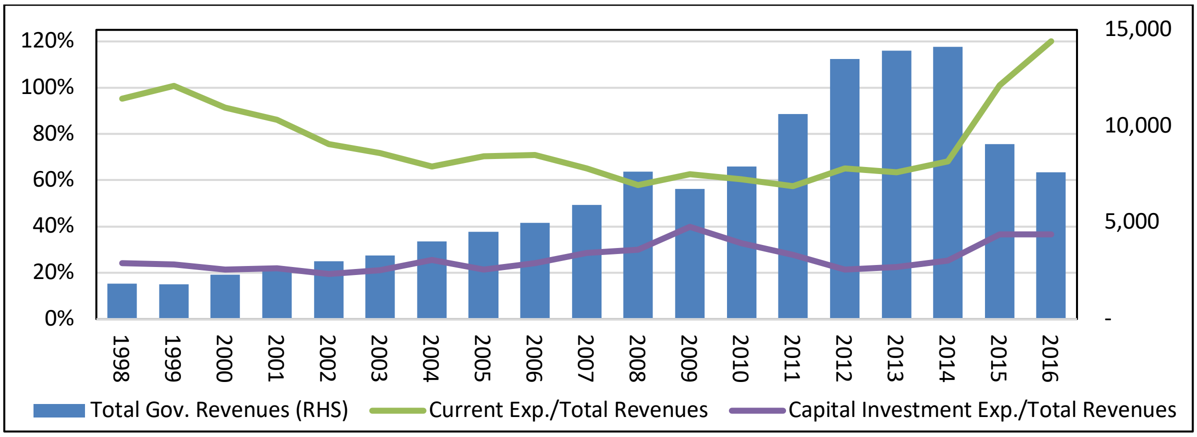



*Figure 2. 7: Oman's Government Current and Capital Investment Expenditure Components in relation to Total Government Expenditure OMR (Mn), During the Period 1998–2016*

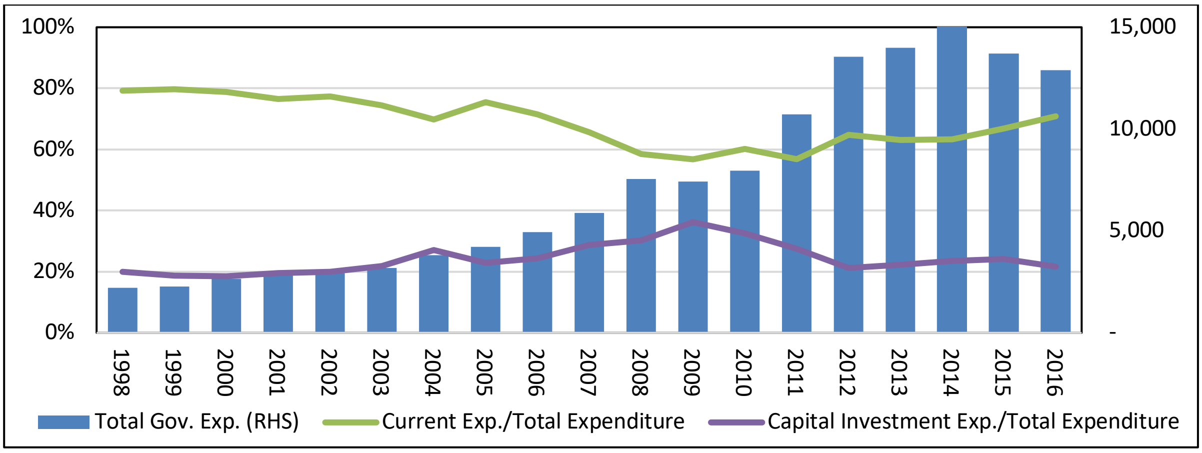
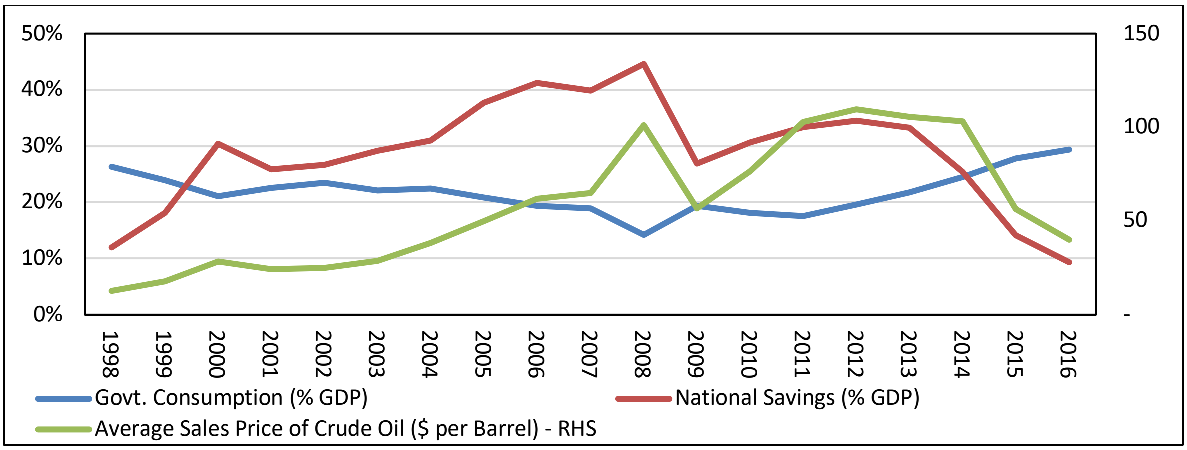



*Figure 2. 8: Oman's Government Consumption and National Savings as Percentage of GDP, and Average Crude Oil Price, During the Period 1998–2016*

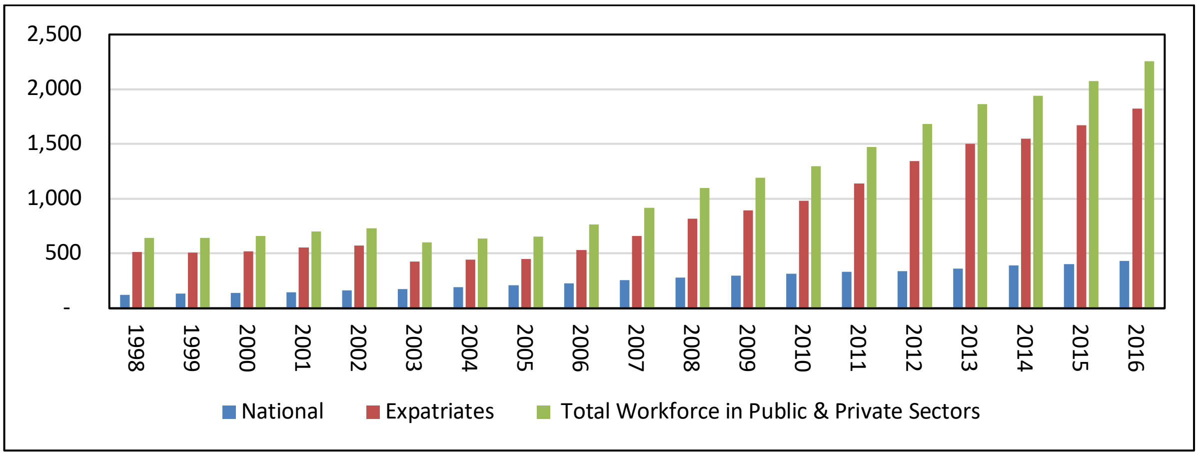



*Source: Figures (2.6, 2.7, and 2.8) Compiled by Author using NCSI Data*

## 2.5 Labour Market, Credit Growth, Outward Remittances and Foreign Direct Investment

The discovery of M&Q products and their export in the 1960s enabled Oman to expand its economy rapidly. This rapid development required skills and manpower that were not available domestically, so Oman, in common with other GCC countries,[13] resorted to employing guest workers in various activities ranging from building and construction, healthcare, education, trade and domestic work. The migrants brought the required skills and manpower to the country in exchange for financial rewards. In 2016, the total workforce across the public and private sectors was 2.25 million, as shown in Figure (2.9), with 89.8% of this in the private sector, and 80.9% of that private sector workforce being expatriate. During the period 1998–2016, the total workforce in the private sector increased from 0.55 million to 2.02 million, as shown in Figure (2.10), with an average growth of 7.9% per annum during that period. The growth in the expatriate workforce was in line with this trend, comprising an average of 76.3% of the workforce, with an average 7.8% growth per annum during the same period.

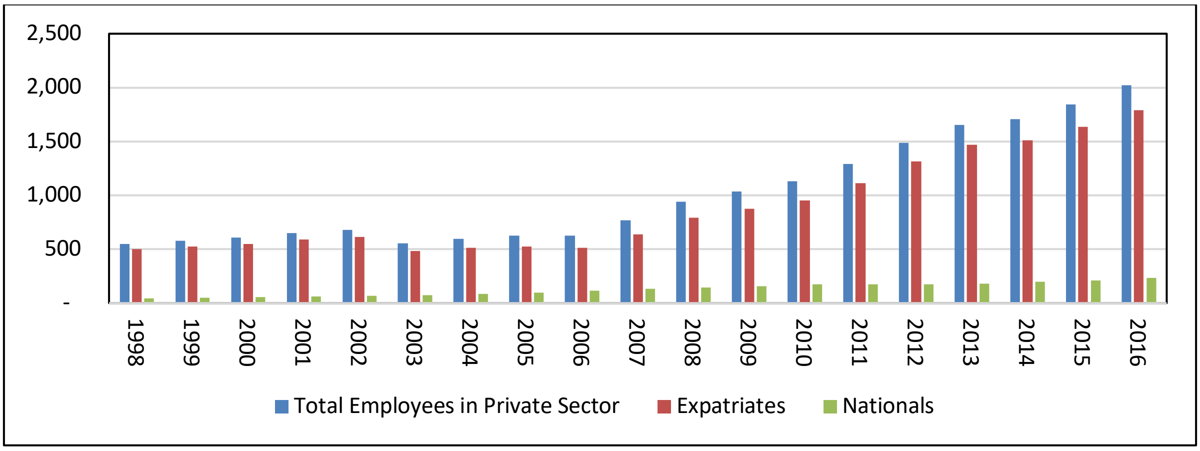
*Figure 2. 9: Oman's Total Workforce Composition, (000'), During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

[13] As will be discussed in more detail in Chapter (3).

*Figure 2. 10: Oman's Private Sector Composition, (000'), During the Period 1998–2016*

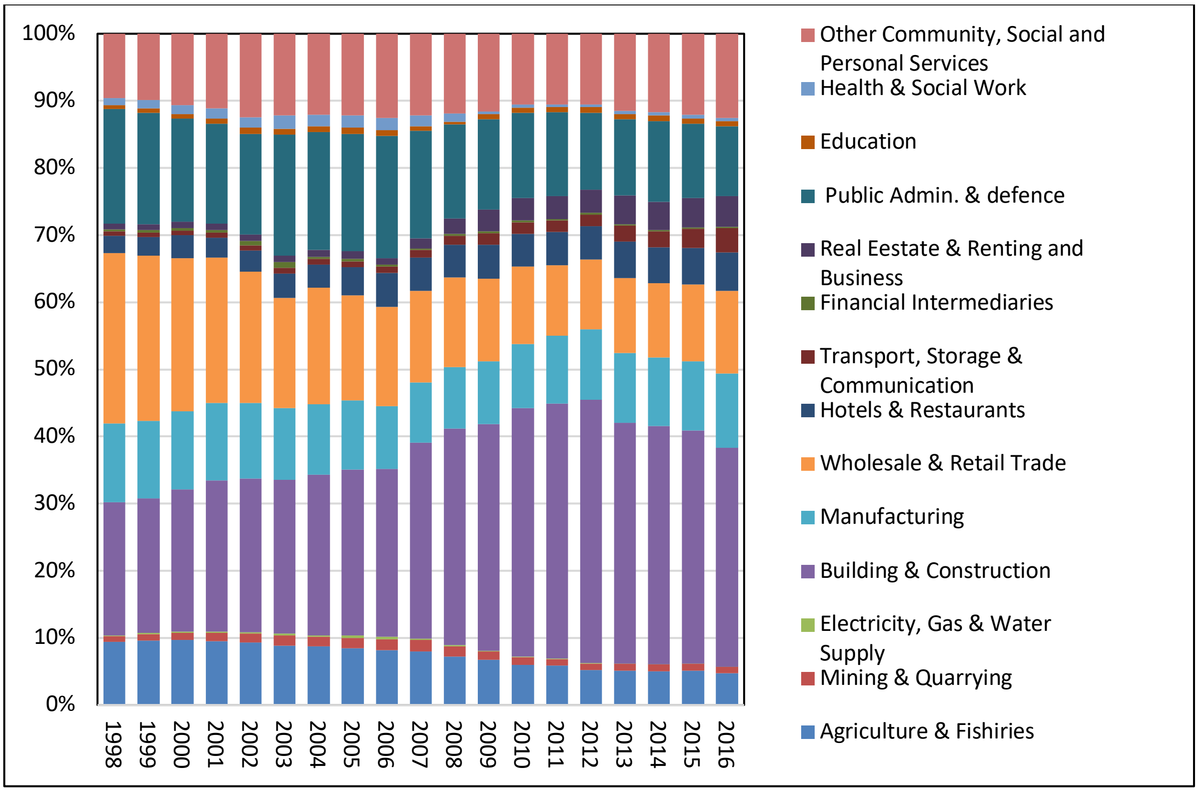



*Source: Compiled by Author using NCSI Data*

Analysing Oman's workforce on a multi-sectoral level, Figure (2.11) shows the building & construction; wholesale & retail trade; public administration & defence; other community, social and personal services; and manufacturing sectors having the highest proportions of the total workforce, with an average total share of 80.8% of the whole workforce and with individual shares of 29.5%, 15.0%, 14.3%, 11.5% and 10.4%, respectively, during the period 1998–2016.

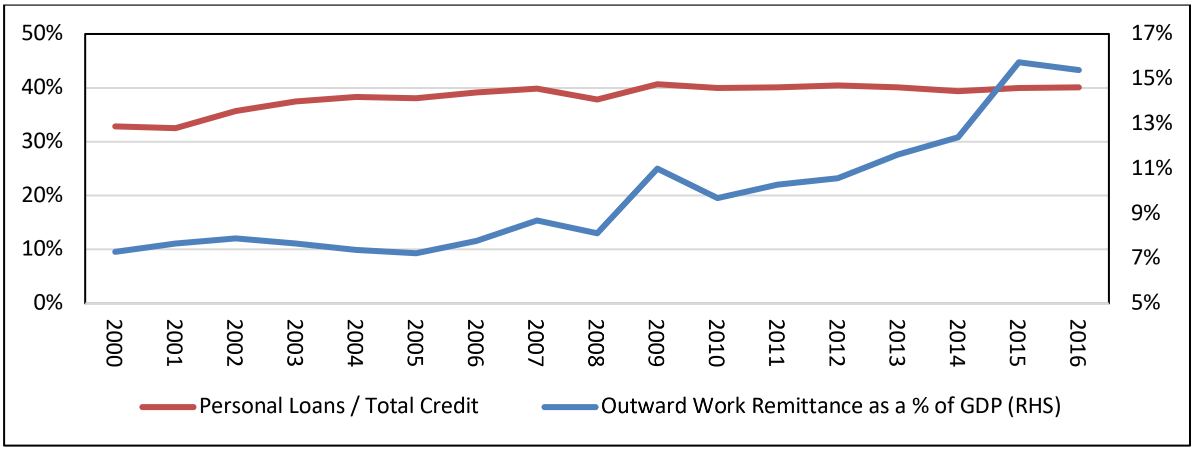
The increase in the total workforce in Oman has also directly affected the banking sector. A large proportion of the banking capital has been channelled into the non-productive segment of personal lending, meaning that the capital is used for consumables. Indeed, personal lending formed almost 40.0% of total banking credit during the last decade. Furthermore, the rapid increase in the number of guest workers has also had a direct effect on remittances, which have increased from 7.2% of the GDP in 2005 to 15.8% in 2016, as shown in Figure (2.12).

*Figure 2. 11: Oman's Multi-Sectoral Total Workforce Composition, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

*Figure 2. 12: Oman's Personal Loans and Outward Remittances, During the Period 2000–2016*

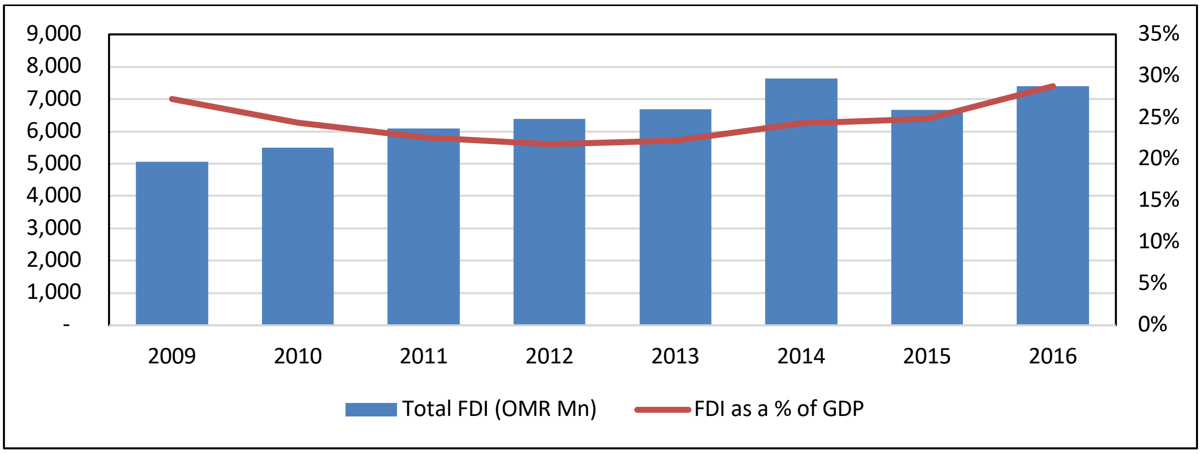



*Source: Compiled by Author using NCSI Data*

Moreover, Foreign Direct Investments (FDI) has also played a significant role in Oman's development. Figure (2.13) shows that total FDI grew from OMR 5.5 billion in the year 2009 to OMR 7.4 billion in 2016, and marginally increased as a percentage of the GDP from 27.2% to 28.8%, for the same period.

M&Q, manufacturing, financial intermediation, and building & construction were the sectors attracted the highest proportions of the total FDI, having an average total share of 90.1%, and with individual shares of 48.8%, 16.1%, 15.6%, and 9.6%, respectively, during the period 2009–2016.

*Figure 2. 13: Oman's Total Foreign Direct Investment (FDI) and as Percentage to GDP, During the Period 2009–2016*




*Source: Compiled by Author using NCSI Data*

## 2.6 Capital Investment Distribution

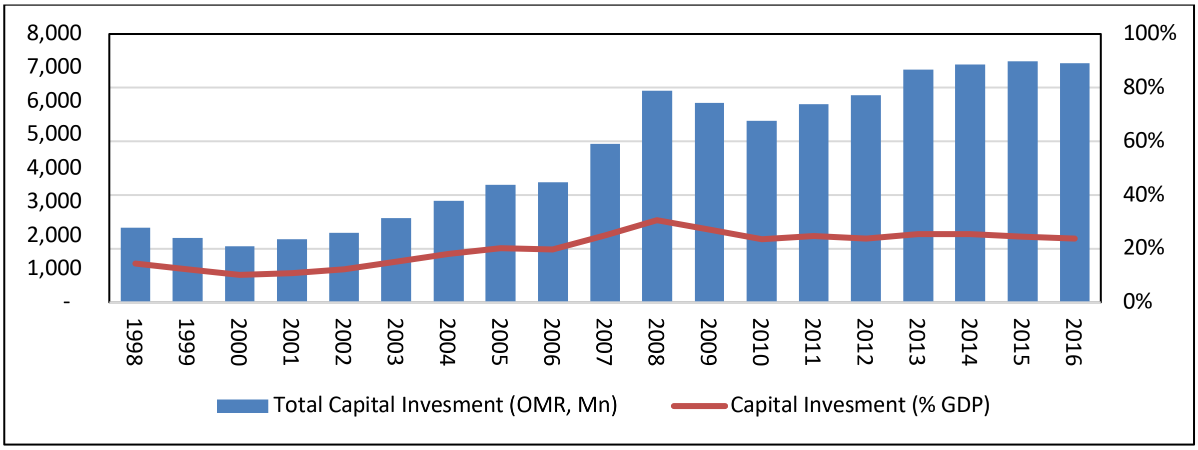
As was highlighted in section (2.4) expenditure on capital investments represented, on average, 26.7% of total government revenues, and 24.3% of total government expenditure during the period 1998–2016. The total capital investment in Oman increased from OMR 2.2 billion in 1998 to OMR 7.1 billion in 2016, with an average growth of 7.5% per annum, and an average of 20.7% of the GDP during the same period, as shown in Figure (2.14). The private sector share in this capital investment was more than 50% during the period.[14]

Analysing the capital investment on a multi-sectoral level, we find that the M&Q; manufacturing; public administration & defence; real estate & renting business; electricity, gas & water; and transportation, storage & communication sectors received the most capital

[14] NCSI reports.

investments during the period, having an average total share of 84.8% of all the total capital investment, with individual average shares during the period being 32.4%, 17.0%, 15.3%, 8.3%, 6.4%, and 5.4%, respectively, as shown in Figure (2.15). The sectors in which capital investment grew most rapidly during the period 1998–2016, were manufacturing (31.4%),[15] hotels & restaurants (30.0%), electricity, gas & water (25.8%), financial intermediation (23.8%), and building & construction (20.4%). There are two possible reasons for the lower response of the aggregate output (GDP) growth of 3.8%,[16] as against 7.5% growth in total capital investment during the period 1998–2016. First, the highest share of capital investment was in the M&Q sector, which is a capital-intensive sector with large investments required in equipment and R&D, beside the rising costs of extraction of its products[17] and the recent downwards fluctuation of its prices. Second, the increased share of public investment in electricity, water supply, transport infrastructure, housing, telecommunication, and real estate development takes a long time to pay off.

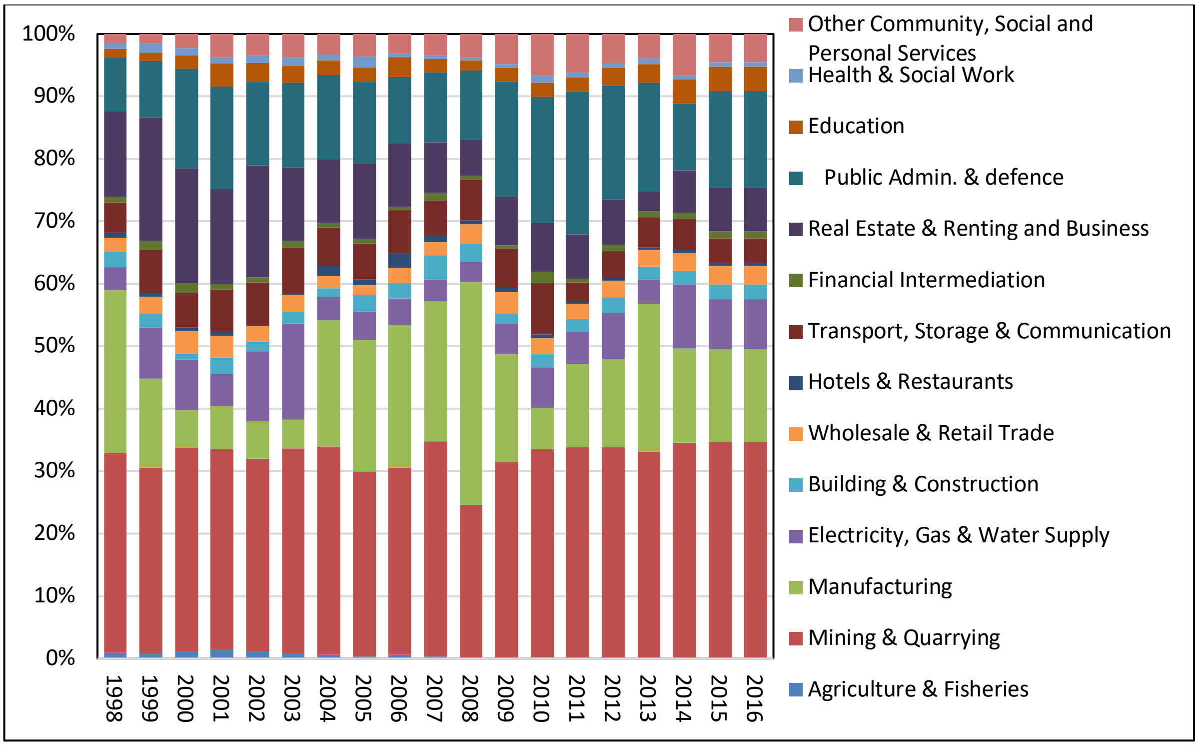
*Figure 2. 14: Oman's Capital Investment and as Percentage of GDP, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

[15] This significant share of capital investment was also the result of the heavy investments in a Liquefied Natural Gas (LNG) plant which has been considered as part of the manufacturing sector.
[16] As will be discussed in more detail in section (2.8).
[17] Oil and gas extraction is getting more difficult and expensive over time in Oman, due to high extractions and the need to use new Enhanced Oil Recovery (EOR) techniques to maintain the production flows such us directional drilling and drilling extra wells for chemical (polymer and surfactant) injection into the reservoirs.

*Figure 2. 15: Oman's Multi-Sectoral Capital Investment Compositions, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

## 2.7 Export Structure

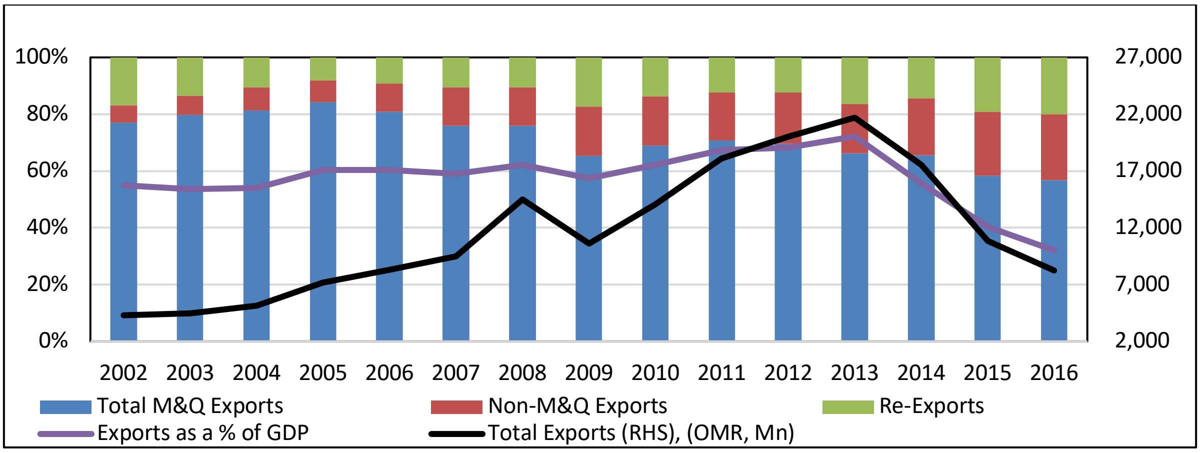
Exports have been a dominant contributor to Oman's economy. The average share of exports to GDP[18] was 57.3% during the period 2002–2016, as shown in Figure (2.16). The M&Q sector was consistently the largest contributor, with an average share of 74.4% of the total exports during the period. With increasing crude oil prices, total exports increased from OMR 4.3 billion in 2002 to OMR 21.7 billion in 2013. As international crude oil prices declined by over 60% since the year 2014, however, the value of total exports sharply declined to OMR 8.2 billion in 2016, resulting in the share of re-exports[19] increasing from 16.9% in 2002 to 25.0% in 2016.

[18] At current prices.

[19] Which is just a trading activity and thus does not contribute directly to the overall output (GDP) growth of the economy.

Although the share of total exports held by non-M&Q sectors increased from 17.5% in 2013 to 29.1% in 2016, this seems to be mainly due to the decrease in total exports arising from the decline in the M&Q sector's exports. In absolute terms the value of non-M&Q sector exports declined from OMR 4.1 billion in 2014 to OMR 2.4 billion in 2016, which seems to be in line with the decline in the value of the M&Q sector's exports. This highlights the strong link between the proportion of the total exports held by the non-M&Q sectors and the M&Q sector's exports, and between the M&Q sector's exports and the international crude oil prices.

*Figure 2. 16: Oman's Exports Structure, During the Period 2002–2016*



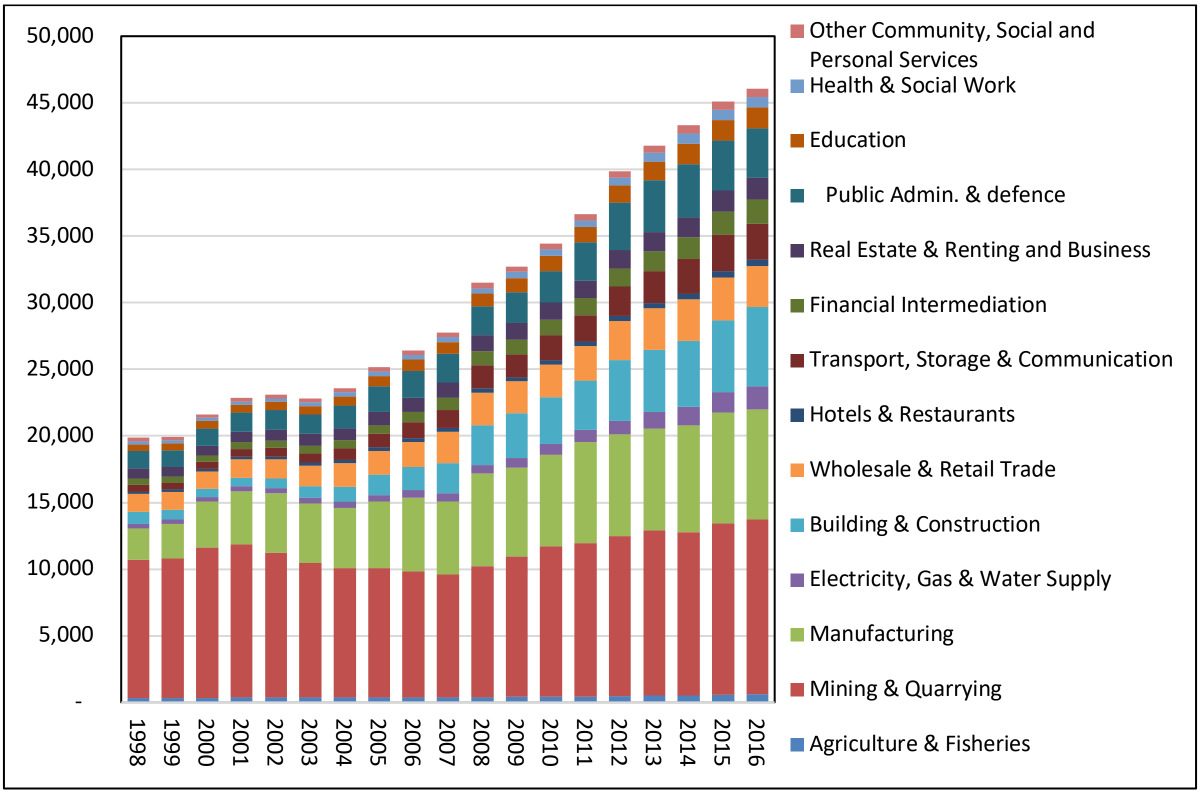

*Source: Compiled by Author using NCSI Data*

## 2.8 Gross-Output and GDP Structures

The aggregate gross-output of Oman's economy increased from OMR 19.8 billion[20] in 1998 to OMR 46.1 billion in 2016, as shown in Figure (2.17), with an average growth of 4.8% per annum during the period. M&Q; manufacturing; building & construction; public administration & defence; and wholesale & trade were the sectors contributing the most to aggregate gross-output, having an average total share of 78.6% and average individual shares of 37.9%, 18.5%, 7.6%, 7.4% and 7.1%, respectively, during the period.

[20] At constant prices, 2010 being the base year .

*Figure 2. 17: Oman's Multi-Sectoral Gross-Output Contributions OMR (Mn), During the Period 1998–2016, Constant Prices*

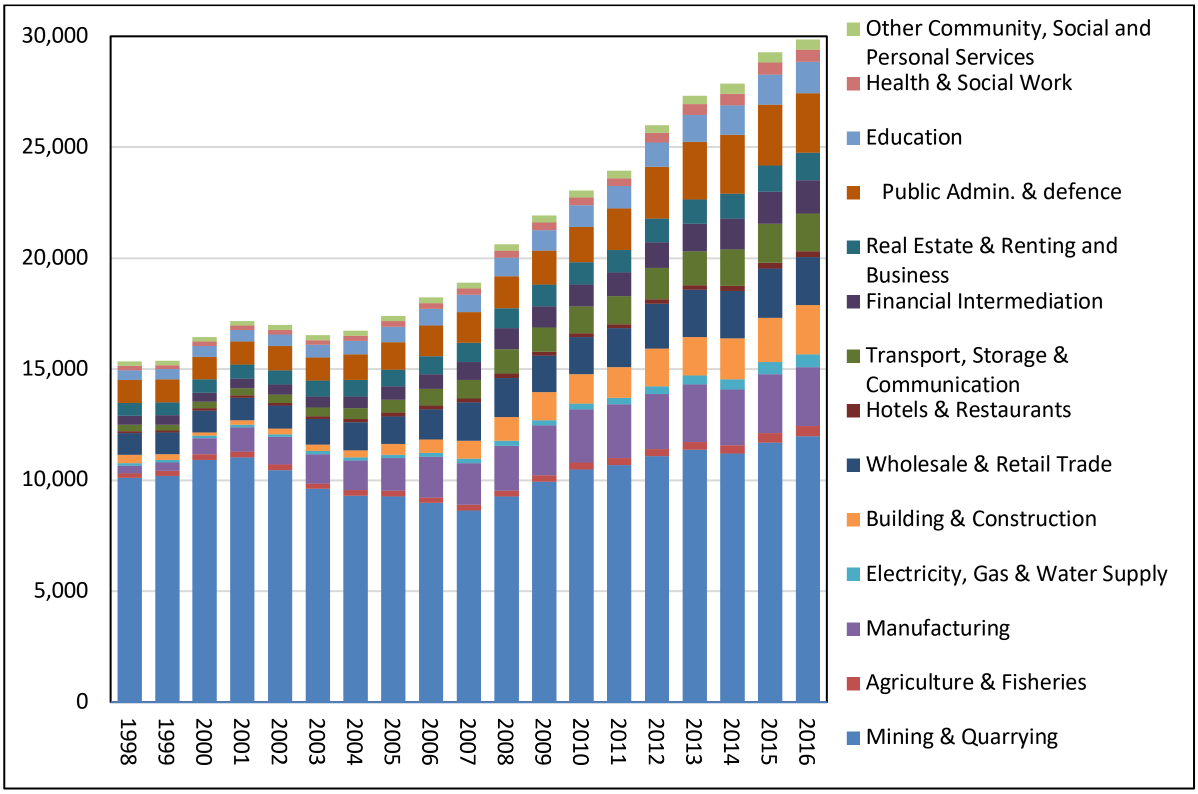



*Source: Compiled by Author using NCSI Data*

Whereas the aggregate output[21] (GDP) increased from OMR 15.4 billion in 1998 to OMR 29.9 billion in 2016, as shown in Figures (2.18), with an average growth of 3.8% per annum during that period. At a sectoral level, meanwhile, the highest average GDP growth of 13.9% per annum during the period was in the manufacturing sector, while the lowest average GDP growth was in the M&Q sector, being 1.0% per annum during the same period.

[21] Value-added.

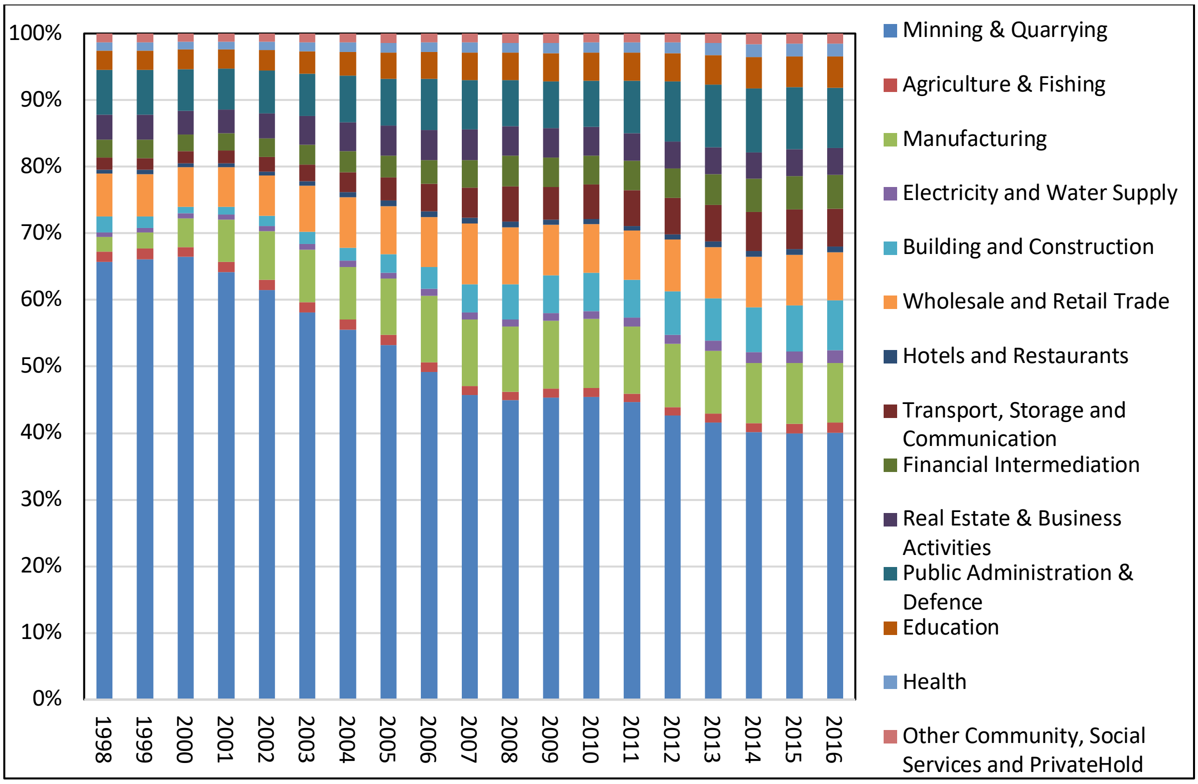
*Figure 2. 18: Oman's Multi-Sectoral GDP Contributions OMR (Mn), During the Period 1998–2016, Constant Prices*




*Source: Compiled by Author using NCSI Data*

Moreover, as shown in Figures (2.19), M&Q; manufacturing; public administration & defence; wholesale & retail trade; and real estate & renting business; and finally, building & construction were the main contributors to Oman's GDP during the period, having an average total share of 78.0% and average individual shares of 51.1%, 8.1%, 7.5%, 7.2%, and 4.1%, respectively.

*Figure 2. 19: Oman's Multi-Sectoral GDP Compositions, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

To analyse the dynamics of the main sectors in Oman's economy we consolidate the 14 sectors of the economy into four sectors as follows:

1) Agriculture and fisheries,

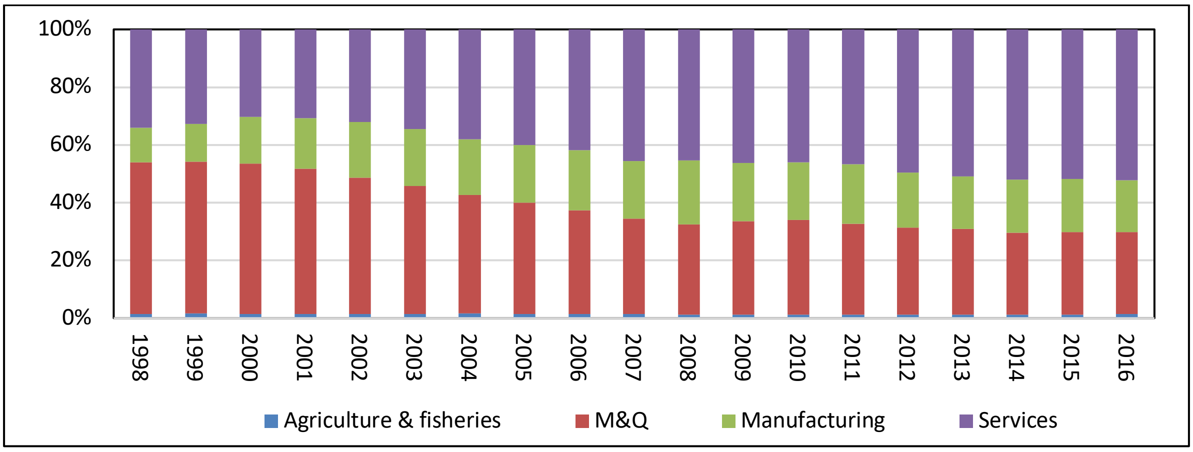
2) Mining & Quarrying,

3) Manufacturing, and

4) Services.

Figure (2.20) shows that the agriculture and fisheries, and manufacturing sectors have not been able to increase their shares in the economy's gross-output, remaining with an average of 1.4% and 18.5%, respectively, during the period 1998–2016. The services sector, however, has increased its contribution from 34.2% in 1998 to 52.2% in 2016, with the average being 42.2% during the period, while the M&Q sector's share reduced from 52.4% in 1998 to 28.5% in 2016, with an average of 37.9% during the same period.

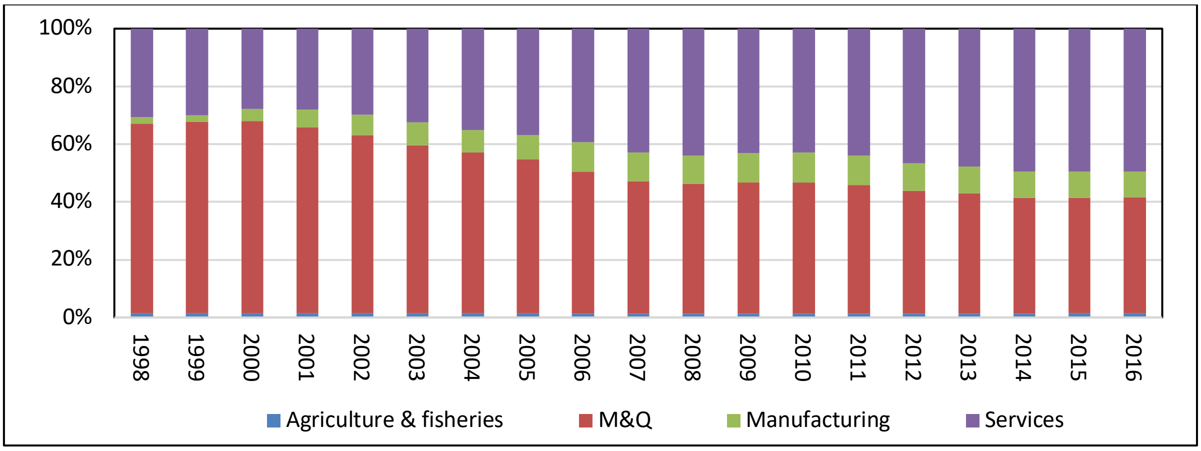
*Figure 2. 20: Oman's Main Multi-Sectoral Gross-Output Compositions, During the Period 1998–2016*




*Source: Compiled Author using NCSI Data*

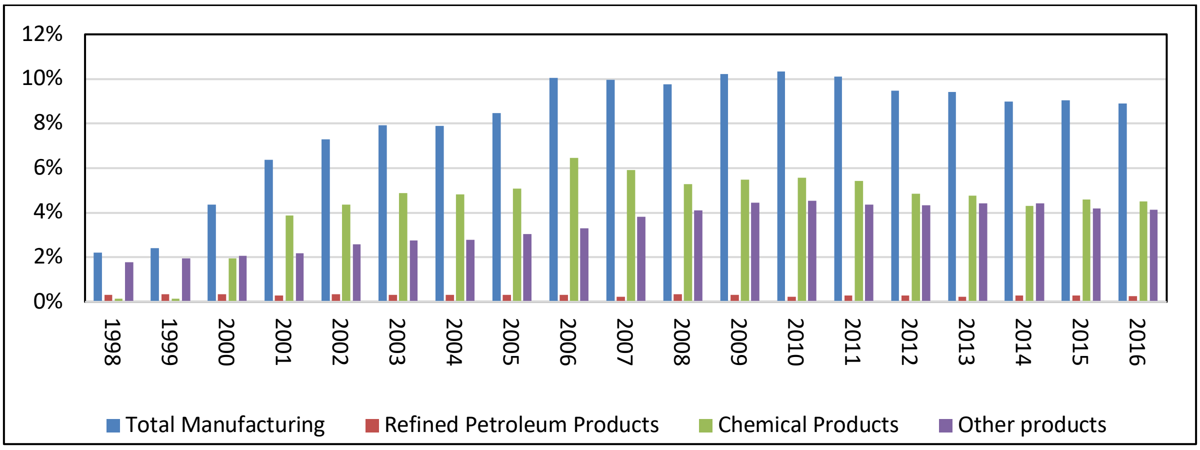
Figure (2.21) shows the main consolidated sectors shares in the economy's output (GDP) during the period 1998–2016. As can be seen, again the agriculture and fisheries and manufacturing sectors remained with low average shares of 1.4% and 8.1%, respectively. Thus, these sectors were not able to contribute substantially to Oman's economy over the period. Although the share of the manufacturing sector increased from 2.2% in 1998 to 8.9% in 2016, and its average growth was the highest in the economy during the period (13.9% per annum), as was highlighted earlier, this was mainly the result of the start of LNG production and its GDP contribution as part of the manufacturing sector. Figure (2.22) shows that manufacturing of refined petroleum and chemical products accounted for, on average, 56.9% of the manufacturing sector's GDP share during the period, meaning that actual non-M&Q related manufacturing GDP share was on average only 3.4% of Oman's GDP.

*Figure 2. 21: Oman's Main Multi-Sectoral GDP Compositions, During the Period 1998–2016*




*Source: Compiled Author using NCSI Data*

*Figure 2. 22: Oman's Manufacturing Sector's Composition as Percentage of Total GDP, During the Period 1998–2016*

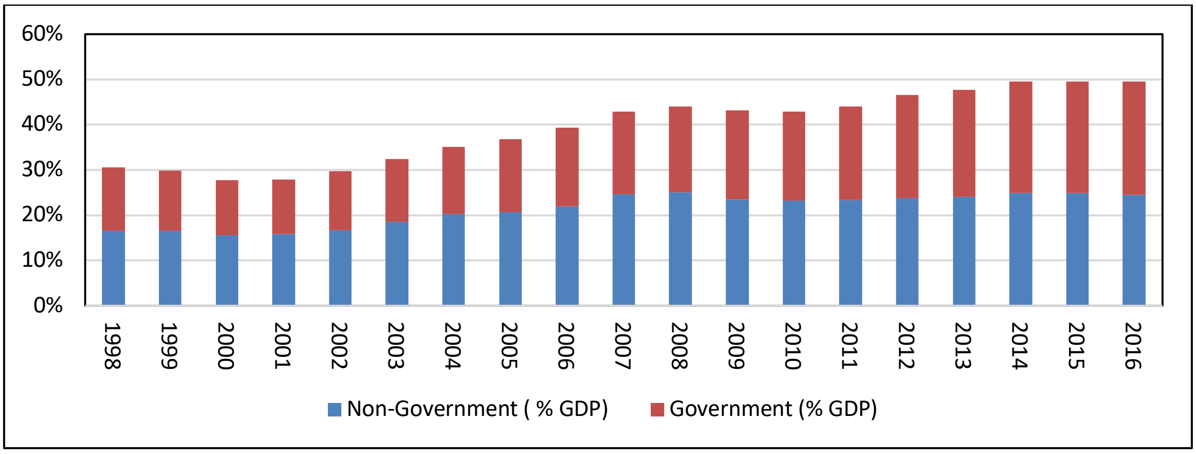



*Source: Compiled Author using NCSI Data*

The share of GDP held by the consolidated services sector increased from 30.6% in 1998 to 49.5% in 2016, with an average share of 39.4%, and growth of 6.7% per annum during the period, as shown in Figure (2.23). This sharp increase in the service sector's share of the GDP was mainly due to the high demand for services both from the governmental and non-government sectors. The non-government sector's demand for services accounted for an average of 54.4% of the total services, with the rest being accounted for by government demand. Crucially, there with a significant average growth rate of 6.7% per annum during the period.[22] The effect of the large revenues from the M&Q sector on government revenues seem, therefore, to have had a direct effect on the services sector through government expenditure and demand for services, besides the M&Q sector's own demand for services for its own support and growth.

On the other hand, the share of GDP held by the M&Q sector decreased from 65.7% in 1998 to 40.1% in 2016. Although the M&Q sector's share decreased it remained the dominant sector, however, contributing an average of 51.1% to Oman's GDP during the period.

*Figure 2. 23: Oman's Service Sector's Composition as Percentage of Total GDP, During the Period 1998–2016*




*Source: Compiled Author using NCSI Data*

## 2.9 Summary

The overall objective of this chapter was to review and analyse Oman's overall development experience, how the structure of the economy has changed during the period 1998–2016, and the impact of the M&Q sector on the development of the economy and on other sectors of the economy.

The results of this analysis show that the discovery of the M&Q resources, their extraction, export, and export revenues have played a drastic role in transforming Oman's economy. In

[22] The average GDP growth during the period 1998–2016 was 3.8%.

summary, the export of the M&Q products has been the main source of government revenue during the period under study, and has enabled the government to play a major role in the country's development programme, especially through building infrastructure and providing the main utilities (Mellahi *et al.*, 2003). The M&Q sector has also been the dominant sector in the economy during the period, with an average GDP share of 51.1%, and has dominated exports during the same period, with an average of 74.4% share of all exports.

The proportions of the GDP held by the agriculture and fisheries, and manufacturing sectors have always been marginal, with averages of 1.4% and 8.1%, respectively, during the period; and their share of the total capital investment have also been marginal, especially for the agriculture and fisheries sector. Although the manufacturing sector has grown the most of all sectors during the period of study, at 13.9% per annum, closer analysis revealed that this growth could mainly be attributed to sub-sectors that were directly related to the M&Q sector's products (LNG). The actual net average non-M&Q related manufacturing sector share of the GDP was only 3.4%. Hence it could be said that the core manufacturing sector's share of the GDP has been relatively small and has increased only marginally from 1.8% to 4.1% during the period.[23]

Despite the increasing share of the GDP held by the services sector during the period[24] it is very unlikely that the services sector would be able to drive Oman's future economic growth. Its contribution to the total exports of the economy is almost negligible and has been mainly driven by the high government and the M&Q sector's demands. In the absence of the M&Q revenues, therefore, the amount of continuing demand could be questionable. The same could be said for the wholesale & retail trade and transport, storage & communication sectors, which

[23] After removing the LNG portion of the GDP from the manufacturing sector.
[24] The services sector's share in the GDP increased from an average of 30.6% in 1998 to 49.5% in 2016, with an average growth of 6.7% per annum during the period.

are considered as part of private services, and which are mainly linked to foreign trade with little direct local content. The hotels & restaurants, and real estate & renting businesses sectors, meanwhile, are non-tradable sectors. Hence these private services, which accounted for on average 41.3% of the total services sector (and 75.9% of private services) would not add any direct value to the economy in the long-term. As it stands, therefore, the services sector cannot become the driver for Oman’s future economic growth.

Oman's GDP growth rates have been mainly due to the contribution of the M&Q sector, despite the government’s longstanding objective of diversifying sources of income and reducing the dependency on the M&Q sector and its products. Fiscal policy through the government expenditure has been the main driver of growth and development in the other sectors of the economy. The M&Q sector’s proceeds accrue to the government and are channelled to other sectors of the economy through the government expenditure and capital investments. Although the M&Q sector’s products are directly affected by the fluctuations in the international market prices, so far, the overall average prices have been in favour of the M&Q resource-based countries such as Oman. While demand has been sustained over a long period, ultimately, the M&Q sector’s resources are finite, the extraction of its products will become more difficult and expensive, and demand will diminish sooner or later due to substitutions and new energy sources. Before then, it is crucial for Oman to decouple itself from dependency on the M&Q sector through a dynamic reallocation and deployment of its current M&Q resources towards other non-M&Q tradable and productive sectors of the economy.

# Chapter 3: Measurement of Oman's Multi-Sectoral Input Factors

The main objective of this chapter is to estimate and analyse the main sources of input factors in Oman's economy on national and multi-sectoral levels, during the period 1998–2016. This will be achieved through an empirical growth accounting exercise which uses the aggregate neoclassical production function to decompose the growth rate of aggregate output into contributions of capital stock, labour and Total Factor Productivity (TFP).

Determining the input factors for Oman's economic growth will also allow an estimate of the potential for diversification (in the sense of being less dependent on capital and labour, and more on TFP, and in the sense of the potential of Oman to become less dependent on income from the Mining and Quarrying (M&Q) sector's resources), and hence the ability of Oman's economy to sustain its level of income and growth. In addition, analysing how the multi-sectoral input factors contributed to the output growth of the main productive tradable sectors will make it possible to support those sectors more effectively, which in turn will assist the task of diversifying away from the M&Q sector and its stream of revenue.

TFP is a useful analysis for our proposes because, if Oman's output growth has been mainly the result of using the M&Q sector's resources to employ more labour and more capital investments, then any decrease in that income would have a negative impact on the output and its growth, ultimately calling into question the possibility of sustaining income levels and output growth. On the other hand, if the output growth has been a function of TFP, and not just labour and capital investments, then the loss of the M&Q sector's income could have less impact on output growth. Output growth led by TFP contribution may suggest increasing efficiency in the use of input factors, and could indicate that output is much more diversified, and that the economy is less dependent on the M&Q sector's income.

Estimating and analysing the input factors in Oman's output growth is therefore crucial for the following reasons. First, such an analysis is important to understand the contribution of input factors to output growth, and how they have changed through the course of the period being studied. Secondly, it shows the role and contribution of TFP in the overall economy, and each sector's output growth, as well as whether the growth was simply an accumulation of capital and labour or whether it was also due to TFP. Thirdly, it shows how efficiently input factors have been used in the overall economy and in each sector, since resources are finite, and their efficient allocations have an important role in the economy's long-term growth. Fourth, estimations of TFP contributions for consolidated sectors, excluding the M&Q sector, would suggest if these sectors can sustain output growth in Oman's economy in the absence of the M&Q sector income. Finally, it supports the task of identifying which sectors in the economy are the most productive, and thus which sectors are likely to be central to delivering sustainable growth of the economy's output in the context of future diversification.

This chapter will answer the following major questions:

1) What are the main general facts of Oman's long-term output growth model?
2) Which are the main input factors contributing to Oman's output growth on national as well as on multi-sectoral levels?
3) Has the multi-sectoral allocation of resources been efficient in Oman's economy?
4) Which are the main non-M&Q productive tradable sectors in Oman's economy that can be identified for further allocation of resources so as to support their expansion, for economic diversification and future economic growth?.

## 3.1 Literature Review

### 3.1.1 Economic Growth Models

The recent empirical literature on economic growth has suggested a wide range of growth correlates. The list includes, among others, initial conditions, macroeconomic performance, trade openness, government size, income distribution, financial markets development, institutions, politics and geography. These ultimate sources of growth have been shown to be as important as the proximate input factors of growth, namely, physical capital, labour, and the efficiency with which these input factors are combined. Among the variables recently introduced into the empirical literature is natural resource[25] abundance (Makdisi, Fattah and Limam, 2006).

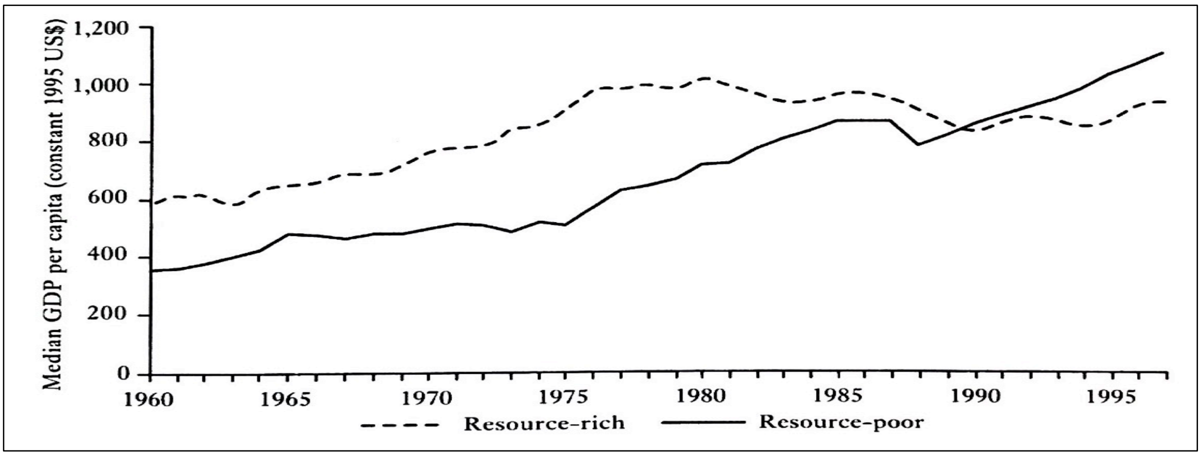
There are different views as to the role of natural resources in economic development. Some studies, such as Ginsburg (1957), considered natural resources to be the fifth means of production after land, labour, capital and technology, and thus saw endowment with resources as promoting fast economic growth. For example, Sarraf and Jiwanji (2001) suggested that Botswana's economic success story of achieving economic development and sustained growth was based on the good management of its diamond resources. According to Wright and Czelusta (2003), meanwhile, in nineteenth-century the USA was a mineral and an industrial-based economy, and the technological advances driven by mineral extraction activities added overall value and know-how to the economy.

Other researchers, however, have suggested that an abundance of natural resources could be quite a disadvantage and actually reduce economic output growth. For instance, Sachs and Warner (1995, 1997) found that economies with abundant natural resources and a high ratio of

[25] Natural resources are defined as primary agriculture, land, fuels and minerals.

natural resources exports to output tend to have lower growth rates during the subsequent period, if compared to economies with less natural resources. This negative relationship holds true even after controlling for variables found to be important for economic growth, such as initial per capita income, trade policy, government efficiency, investment rates, and other variables. Using a sample of 85 countries for the period 1960–1990, Auty (2001) showed that the non-resource-based countries grew two to three times faster than resource-based countries, apparently confirming the significant negative linkage between economic growth and natural resources abundance. World Bank (1999), meanwhile, compared the growth trajectories of resource-abundant and resource-poor countries to show that the growth in GDP per capita of the resource-abundant countries collapsed after the oil shocks of the 1980s, whereas the growth in output per capita of the resource-deficient (manufacturing-led) countries actually accelerated, as shown in Figure (3.1).

*Figure 3. 1: Median GDP per Capita, for Resource-rich and Resource-poor Developing Countries, (Constant 2005 prices)*




*Source: World Bank (1999)*

The literature suggests that an abundance of natural resources negatively affects output growth through several channels. It is supposed to have an adverse impact on output growth mainly due to so-called “Dutch disease”[26] (Sachs and Warner, 1997). According to this argument, high prices (and thus revenue) for a natural resource attract factors of production from other sectors, so that the abundant natural resource sector expands at the expense of other sectors. In addition, these high prices lead to an over-valued exchange rate which in turn hurts exports in general and the exports of other sectors in particular. Corden and Neary (1982) formalized the above argument by showing how an abundant natural resources sector first sucks in the input factors (capital and labour) from the manufacturing and services sectors, which they refer to as the “resource movement effect”. They then show a second economic impact, in that the large income from the booming sector leads to an increase in prices and wages, which results in an increase in overall demand within the economy. This increased spending from the booming sector’s income is called “the spending effect”. Both Auty (2001) and Sachs and Warner (2001) also confirmed that resource-based revenue leads to rent-seeking behaviour and non-productive sectors. Resource-rich countries are also usually associated with wasteful use of resources, high consumption and high public investment behaviours, induced by the natural resource-abundance and the lack of incentive for proper resource management, which impacts negatively on growth. The cyclical variations in international prices of natural resources, and their high volatility, also translate into high uncertainty, which in turn, impacts negatively on growth.

The academic debate on diversification for a single resource, or a depletable resource economy has centred around: (i) avoiding shocks arising from adverse terms of trade between primary commodities and manufactured products, (ii) encouraging domestic resource-based industrialization and creating new sources of income (Auty, 1990), (iii) developing new economic sectors and promoting employment, and (iv) strengthening the inter-linkages between the different sectors of the economy (Hirschman, 1958).

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[26] Also called the Resource Curse. Will be discussed in more detail in Chapter (4), section (4.3).

Also, diversification in output and exports are closely linked to one another, and are considered to be the outcome of structural transformation and the growth of an economy, and the dynamic reallocation of resources from less productive to more productive sectors (McMillan, Rodrik and Verduzco-Gallo, 2014). This transformation typically involves a reallocation away from agriculture and natural resources, and towards manufacturing, since the latter has greater potential for improvements in productivity and quality (Cadot, Carrère and Strauss-Kahn, 2011). Indeed, Papageorgiou and Spatafora (2012) found that upgrading quality and productivity growth are positively correlated with economy's growth. Concentration on sectors with limited scope for upgrading quality and productivity growth, such as primary commodities, may result in less broad-based and sustainable growth, however. Since export sophistication is crucial for growth, the manufacturing sector, with its high potential for sophistication, represents an important sector to focus on. Herrendorf, Rogerson and Valentinyi (2014) also confirmed that the process of structural transformation, that is the reallocation of inputs to more productive sectors, is recognized as an important feature of successful economic development.

### 3.1.2 Total Factor Productivity (TFP)

Besides the importance of the contributions of physical and human capital as input factors to output, and thus to real income expansion, it is widely accepted in the economic literature that productivity growth can also arise from changes in technology, competitiveness, market structure, government regulations, business environment, etc. This is referred to as TFP, or the Solow residual, after the original proposer, Robert Solow.

In an effort to explain the enormous disparity in growth rates in per capita output across countries,  the initial neoclassical theories endogenized country's technologies, such as (e.g. Romer, 1990; Grossman and Helpman, 1991). The belief was that the level and growth rate of productivity is roughly the same across countries, so that differences in output levels and growth rates are largely due to differences in physical and human capital (Klenow and Rodriguez-Clare, 1997).

This belief has been argued in a series of empirical studies. Mankiw, Romer and Weil (1992) argued that the share of physical and human capital, together with population growth, account for as much as 80 percent of the international variation in per capita income. Romer (1993) argued that idea gaps are much more important than object gaps.[27] Benhabib and Spiegel (1994) used cross-country estimates of physical and human capital stocks to find that human capital affects TFP growth, through its impact on the capacity of a country to innovate and the capability of using and adapting foreign technology. Klenow and Rodriguez-Clare (1997) showed the importance of productivity versus physical and human capital in explaining international differences in levels and growth rates of output, arguing that TFP is the key to economic growth, and that factor accumulation plays only a less important role.

Beside the importance of measuring TFP at an aggregate level, Herrendorf, Rogerson and Valentinyi (2014) argued that measuring TFP at multi-sectoral levels delivers new and sharper insights for understanding the economic development of an economy, and that it is able to account for many salient features of structural transformation.

In summary, the neoclassical growth model suggests that economies' output will grow by the accumulation of labour and capital until the marginal return to capital is equal to the marginal return in labour, and thus that accumulation of input factors only exhibits diminishing returns. This means that a country cannot solely rely on labour and capital accumulations as input factors, but must strive to sustain TFP contribution and its growth in each of its sectors if its economy overall is to grow sustainably.

[27] A nation that lacks physical objects like factories and roads suffers from an object gap, whereas a nation that lacks the knowledge used to create value in a modern economy suffers from an idea gap.

Moreover, in addition to the importance of physical and human capitals as input factors for output and its growth, their efficient allocations across the sectors of the economy also plays an important role. Restuccia and Rogerson (2007) investigated the underlying causes of the differences in output per capita between countries. Instead of focusing on the efficiency and productivity, however, they looked at the contributions of the input factors and the effect of their misallocations on aggregate TFP. They argued that differences in the allocation of resources across heterogeneous plants can lead to sizeable decreases in output, and hence on measured TFP (in the range of 30% to 50%). Hsieh and Klenow (2009) used micro-data on manufacturing establishments to quantify the potential extent of misallocation of resources in China and India versus the USA. When they hypothetically reallocated capital and labour to equalize the marginal products to the extent observed in the USA, they found that manufacturing sector TFP increased by between 30% and 50% in China, and between 40% and 60% in India. Similar work has been performed by Inklaar, Lashitew and Timmer (2017) using World Bank survey data for formal manufacturing firms in 52 low-and-middle-income countries. They showed that manufacturing productivity increased by an average of 62%, when the misallocations were eliminated. Jones (2011) argued that precise resource input allocations can maximize the overall output in the long run. He showed that misallocation of resources results in lower levels of output, and therefore shows up in aggregate as a lower level of TFP. He also showed how the misallocation of resources gets amplified and has an even more negative effect on the output, through the Input-Output (IO) structure of an economy; a feature that will be discussed in more detail in Chapter (5). In summary, it is not only the level of accumulation of input factors that matters, but also how these input factors are allocated across the sectors of an economy.[28]

### 3.1.3 GCC Growth Model and TFP Performance

Governments are the dominant force in the economies of the Gulf Cooperation Council (GCC) countries, receiving export revenue from the M&Q sector and in turn distributing this to their citizens. A portion of these revenues are spent directly by the governments and provided to their citizens through transfers and public-sector jobs; another part is invested in infrastructure, real estate, education, and health, while the remainder, if any, is saved.

The proceeds from the extraction of large oil and gas reserves,[29] as shown in Table (3.1), are the main source of export and fiscal revenues for the GCC countries, as shown in Figure (3.2). These revenues represent almost 75.0% of governments' revenue, 30.2% as a share of the GDP, and 80.1% of the total export of the GCC countries.

*Table 3. 1: GCC and World Oil and Gas Reserves, for the Year 2017*

| Country | Oil Reserves (Billion Barrels) | Oil Reserves/ Production Ratio (Years) | Proven Gas Reserves (TCM) | Gas Reserves / Production Ratio (Years) |
|---|---|---|---|---|
| Saudi Arabia | 266.5 | 60.8 | 8.4 | 77 |
| Kuwait | 101.5 | 89.8 | 1.8 | 104.2 |
| UAE | 97.8 | 68.7 | 6.1 | 98.5 |
| Qatar | 25.2 | 36.4 | 24.3 | 134.1 |
| Oman | 5.4 | 15.5 | 0.7 | 19.9 |
| *Total World* | *1,706.70* | *17.8* | *186.6* | *52.5* |

*Source: BP Statistical Review of World Energy*

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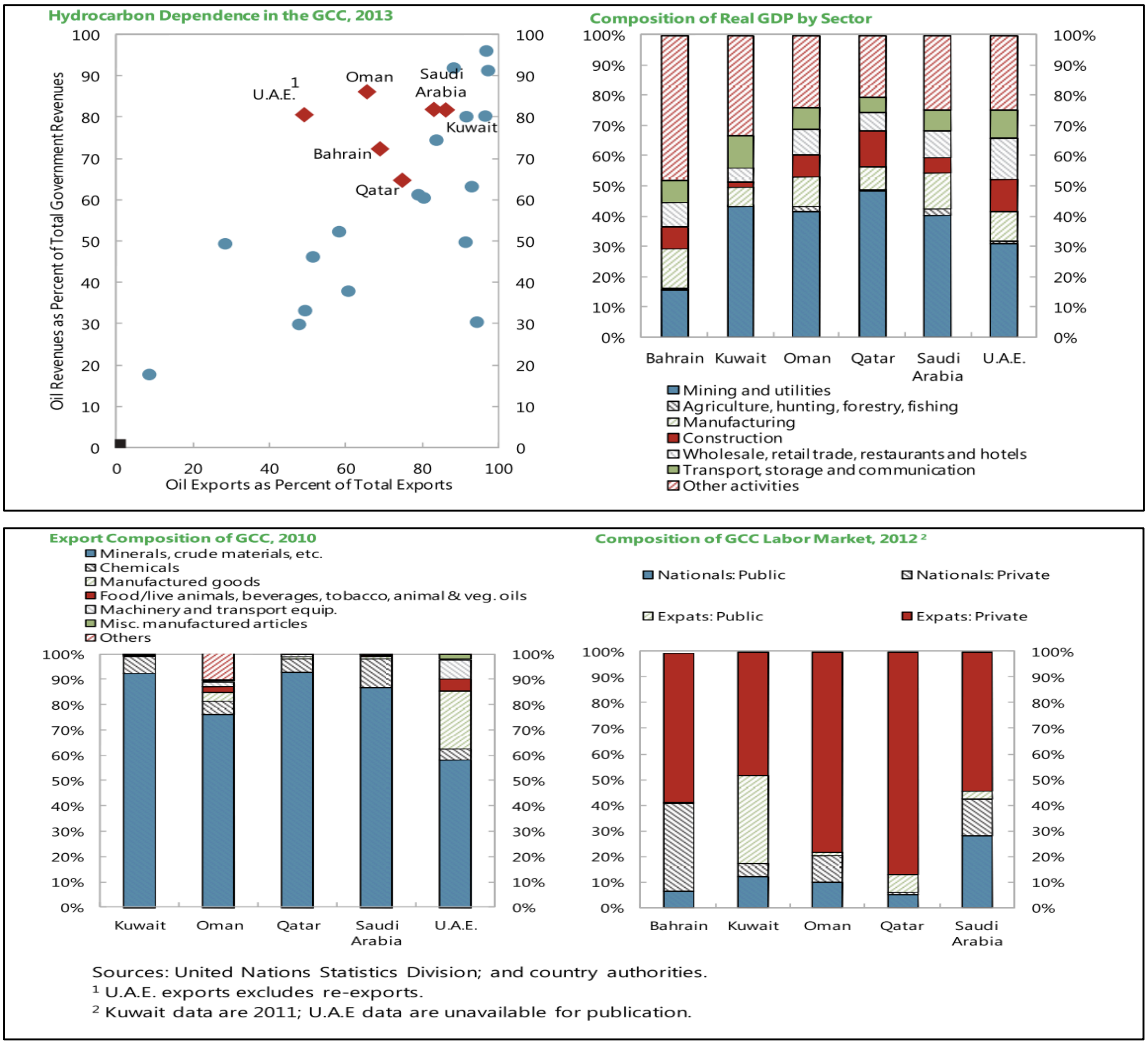
[28] Baily, Hulten and Campbell (1992) documented that almost half of overall productivity growth in the US manufacturing sector in the 1980s could be attributed to input factor reallocation from low productivity to high productivity plants.

[29] 29.1% and 22.1% of world oil and gas reserves, respectively, measured using the data reported in Table (3.1).

*Figure 3. 2: Structure of the GCC Economy*




This M&Q resource-based model has allowed the GCC countries to become one of the fastest-growing regions in the world. Figure (3.3) shows the increase in the output of the GCC countries as compared with the USA, for the period 1980–2016. The combined output of the GCC countries showed an increase from $253.7 billion in 1980 to $1,357.0 billion in 2016, with an average growth of 5.5% per annum. Over the same period, the output of the USA showed an increase from $2,862.5 billion to $18,624.5 billion, with an average growth of 5.4% per annum.[30]

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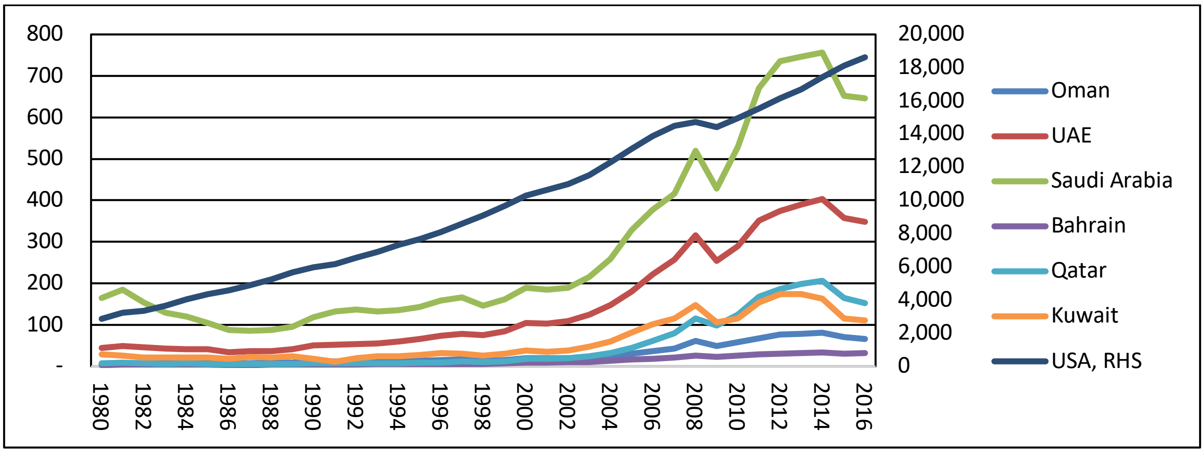
[30] The USA is considered to be one of the fastest growing economies during this period, Wikipedia.

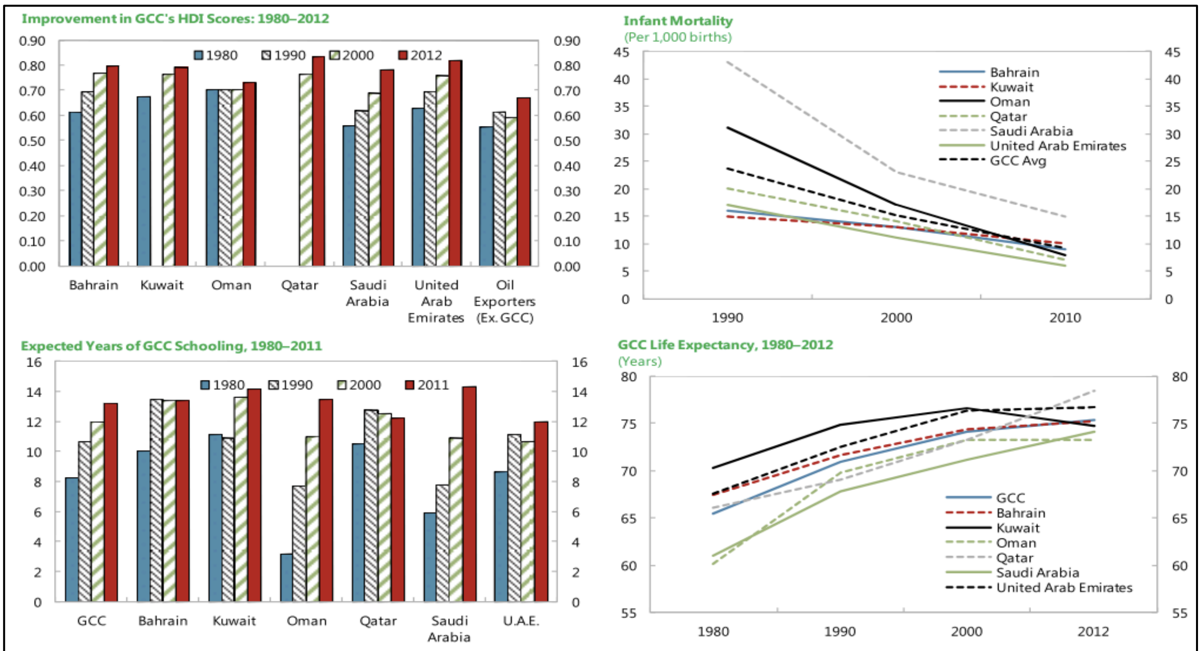
*Figure 3. 3: GCC and the USA Economies' GDP Dynamics, USD (Billion), During the Period 1980–2016, Current Prices*




*Source: Compiled by Author using Penn World Table, version 8.1*

Alongside the significant output growth in the GCC economies, the human and social indicators have also improved substantially during the period: infant mortality has decreased, expected years of schooling have increased and life expectancy has risen, as shown in Figure (3.4).

*Figure 3. 4: Human and Social Development Indicators of the GCC Countries*




Sources: United Nations Development Programme; "World Population Prospects: The 2008 Revision," UNDESA, New York: Department for Economic and Social Affairs, 2009; UNESCO Institute for Statistics.

Despite the remarkable increase in their output growth, and the improvement in their human and social development indictors, the productivity growth in the GCC countries has generally been unsatisfactory. Table (3.2) shows that capital investments and labour force growth (underpinned by the availability of relatively low-cost foreign labour) have been the main drivers of growth in the non-M&Q sectors during the period 1990–2012, while the contribution of TFP to growth has generally declined. Input factors have risen significantly over the past two decades, with capital investments growth outpacing employment growth. Figure (3.5) shows the significant increase in capital investments in the GCC during the period 1990–2012 (IMF, 2013) .

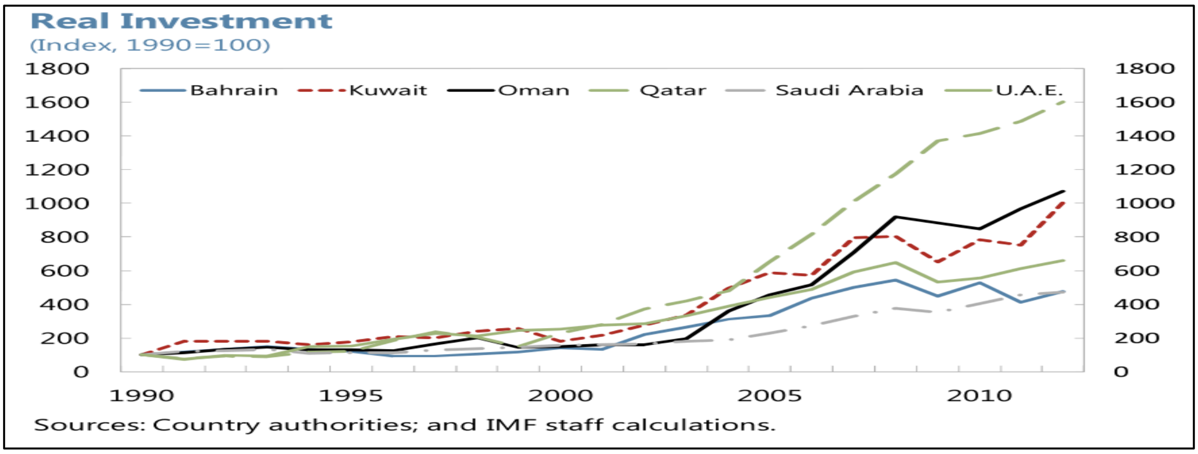
*Table 3. 2: GCC average Input Factors Contributions to Non-M&Q Sectors' Growth*

| | Bahrain | Kuwait | Oman | Qatar | Saudi Arabia | U.A.E. |
|---|---|---|---|---|---|---|
| | | | 1990–99 | | | |
| Growth | 4.2 | 6.6 | 5.8 | 3.8 | 3.4 | 9.0 |
| TFP | 0.4 | -3.1 | 1.8 | 0.2 | -0.1 | 0.0 |
| Capital | 1.8 | 3.6 | 2.5 | 2.5 | 2.0 | 3.0 |
| Labor | 2.0 | 6.1 | 1.6 | 1.1 | 1.5 | 6.0 |
| | | | 2000–12 | | | |
| Growth | 6.8 | 6.2 | 7.3 | 14.5 | 6.3 | 6.7 |
| TFP | -2.4 | -0.6 | -2.3 | -0.2 | 0.4 | -1.0 |
| Capital | 3.7 | 4.0 | 4.8 | 6.0 | 2.9 | 3.6 |
| Labor | 5.5 | 2.9 | 4.8 | 8.6 | 3.0 | 4.1 |

Source: IMF staff calculations.
[1]Cost share of capital=0.4

*Source: IMF 2013*

*Figure 3. 5: GCC Capital Investments Growth, During the Period 1990–2013*




*Source: IMF 2013*

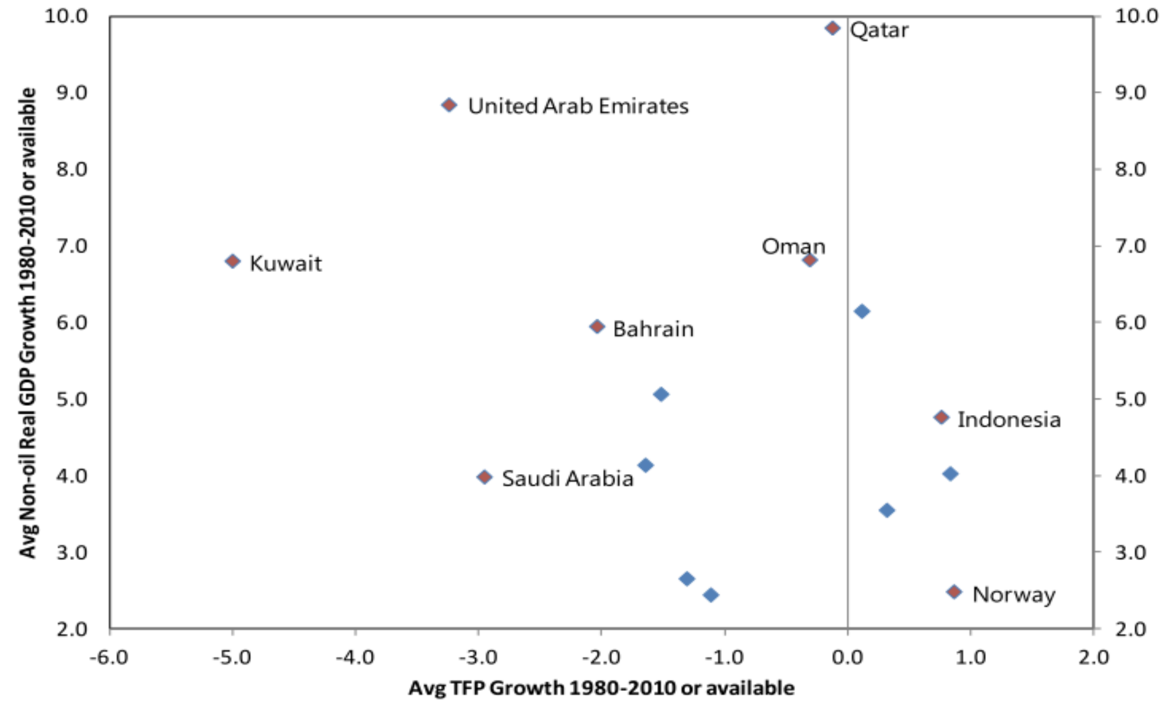
Elhiraika and Hamed (2002) attempted to explain the determinants of the output growth in the United Arab Emirates for the period 1975–1999. They found that the labour contribution amounted to 104% of the overall average output growth of 5%, and the capital investment contribution was 30%, whereas the TFP contribution was negative 34%.

Makdisi, Fattah and Limam (2006) found that, with the exception of Egypt, Morocco, Tunisia and Turkey, all the Middle East and North Africa (MENA) countries included in their sample had negative TFP growth from 1960–1998. In addition, those countries within the MENA region with non-M&Q resources and diversified economies performed much better than the M&Q resource-exporting countries—mainly the GCC countries—both in terms of output and TFP growth.

Yousef (2004) acknowledged that the Middle East region sustained the highest growth in the world, of 6.0% per worker per year during 1960s and early 1970s, but it suffered from falling TFP, from positive 3.4% in the 1960s to negative 1.5% and negative 0.2%, in the 1980s and 1990s, respectively.

Cherif and Hasanov (2014), meanwhile, estimated the average TFP growth versus non-M&Q real output growth of the GCC countries for the period 1980–2010, as shown in Figure (3.6). Their results showed high capital investments and population growth accumulations contributed to the large increase in output growth in the GCC countries, but this was not accompanied by increasing relative performance on a per capita basis; thus, TFP growth declined in all the GCC countries.

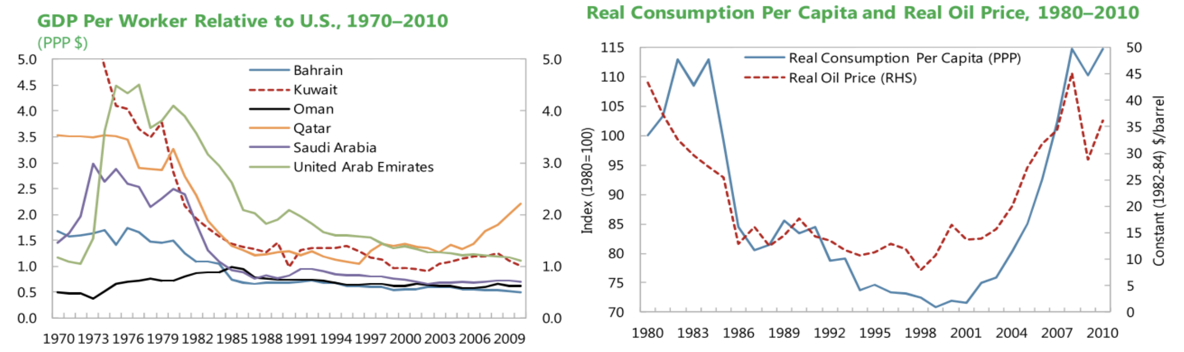
*Figure 3. 6: GCC Real Average TFP Growth vs. Non-Oil Real Average GDP Growth, During the Period 1980–2010*




Source: Penn World Tables 7.1; IMF World Economic Outlook
Note: Oil exporters sample. For some countries, non-oil growth data start in the 1990s

The dependence on revenues from the M&Q sector means that the GCC economies are exposed to the, often volatile, fluctuations in the global market prices of these resources, which represents a key source of macroeconomic volatility for the GCC economies. The fall in oil prices, especially in the early 1980s, for example, provoked a long decline in consumption per capita, which on average fell by more than 30% from its early 1980s' peak; only returning to that level in the late 2000s as prices recovered, as shown in Figure (3.7). This decline, and the poor productivity performance, caused a substantial fall in relative income for most the GCC countries, from 1.5 to 4 times the USA income per capita in 1980 (Callen *et al.*, 2014).

*Figure 3. 7: GCC GDP per worker and Real Consumption, During the Period 1980–2010*




Source: Penn World Tables 7.1.
Note: Real consumption per capita is measured in PPP terms and calculated as the simple average of indices for GCC countries; Oil price is deflated by U.S. CPI.

The average output growth of the non-M&Q sectors in the GCC economies stood at 6.8% per annum during the period 2000–2013, and their share of the output increased from 12% to 70% during the same period, driven mainly by the Saudi Arabia and the United Arab Emirates. These high rates of growth were primarily driven by concurrent growth in prices of (and revenue from) the M&Q sector's resources, however. In particular, rising oil prices in the first decade of this century helped the GCC governments finance a rapid increase in spending which led to strong growth in consumption demand and in low-productivity domestic non-tradable sectors, implying that progress towards genuine output diversification has been modest (Callen *et al.*, 2014; Cherif and Hasanov, 2014).

Output diversification and growth in the non-M&Q sectors could be misleading indicators of diversification and sustainable growth, however. The example of Oman shows that a relatively diverse output (GDP) composition, as exhibited in Figure (3.2), does not necessarily imply export diversification. As discussed in section (2.7) of this thesis, the export structure is a proxy for tradable production and one of the main sources of productivity gains for sustainable growth. In fact, the GCC countries have witnessed a decline in TFP growth over the past decades, despite high non-M&Q growth over the same period. This apparent paradox can be explained, however, by the fact that the increase in the non-M&Q growth is mostly due to the channelling of the M&Q sector revenues to the economy through fiscal and related private spending. The GDP arising in the non-M&Q sectors mainly comprises energy-intensive and resource-related industries like metals, and petrochemicals and construction, as well services such as retail and restaurants, transport and communications and social services. High non-M&Q growth in these economies is not an indicator that growth could be sustained in the long run, or if the M&Q resource prices were to fall for a sustained period of time. Hence, the decline in productivity and relative income stagnation in the GCC countries can be explained by the export of non-diversified products and stagnating export sophistication.[31]

The prevailing M&Q resource-based economic model in the GCC countries has achieved large improvements in human development indicator scores, a large infrastructure base and significant output growth. Its main features are reliance on the M&Q resources as the main export economic activity, and on low skilled imported labour. Although this model has resulted in higher per capita incomes relative to the era before the exploitation of the M&Q resources, per capita incomes have declined relative to the USA since the 1970s, due to negative TFP growth (IMF, 2013).

### 3.1.4 Oman's TFP Performance

Mansur and Treichel (1999) assessed the input factors that have contributed to Oman's economic growth for the period 1981–1997, as shown in Table (3.3). Their results showed that, on average, TFP has made no contribution to growth performance in Oman. In essence, the average real growth in GDP of 7.0% per annum during the period was more than accounted for by the accumulation of substantial capital investments and the expansion of the labour force. They argued that the significant average productivity gain achieved during the period 1986–

[31] Oil and gas being c.80% of GCC countries' exports.

1989 was associated with a significant decline in oil prices, strongly suggesting that both capital and labour were more efficiently utilized in a period of relative scarcity.

*Table 3. 3: Oman's Average Input Factors Contributions to Economy's Output Growth, During the Period 1981–1997*

| | | Contributions (In Percentage of GDP) | | |
|---|---|---|---|---|
| Rapid Growth Periods | Growth in GDP | Capital | Labour | TFP |
| 1981-85 | 14.1 | 6.1 | 9.2 | -1.2 |
| 1990-93 | 7.3 | 4.4 | 9 | -6.1 |
| Slow Growth periods | | | | |
| 1986-89 | 1.6 | -6 | -0.1 | 7.7 |
| 1994-97 | 4 | -1.7 | 6.8 | -1.1 |
| Source: Data provided by the Omani authorities; IMF staff estimations | | | | |

*Source: IMF*

AlSaqri (2013) measured input factors that contributed to output growth in Oman during the period 1970–2013. As shown in Table (3.4), he found that capital investments growth contributed an average of 161% to output growth and labour 29%, whereas the contribution of TFP growth was negative 91%. In addition, capital investments growth contributed 77% to oil[32] GDP growth and labour 23%, while TFP growth contributed 16%. Furthermore, in respect to non-oil GDP growth, the average growth contribution of capital investments was 89%, labour 18%, and TFP negative 6%. He therefore concluded that output growth in Oman was driven mainly by capital accumulation and labour employment rather than innovation and efficient utilization of resources.

[32] We define this as the M&Q sector in this thesis.

*Table 3. 4: Oman's Average Input Factors Contributions to Economy's Output Growth, During the Period 1970–2013*

| | $\Delta$ln Y | $\Delta$ln K | $\Delta$ln L | $\alpha\Delta$ln K | (1-$\alpha$) $\Delta$ln L | $\Delta$ln TFP |
|---|---|---|---|---|---|---|
| Aggregate Growth | | | | | | |
| Average | 0.06 | 0.14 | 0.05 | 0.09 | 0.02 | (0.05) |
| Input Factor Contributions to Growth | | | | 161 | 29 | (91) |
| Oil GDP growth | | | | | | |
| Average | 0.09 | 0.10 | 0.06 | 0.07 | 0.02 | 0.00 |
| Input Factor Contributions to Growth | | | | 77 | 23 | 16 |
| Non-Oil GDP growth | | | | | | |
| Average | 0.1 | 0.13 | 0.05 | 0.09 | 0.02 | (0.01) |
| Input Factor Contributions to Growth | | | | 89 | 18 | (6) |

*Source: (AlSaqri, 2013)*

## 3.2 Oman's Stylized Economic Facts

Prior to measuring the input factors that contributed to Oman's output, it is worth reviewing Oman's long-term growth based on a few stylized general facts. The stylized facts of economic development proposed by Kaldor (1957) would help to understand the estimated TFP measures set out later in this chapter, and the overall long-term determinants of economic growth of Oman. Kaldor argued that the purpose of a theory of economic growth is to show the nature of the non-economic variables which ultimately determine the rate at which the general level of production of an economy is growing, thus contributing to an understanding of the question of why some economies grow much faster than others. He confirmed that there is general agreement that the critical factors determining the trend rate of growth are to be sought in the savings tendencies of the community (which determines the rate of capital accumulation), the flow of invention or innovation (which determines the rate of growth of productivity), and the population growth. He regarded these factors as the parameters of a growth model, i.e., as non-economic variables; thus he suggested that theoretical inquiry was confined to the more modest task of showing the particular relationships that must prevail between the values of these different parameters in order that they should be consistent with a steady rate of growth for the economy as a whole.

Hence, he suggested a simple stylized facts model of economic growth based on a minimum number of relationships, as follows:

1) Constant GDP growth and GDP per capita growth rates for developed countries but rapid growth rates for a developing economy,

2) Average capital stock/labour ratio (K/L) grows over time,

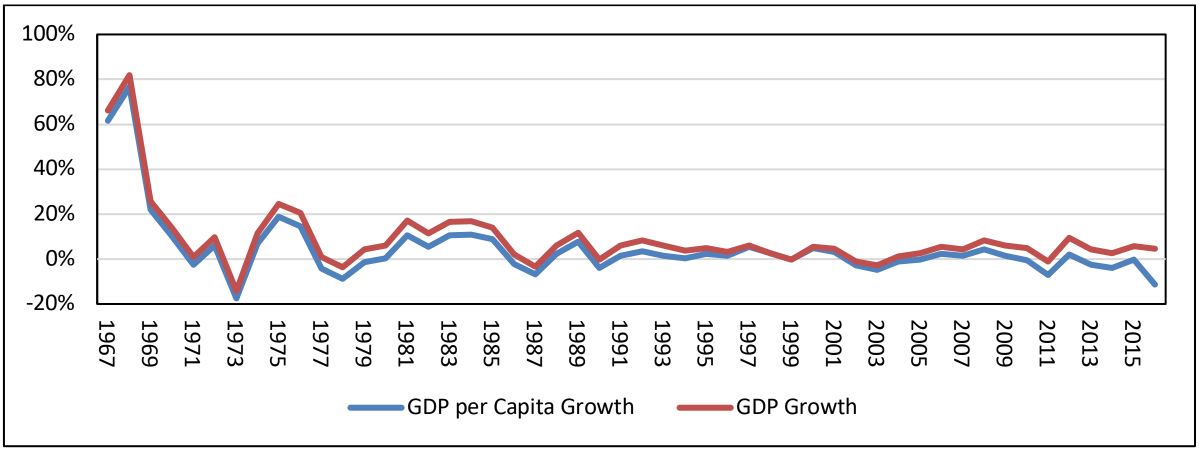
3) Average labour productivity (Y/L) grows over time, and

4) Average capital stock productivity (K/Y) is constant.

Figure (3.8) shows GDP growth and GDP per capita growth rates for the period 1967–2016[33] for Oman's economy. The period from 1967 to 1989 can be characterized by exceptional swings in both the measured variables, reflecting the impact of the discovery and initial exploitation of the M&Q resources from 1967. After 1998 and till 2016,[34] both the variables continued to exhibit swings, but the peaks were flatter. As discussed previously, the fluctuation of both the variables seems to be mainly due to the changes in the international price of the M&Q products. Hence, Oman seems to exemplify the typical features of a growing developing economy implied by the first stylized fact.

[33] A longer period been selected given the high rates of growth achieved in early years of the M&Q sector's products' discovery and export.
[34] Being the period of our study.

*Figure 3. 8: Oman's GDP Growth and GDP per Capita Growth, During the Period 1967–2016 (Constant Prices, Base 2010)*

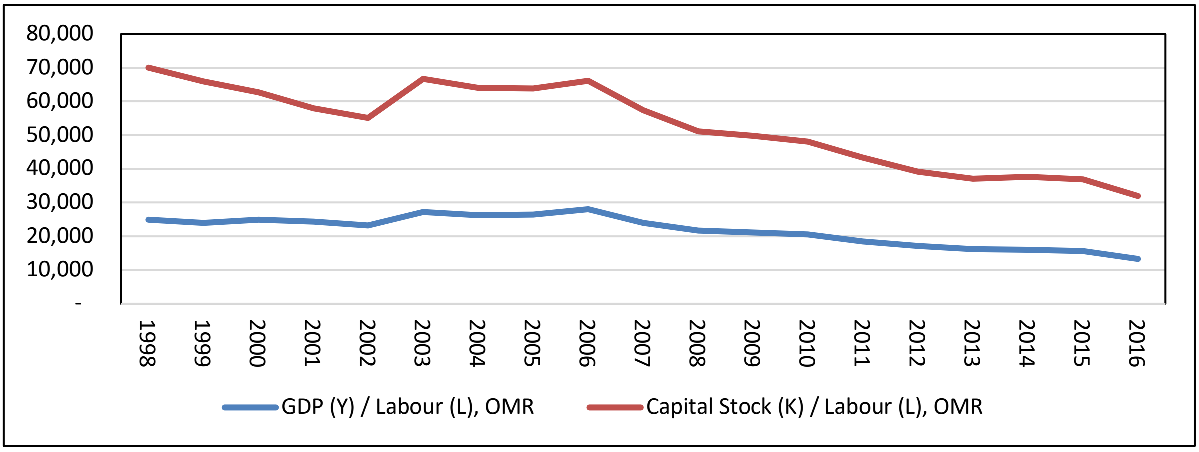



*Source: Compiled by Author using WB Data*

Figure (3.9) shows the ratios of capital stock per labour (capital efficiency) and output per labour (labour productivity) in Oman's economy, the second and third stylized facts, for the period 1998–2016. Both the variables showed overall unstable trends until 2006, after which both declined until the end of the period. The average decline per annum in the growth of capital efficiency and labour productivity ratios during the period were 3.7% and 2.9%, respectively.

Alongside the effect on GDP (and hence on overall capital investment in Oman) of the fluctuations in the prices of the M&Q products, the other reason for the decline in these variables seems to be the significant increase in the labour force after the year 2006. The average growth per annum of labour, capital stock and GDP from 1998–2006 were 2.1%, 0.0%, and 2.2%, respectively, while for the period from 2007–2016 the respective rates were 11.5%, 5.3% and 5.1%. From these results, it seems that the second and the third of Kaldor's stylized facts are not confirmed by the data set over the period as a whole for Oman's economy.

*Figure 3. 9: Oman's Capital Stock to Labour (K/L) and Labour Productivity (Y/L) Ratios, During the Period 1998–2016*




*Source: Measured by Author from NCSI Data*

The fourth stylized fact is the average capital stock productivity (K/Y) to be constant. As shown in Figure (3.10), initially the ratio showed a decrease, while thereafter it fluctuated until the end of the period. Over the whole period, the average capital stock to GDP ratio was 2.4, while the average growth per annum was marginally negative 0.8%. If an economy's accumulation of capital stock is greater than its output, it may suggest that the capital accumulation is not efficiently utilized,[35] and thus less productive than if a large quantity of capital is being invested to sustain or raise output. The extraction and processing of the M&Q products, and the infrastructure needed to support that, are capital intensive, and thus a high capital to output ratio is to be expected given the dominance of the M&Q sector in Oman's economy.[36] Because of the high intensity nature of the capital, which somehow nonetheless remained underutilized,[37] Kaldor's fourth stylized fact is also not apparent overall in Oman's economy during the period.

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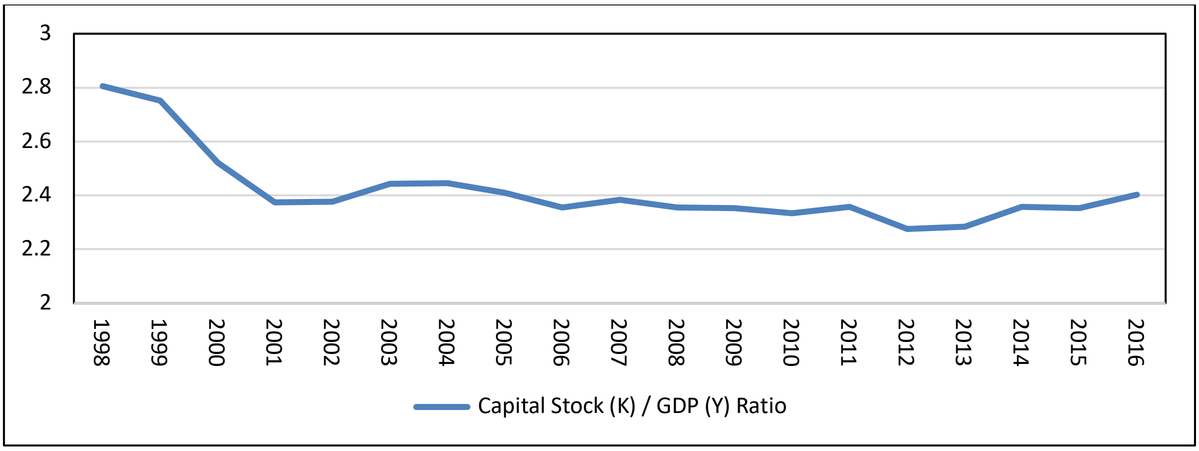
[35] This also could be considered as misallocation of resources within the economy. Misallocation of resources will be discussed in more detail in the up-coming sections.

[36] For comparison, the capital stock to GDP ratios for the period 1998–2016 for the USA, United Kingdom, Kazakhstan, Kuwait and Saudi Arabia were measured using Pen World Data Version 8.1, and found to be 3.1, 2.3, 4.1, 2.1 and 2.7, respectively.

[37] We will discuss this issue in more detail in upcoming sections when analysing capital efficiency and intensity at a sectoral level.

*Figure 3. 10: Oman's Capital Stock to GDP ratio (K/Y), During the Period 1998–2016*




*Source: Measured by Author from NCSI Data*

## 3.3 Methodology of Measuring Input Factors Contributions to Output Growth

In this section, we use data on Oman for the period 1998–2016, which is mainly compiled from the NCSI database, and apply growth accounting techniques to measure the actual coefficients of capital stock and labour to output (GDP) on national[38] and multi-sectoral levels.[39] Thereafter, we use these coefficients to compute the input shares of capital stock, labour and TFP to the output growth so as to estimate the sources of output growth in Oman's economy. To achieve this, we would need to specify the marginal products (i.e., for capital stock and labour) to estimate the shares of capital stock and labour to the output, and then of capital stock and labour inputs to the output. From this we can estimate the yearly TFP growth using the log linear production function, and then finally, the average TFP growth contribution to the average output growth for the period of our study.

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[38] Aggregate level.
[39] A total of 14 sectors.

### 3.3.1 Aggregate Growth Accounting Framework and TFP

According to Khan (2005), a growth accounting framework breaks down observed economic growth into components associated with changes in input factors and a residual that reflects technological progress and other elements. Generally, it is viewed as a preliminary step for the analysis of fundamental determinants of economic growth. The growth accounting framework can be particularly useful if the fundamental determinants that affect factor growth rates are substantially independent from those that affect technological change, such as government policies, household preferences, natural resources, initial levels of physical and human capital, financial sector development, and so on.[40]

Whereas, an empirical growth accounting exercise uses the aggregate neoclassical production function to decompose the growth rates of aggregate output into the contributions of growth of measured inputs and TFP. The results of this exercise depend critically on the specification of the production function, however. In the literature, the Cobb-Douglas production function has been widely used.

To measure TFP growth shares in the output growth on national and multi-sectoral levels for Oman's economy, we use the empirical growth accounting model and the Cobb-Douglas production function as our log linear production function (Cobb and Douglas, 1928): $Y_{sc,t} = A_{sc,t}\ F\ (K_{sc,t}\ L_{sc,t})$, where $Y_{sc,t}$, $K_{sc,t}$, $L_{sc,t}$, and $A_{sc,t}$ are output (GDP) of a sector at year $t$, capital stock, labour and the level of productivity/efficiency/technology term (i.e., the so-called TFP), respectively.

[40] The basics of growth accounting are presented in Solow (1956).

Introducing log to the production function, then differentiating with respect to time, we obtain the growth rate of output decomposed into three growth rates: improvement in productive efficiency ($\frac{\dot{A}_{sc}}{A_{sc}}$), and increase in factor inputs ($\frac{\dot{K}_{sc}}{K_{sc}}$), and ($\frac{\dot{L}_{sc}}{L_{sc}}$), as follows:

$$Y_{sc,t} = A_{sc,t}\, K_{sc,t}^{\propto}\, L_{sc,t}^{(1-\propto)} \tag{3.1}$$

where $\propto$ is the share of capital stock in the output:

$$\mathrm{Log}\left(Y_{sc,t}\right) = \mathrm{Log}\left(A_{sc,t}\right) + \propto \mathrm{Log}\left(K_{sc,t}\right) + (1-\propto)\, \mathrm{Log}\left(L_{sc,t}\right) \tag{3.2}$$

$$\frac{\dot{Y}_{sc}}{Y_{sc,t}} = \frac{\dot{A}_{sc}}{A_{sc,t}} + \propto \frac{\dot{K}_{sc}}{K_{sc,t}} + (1-\propto) \frac{\dot{L}_{sc}}{L_{sc,t}} \tag{3.3}$$

Having data on growth rates of output, and input factors (capital stock and labour) along with their shares, we can measure TFP growth rate from equation (3.3) as a residual:

$$\frac{\dot{A}_{sc}}{A_{sc,t}} = \frac{\dot{Y}_{sc}}{Y_{sc,t}} - \propto \frac{\dot{K}_{sc}}{K_{sc,t}} - (1-\propto) \frac{\dot{L}_{sc}}{L_{sc,t}} \tag{3.4}$$

### 3.3.2 Construction of Variables

#### 3.3.2.1 Measure of Output (GDP)

Different measures of output have been used in the literature: output at current prices, output at constant prices, output per capita and output per employee (Herrendorf, Rogerson and Valentinyi, 2014). We use national and multi-sectoral output (GDP)[41] at current prices from the NCSI database for the period 1998–2016.[42] Since we will be measuring different growth rates, GDP at current prices could be an unsatisfactory and misleading measure of economic

[41] The GDP data on national and multi-sectoral levels are available in NCSI only after tax adjustments, and the tax data are not available at the multi-sectoral level. That said, the contribution of taxes to the aggregate GDP in Oman is insignificant (representing 0.64% of GDP in 2016).

[42] We wanted to be consistent with the source of the data since compiling data from different sources might create estimation errors. Detailed data on the individual sectors is only available on Oman through the NCSI, and only for the mentioned period.

progress. This is because economic well-being is based on the quantity of goods and services consumed, not on the amount spent on these goods. Besides, prices could have risen or fallen during the period. Hence, what is needed is a parallel accounting identity that records the volume of economic activity that holds the price level constant, using the prices of some baseline year for valuing current output and input (Hulten and Hulten, 2001). We therefore convert GDP current prices during the period 1998–2016 to constant prices with a base-year of 2010, using NCSI GDP deflators.

#### 3.3.2.2 Measure of Labour (L)

Different methods are used to measure labour inputs, such as, the number of hours worked by labour, number of labour in an economy and the human capital stocks (Herrendorf, Rogerson and Valentinyi, 2014). Another method includes the education level because of the positive impact of education on worker quality and/or efficiency (Shekhar and Dalgaard, 2004). We use the yearly figures available from the NCSI database for the workforce in Oman's economy at national and multi-sectoral levels during the period 1998–2016.

#### 3.3.2.3 Measure of Depreciation ($\partial$)

The capital stock depreciation rate is compiled from Penn World Tables[43]. Figure (3.11) shows the capital stock depreciation rates for the period 1970–2011 for different countries. To estimate the capital stock depreciation rate for Oman at a national level, we use the average capital stock depreciation rate for the period 1998–2011, which is equal to 6.13%. Since the depreciation rate for capital stocks at sectoral levels are not available, we assume that all depreciation rates for all the sectors are the same as the national level.

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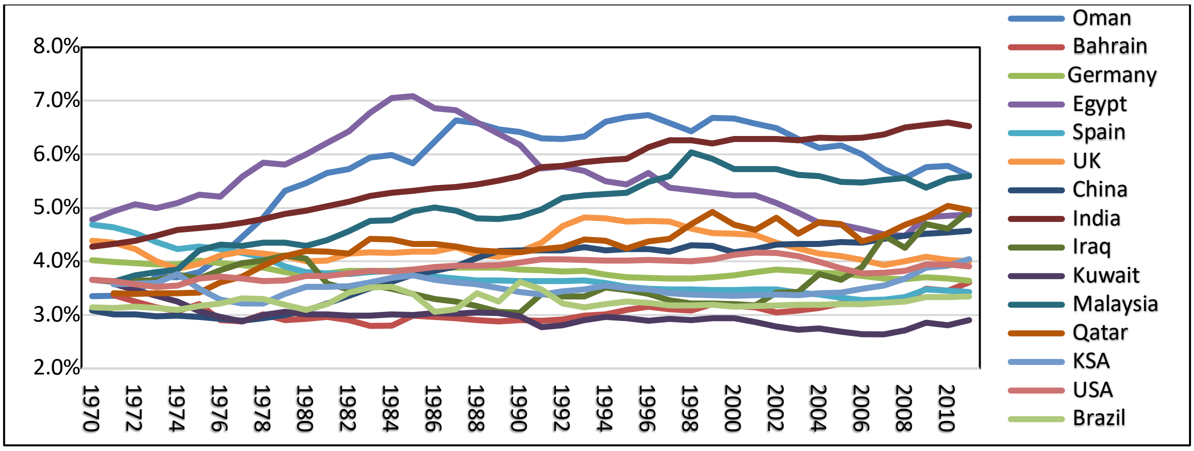
[43] Since the capital stock deprecation rates at national and multi-sectoral levels are not available in NCSI data base.

*Figure 3. 11: Capital Stock Deprecation Rates for Different Countries, During the Period 1970–2010*




*Source: Compiled by Author using Penn World Tables, Version 8.1*

#### 3.3.2.4 Measure of Capital Stock (K)

Capital stocks may be measured directly from stock survey results, or indirectly using yearly investment data from the national accounts (Al-Saqri, 2010). The indirect method of estimating capital stock in turn uses two alternative methods. The first method is called the benchmark-year method, which estimates capital stocks by direct observation, through surveys, for a benchmark year. The second indirect method uses a discounted accumulated value of historical investments up to a benchmark year and is called the perpetual inventory method.

To estimate the capital stocks for Oman at national and multi-sectoral levels, we use the perpetual inventory method, which takes the stock of capital as the accumulation of the stream of past capital investments. The estimation technique can be expressed as below (Khan, 2005):

$$K_{sc,t} = I_{sc,t} + (1 - \partial)K_{sc,t-1} \tag{3.5}$$

where $K_{sc,t}$ is the capital stock of each sector at year t, $I_{sc,t}$ is the capital investment at year t, and $\partial$ is the depreciation rate. For the capital investment (I) data, we use yearly Gross Capital Formation (GCF) data at current prices from NCSI for the period 1998–2016, and then convert them to constant prices with a base-year of 2010, using NCSI GDP deflators.

Given the initial capital stock, $K_{sc,t-1} = K_{sc,0}$ , equation (3.5) can be converted into:

$$K_{sc,t} = \sum_{i=0}^{t-1} (1-\partial)^{i} I_{sc,t-i} + (1-\partial)^{t} K_{sc}(0) \tag{3.6}$$

From equation (3.6) it is clear that the value of the capital stock can be computed only if the initial value of capital stock, $K_{sc}(0)$, is known. Ignoring the initial capital stocks at national and multi-sectoral levels would bias the capital stock growth rate upwards. For example, if the rate of decay was taken at 7.0% a year, then investment undertaken 15 years ago would have at least a third of the efficiency of investment in the current year (Nehru, 1993). Various approaches have been used to estimate the initial value of the capital stock (Yanrui, 2015):

a) The back-casting approach: according to this method the data series for incremental capital investment is as in equation (3.6). If back-casted for long, however, say to the year 1900, the time-series sample has more than 100 observations. Accordingly, equation (3.6) can be expressed as:

$$K_{sc,t} = \sum_{i=0}^{t-1901} (1-\partial)^{i} I_{sc,t-i} + (1-\partial)^{t-1900} K_{sc,1900} \tag{3.7}$$

Equation (3.7) implies that capital stock series at the national level, and for each sector, can be derived given the value of capital stock in 1900 and an appropriate rate of depreciation. Due to capital decay and a long-time horizon, $K_{sc,1900}$ can be assumed to be zero. In our case, since the time horizon is only from 1998 to 2016, $K_{sc,1997}$ cannot be considered to be zero and neglected.

b) The integral approach: the core of this approach is that the value of the initial capital stock is assumed to be the sum of all past investments:

$$K_{sc,0} = \int_{-\infty}^{0} I_{sc,t}\ d_{sc,t} = \frac{I_{sc,0}\, e^{\theta}}{\theta} \tag{3.8}$$

where, $I_{sc,t} = I_{sc,0} e^{\theta(t+1)}$, and $\theta$ and $I_{SC,0}$ are estimated by linear regression using the capital investment series. In equation (3.8), the capital stock decay is not taken into consideration, which in practice tends to overestimate the growth of capital stock. Furthermore, in order to adopt this approach, one must have capital investment data for a very long time series, which is not available in our case.

c) The growth rate approach: this approach, based on the method proposed by Harberger (1978), is the one that has been utilized most often in the literature. It is based on the assumption that the function of capital investment is to replace depreciation of the old capital stock and create new capital stock to maintain growth. Thus, rearranging equation (3.5) we achieve:

$$K_{sc,t} - K_{sc,t-1} = I_{sc,t} - \partial K_{sc,t-1} \tag{3.9}$$

$$\frac{K_{sc,t} - K_{sc,t-1}}{K_{sc,t-1}} = g_{sc,t} = \frac{I_{sc,t}}{K_{sc,t-1}} - \partial \tag{3.10}$$

$$K_{sc,t-1} = K_{sc,0} = \frac{I_{sc,t}}{(g_{sc,t} + \partial)} \tag{3.11}$$

Where, $g_{sc,t}$ is the capital stock growth rate of a sector at year t.

Equation (3.11) implies that the incremental capital stock, or capital investment in period t =1, is the sum of the depreciated capital stock from period zero and the new capital stock created. The latter is assumed to grow at the constant rate of $g_{sc,t}$, which is often replaced by the average growth rate of the incremental capital investments in the initial period. Yanrui (2015) used this method to estimate the initial capital stock for China over the period 1979–2015, considering the average capital investment growth for the initial five years.

When yearly initial capital stocks are not available, as in our case, Harberger (1978) suggested a method whereby, if the capital-output ratio is constant in a given period, the rate of growth of capital and output are equal during that period, and hence $g_k$ is equal to $g_{GDP}$ in equation (3.11). He suggested that short-term variations in output and capital investment may make it appropriate to use average growth rate of output over three years, and the corresponding three years' average capital investment level. If this were performed, the base-year capital stock would be centred in the middle of the three-year period, and equation (3.6) for capital investment accumulation would have to be applied in reverse in order to arrive at the initial capital stock. Similarly, if longer averages were adopted, the base-level capital stock would have to be centred accordingly. Nehru and Dhareshwar (1993) used Harberger's method to estimate the initial capital stocks for developing countries, finding that negative output growth in the initial period either inflated the initial capital stock estimate or turned it negative.

In the case of Oman, capital stock data are available for the period 1970–2015 at the national level only (IMF, 2017). Since our analysis includes the individual sectoral levels for the period 1998–2016, we need to estimate the initial capital stocks for each sector.

First, we use Harberger's method, as adapted by Yanrui, to test and estimate the initial capital stocks at the national level, and for each sector, using equation (3.11). Second, we use the estimated initial capital stock at the national level in the year 1998, which was OMR 43,072 million,[44] to calculate the yearly capital stocks at the national level, as well as to estimate the initial capital stock for each sector.

We first tested Harberger's method to estimate the initial capital stock of Oman at national and multi-sectoral levels, using the GDP growth and incremental capital investments. When applying three-year averages of initial capital investment and initial output growth, in equation (3.11), the estimation of the initial capital stock for the national level showed OMR 19,507 million, as against OMR 43,072 million. Applying the same method to all sectors to estimate their initial capital stocks, and then summing them, resulted in OMR 18,442 million, with a 5.5% variation compared to the estimated initial capital stock at the national level, and a 54.7% variation compared to the initial capital stock for Oman measured by the IMF. Besides the significant variation in these results, the building & construction sector's initial capital stock showed a negative initial capital stock. This was expected, however, because the output growth

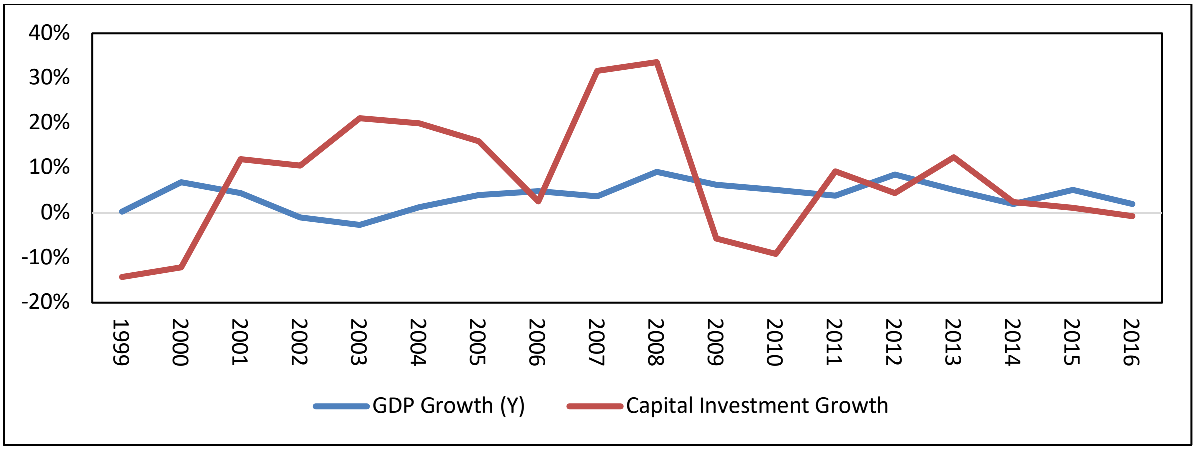
[44] IMF, converted to constant prices with 2010 as the base year.

in the initial three years in the sector was significantly negative (the average of three years was negative 15.3%). Also, using the averages of the output growth to calculate initial capital stocks and capital stock growth, and thereafter using the capital stock growth in equation (3.4) to estimate TFP, would establish a correlation between the output growth and TFP growth estimations for the initial three years. Hence, this method seems not to be suitable for measuring initial capital stocks for developing countries, as confirmed by Nehru, and nor does it seem to provide an accurate estimate at the multi-sectoral level in the case of Oman.

We therefore also tested Yanrui's method to estimate the initial capital stock of Oman at the national and multi-sectoral levels, using the average growth rate of the incremental capital investments in the initial five years as $g_I$ instead of $g_{sc,t}$ in equation (3.11). Estimation of the initial capital stock at the national level showed OMR 23,339 million, as against OMR 43,072 million. Applying the same method to estimate the initial capital stock of all the sectors to estimate their initial capital stocks, and then summing them, resulted in OMR 9,427 million, represented a 59.6% variation from the estimated national level initial capital stock, and a 78.1% variation from the IMF's estimate of the initial capital stock for Oman. Besides the significant variation in results, the manufacturing sector's initial capital stock showed a negative initial capital stock. Again, this was to be expected since the initial five years capital investment growth averaged at negative 20.0%. Hence, this method also seems not to be suitable for measuring initial capital stocks for developing countries, and neither for estimating the initial capital stocks at a multi-sectoral level in the case of Oman.

Next therefore, we tested a method combining Harberger (1978) and Yanrui (2015). Harberger suggested that if the capital-output ratio is constant in a given period, the rate of growth of capital and output are equal during that period; hence $\mathrm{g_{sc,t}}$ is equal to $\mathrm{g_{sc,GDP}}$ in equation (3.11). As per Figure (3.12), the period from 2011 to 2016 seemed to exhibit the least variance between capital investment growth and output growth. We therefore use this period as our five-year period for average capital investment growth in Yanrui's method, instead of the initial five years of capital investment as was used by Yanrui. The estimation of initial capital stock at the national level showed OMR 22,242 million, as against OMR 43,072 million. Applying the same method to all sectors to estimate their initial capital stocks, and then summing them resulted in OMR 17,255 million, representing a 22.4%% variation from the estimated national level initial capital stock, and a 48.3% variation from the IMF's measurement of the initial capital stock for Oman. Hence, this method also seems not to be suitable for measuring initial capital stocks for developing countries, and neither for estimating initial capital stocks at a multi-sectoral level in the case of Oman.

*Figure 3. 12: Oman's GDP Growth vs Capital Investment Growth, During the Period 1998–2016*




*Source: Compiled by Author using NCSI Data*

Overall, therefore, these averaging methods were found not to be suitable for estimating the initial capital stocks, either at the national level, or at multi-sectoral levels for developing countries, such as case of Oman; leading to significant correlations in some cases with output estimations of national and multi-sectoral TFPs, which is our main objective to measure.

Based on this, we therefore use the initial national level capital stock (i.e., OMR 43,072 million) and apportion it to each sector based on its capital stock share contribution in the year 1998, to estimate each sector's initial capital stock. This method would provide estimations of initial capital stock for each sector and would also eliminate any correlation between the data.

Accordingly, the initial capital contribution in 1998 at the national level equals the sum of all sectors' initial capital stock contributions:

$$CC_{N,1998} = \sum_{SC=1}^{14} CC_{sc,1998} \tag{3.12}$$

Where $CC_{N,1998,}$ is the capital contribution at the national level, and $CC_{sc,1998}$ is the capital contribution of each sector. We use the gross-output at national and multi-sectoral levels to compute their capital contributions, where the gross-output equals the value of production minus the costs of intermediate products (compensation of employees and capital contribution):

$$X_{N,1998} = \sum_{sc=1}^{14}(A_{sc,1998}\, K_{sc,1998}^{\propto}\, L_{sc,1998}^{1-\propto} - W_{sc,1998}\, L_{sc,1998} - r_{1998}\, K_{sc,1998}) \tag{3.13}$$

Where $X_{N,1998}$ is gross-output at the national level, $(A_{sc,1998}\, K_{sc,1998}^{\propto}\, L_{sc,1998}^{1-\propto})$ is the value of output $(Y_{sc,1998})$, $(W_{sc,1998}\, L_{sc,1998})$ is compensation of employees, and $(r_{1998}\, K_{sc,1998})$ is the capital contribution (i.e., $CC_{sc,1998}$), respectively, for each sector. By differentiating equation (3.13) with respect to capital $(K_{sc,1998})$ and labour $(L_{sc,1998})$, we get:

$$r_{1998}\, K_{sc,1998} = CC_{sc,1998} = \propto_{sc,1998} Y_{sc,1998} \tag{3.14}$$

$$W_{sc,1998}\, L_{sc,1998} = \left(1 - \propto_{sc,1998}\right) Y_{sc,1998} \tag{3.15}$$

Substituting equation (3.14) in equation (3.15), we get:

$$CC_{sc,1998} = Y_{sc,1998} - W_{sc,1998}\, L_{sc,1998} \tag{3.16}$$

We use the data from NCSI on output[45] $(Y_{sc,1998})$ and compensation of employees $(W_{sc,1998}\, L_{sc,1998})$ for each sector to measure each sector's capital contribution in the year 1998, and hence the national level capital contribution $(CC_{N,1998})$. Knowing the national and each sector's capital contribution in the year 1998, we then use equation (3.12) to apportion each

[45] In NCSI output (GDP) figures are referred as value-added figures.

sector's capital contribution to the national level capital stock. Then, these apportioned shares are used to estimate the initial capital stock in each sector using the national level initial capital stock figure from the IMF (i.e., OMR 43,072 million), as shown in Table (3.5).

*Table 3. 5: Oman's Initial Capital Stocks Estimations at National and Multi-Sectoral levels OMR (Mn), Using Different Methods for the year 1998*

| | *Sectorial Activities* | Capital Contribution | Capital Contribution Share | Initial Capital Stock | Harberger's Method | Yanrui's Method | Combined Method |
|---|---|---|---|---|---|---|---|
| 1 | Agriculture & Fisheries | 142 | 4.1% | 1,759 | 165 | 166 | 190 |
| 2 | Mining & Quarrying | 1,565 | 45.1% | 19,430 | 6,673 | 6,877 | 6,791 |
| 3 | Manufacturing | 181 | 5.2% | 2,247 | 551 | (4,253) | 3,089 |
| 4 | Electricity, Gas & Water Supply | 53 | 1.5% | 660 | 1,125 | 146 | 214 |
| 5 | Building & Construction | 212 | 6.1% | 2,636 | (412) | 148 | 424 |
| 6 | Wholesale & Retail Trade | 349 | 10.1% | 4,337 | 761 | 379 | 344 |
| 7 | Hotels & Restaurants | 27 | 0.8% | 336 | 116 | 140 | 100 |
| 8 | Transport, Storage & Communication | 249 | 7.2% | 3,089 | 963 | 554 | 606 |
| 9 | Financial Intermediation | 230 | 6.6% | 2,861 | 261 | 106 | 88 |
| 10 | Real Estate & Renting and Business | 309 | 8.9% | 3,831 | 3,844 | 3,942 | 1,392 |
| 11 | Public Admin. & defence | 87 | 2.5% | 1,076 | 3,241 | 926 | 3,331 |
| 12 | Education | 24 | 0.7% | 301 | 300 | 113 | 137 |
| 13 | Health & Social Work | 14 | 0.4% | 176 | 287 | 88 | 204 |
| 14 | Other Community, Social and Personal Services | 27 | 0.8% | 334 | 548 | 93 | 346 |
| | Total Oman's Economy | 3,469 | 100.0% | 43,072 | 19,507 | 23,339 | 22,242 |
| | | | | *Sum of all Sectorial Activities* | 18,422 | 9,427 | 17,255 |

*Source: Measured by Author using NCSI and IMF Data*

### 3.3.2.5 Measure of Labour and Capital Shares ($\propto$)

Income or factor shares refer to the shares of national income which reward the different factors of production. Being related to the macroeconomic functioning of the economy, they are typically measured from aggregate data. Labour share, which "shows how much of national income accrues to labour", is computed first, while returns to capital are the residual (Lubker, 2007).

The labour share is conventionally calculated by dividing the total compensation of employees by national income (GDP). The measure of employees' compensation is a better measure than the simple 'wages and salaries', because it encompasses other forms of non-wage compensation such as commissions, bonuses, tips, family allowances, employers' contributions to social security programmes and pension schemes (Krueger, 1999).

To compute the yearly shares of labour in the output (GDP) in Oman's economy at national and multi-sectoral levels, we use NCSI data for the period 1988–2016, where we divide the related shares of labour compensation by the related output (value-added) and then, using the constant returns to scale (CRT), we calculate capital stock shares for each sector.

Generalizing and rearranging equations (3.14), (3.15), and (3.16), we get:

$$r\,K_{sc,t} = \propto_{sc,t} Y_{sc,t} \tag{3.17}$$

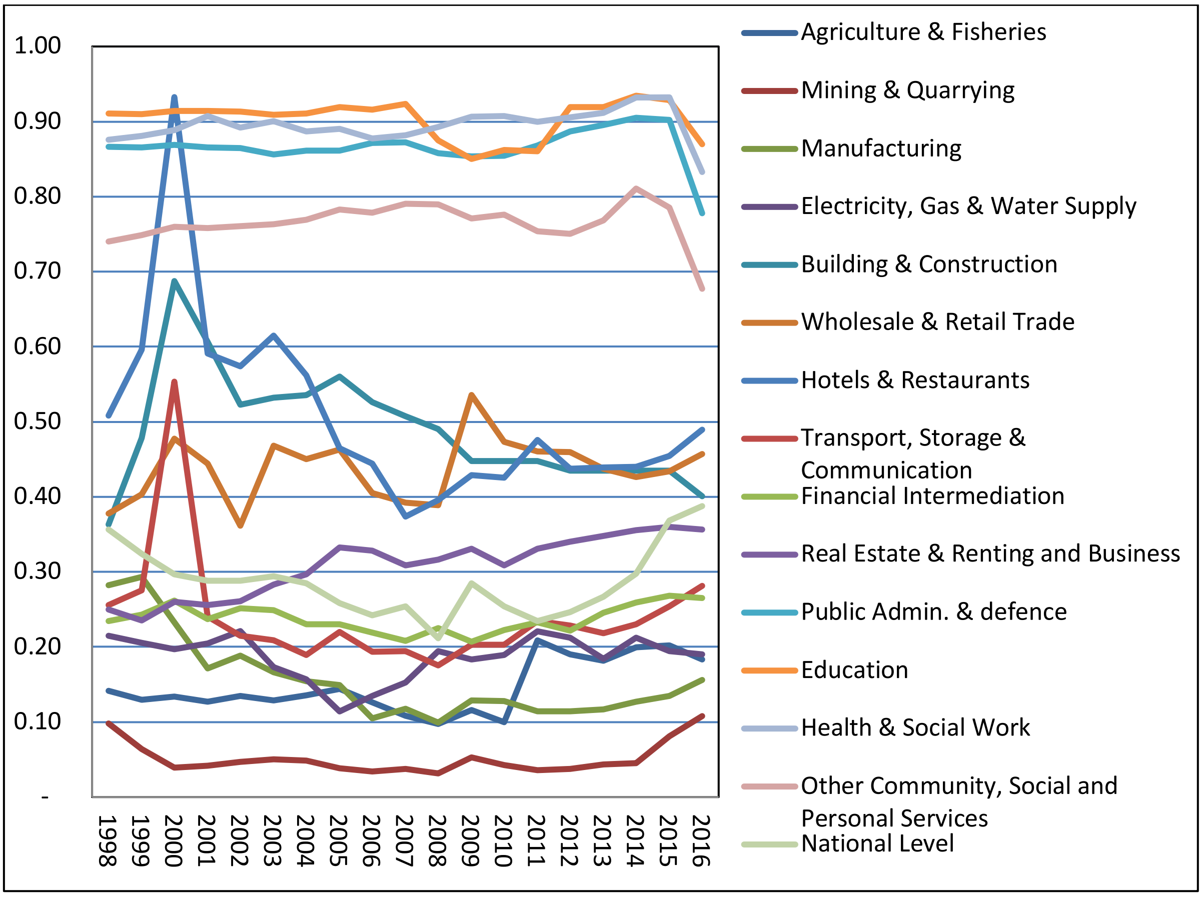
$$W_{sc,t}\,L_{sc,t} = (1 - \propto_{sc,t})\,Y_{sc,t} \tag{3.18}$$

$$Y_{sc,t} = r\,K_{sc,t} + W_{sc,t}\,L_{sc,t} \tag{3.19}$$

$$\text{Hence, share of labour} = \frac{W_{sc,t}\,L_{sc,t}}{r\,K_{sc,t} + W_{sc,t}\,L_{sc,t}} = \frac{(1-\propto_{sc,t})\,Y_{sc,t}}{\propto_{sc,t} Y_{sc,t} + (1-\propto_{sc,t})\,Y_{sc,t}} = (1 - \propto_{sc,t}) \tag{3.20}$$

Where $Y_{sc,t}$, $(W_{sc,t}\,L_{sc,t})$, $(r\,K_{sc,t})$, $\propto_{sc,t}$ and $(1 - \propto_{sc,t})$ are value-added (GDP), employees' compensation, capital stock contribution, share of capital in output, and share of labour in the output at time t, respectively. The measured labour share ratios at national and multi-sectoral levels for the period 1998–2016 are shown in Figure (3.13). Assuming a constant return to scale, the shares of capital stock at national and multi-sectoral levels are measured as residuals for the same period.

*Figure 3. 13: Oman's Labour Shares in GDP at National and Multi-Sectoral levels, During the Period 1998–2016, Current Prices*

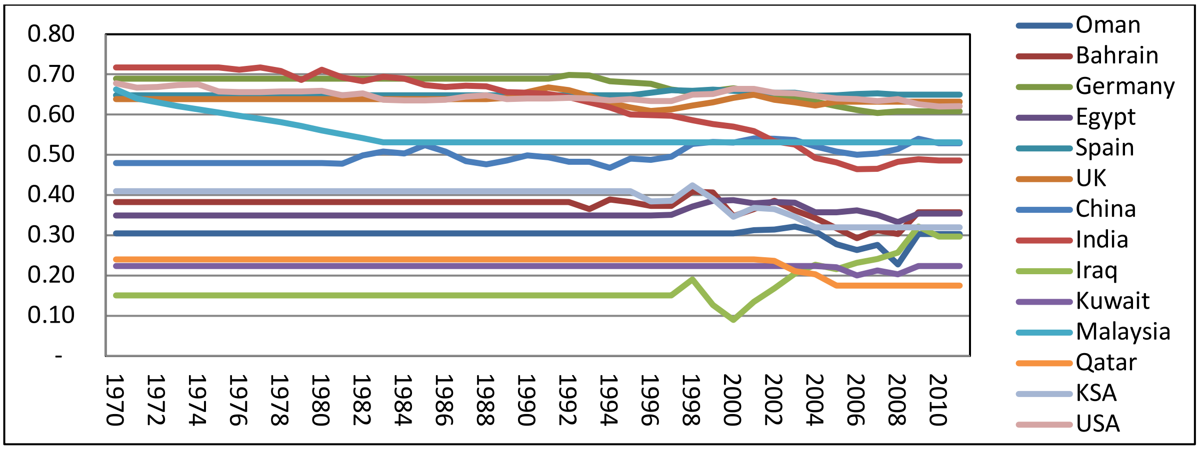



*Source: Measured by Author using NCSI Data*

Most of the previous work on estimating TFP contributions at a multi-sectoral level has used constant coefficient shares of labour and capital for all the sectors in an economy. Here, however, although we have measured yearly shares of labour and capital stock at national and multi-sectoral levels for the period 1998–2016, which is believed to provide better estimations of the multi-sectoral TFPs contributions, we will be using the respective average shares for the period in equation (3.4), since the shares of labour and capital stocks do not change over time in the equation.

The average share of labour in the aggregate output of Oman's economy during the period turns out to be 0.29 as measured using NCSI data, implying that the average share of capital stock is 0.71. To confirm these figures, Penn World Tables version 8.1 was used to compute the labour ratio for Oman and other countries. Figure (3.14) shows the labour shares to output ratios, with Oman's average share of labour compensation in the GDP being 0.30, which is almost aligned with our estimation of 0.29.[46]

*Figure 3. 14: Shares of Labour Compensation in GDP for Different Countries, During the Period 1970–2010, Current Prices*




*Source: Compiled by Author using Penn World Tables, Version 8.1*

### 3.3.2.6 Measure of Capital Intensity (CI)

Measuring of Capital Intensity (CI) with respect to labour at national and multi-sectoral levels will further support the estimation and analysis of TFP results in the next sections. Capital intensity provides information on the exchange of inputs (capital and labour). As per equation (3.21), an increase in CI over time indicates a decrease in capital efficiency and a decrease in

[46] Guerriero (2012) measured labour shares across 89 countries, both developing and developed, for the period 1970–2009. He measured Oman's labour share to be approximately 0.30 during the period, which also confirms our result.

labour productivity, while a decrease in CI indicates an increased capital efficiency and an increase in labour productivity (Abramovitz, 1993):

$$CI_{sc,t} = \propto_{sc} \frac{K_{sc,t}/L_{sc,t}}{Y_{sc,t}/L_{sc,t}}$$

(3.21)

where, $CI_{sc,t}$, $\propto_{sc}$, $K_{sc,t}$, $L_{sc,t}$, and $Y_{sc,t}$ are capital intensity, share of capital stock, capital stock, labour and value-added (GDP), respectively for each sector at time t.

### 3.3.3 Measure of Total Factor Productivity (TFP)

TFP reflects the change in output that cannot be accounted for by the change in combined inputs (capital and labour). TFP as a result reflects the joint effects of many factors (macro and micro levels) including government policies, Research and Development (R&D), new technologies, economies of scale, managerial and labour skills, and changes in the organization of production.

In this section, we use equation (3.4) to estimate the yearly TFP growth rates during the period 1998–2016 for Oman's economy, and then use the averages of the period to estimate TFP growth share to the average output growth. We estimate and analyse TFP growth rates for the period on three different levels:[47]

1) National, M&Q, and consolidated other sectoral levels,
2) National and main consolidated sectoral levels (agriculture and fisheries, M&Q, manufacturing, and services), and
3) National and multi-sectoral levels.

[47] The rationale behind each level will be discussed in each individual section.

#### 3.3.3.1 TFP on National, M&Q, and Consolidated Other Sectoral Levels

Table (3.6) shows the estimated results of the input factors contributions to the output growth at the national level. The average capital stock contribution share during the period was 54.4%, that of labour was 55.8%, while the average TFP contribution share to output growth was negative 10.2%. Hence, it seems that TFP did not contribute to the output growth in Oman's economy during the period, with that being mainly driven by the capital and labour contributions.[48]

Further analysis of the TFP contribution trend at the national level during the period is shown in Figure (3.15). Neither the GDP growth trend nor the input factor contributions to the output growth trends, including the TFP, remained stable during the period. Considering the major variations in the trends during the period, the highest TFP contribution to the output growth, of 7.3%[49] in the year 2000, was mainly due to the high GDP growth of 6.8% in the same year. This high GDP growth was in turn mainly due to the 93.0% GDP growth in the manufacturing sector alone, which was mainly due to the LNG production starting in the same year. Moreover, the downwards trend in the TFP contribution became more pronounced from the year 2006 until the end of the period, indicating a change in the input factor dynamics in the economy, with the average contribution of TFP to the output growth being negative 2.0% per annum, during the period 2007–2016. The main reason for this change seems to be due to the significant increase in capital stock and labour growth contributions within the economy averaging at 3.7% and 3.3%, respectively, during the same period. This negative trend of TFP growth indicates

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[48] Our results showing negative TFP growth in Oman's economy match the work of Mansur and Treichel (1999) and Al-Saqri (2010).

[49] While capital stock and labour growth contributions almost nullified each other.

that Oman's economy was being driven more by capital stock and labour contributions than the TFP contribution during the later period.

In addition, Oman's heavy exposure to the fluctuations in the international prices of the M&Q products is particularly evident in the years 2012 and 2016, when it can be seen that the TFP contributions changed according to the change in GDP due to prices,[50] while the capital stock and labour growth contributions remained unchanged.

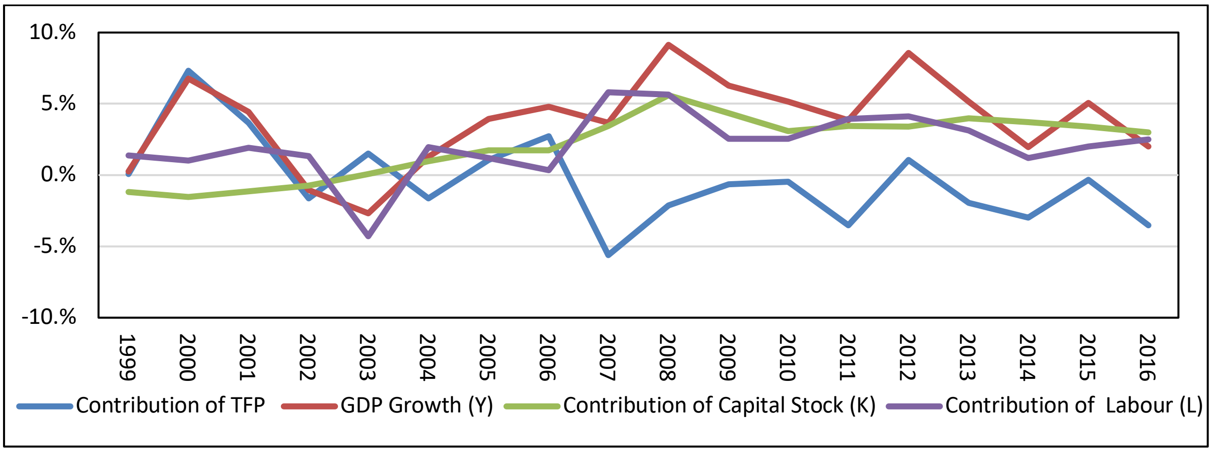
[50] Refer to Figure (2.3).

*Table 3. 6: Oman' s Input factors Contributions to Output Growth at National Level, During the Period 1998–2016*

| Year | GDP (Y), OMR (Mn) | Capital Investment (I), OMR (Mn) | Capital Investment Growth | Capital Stock (K), OMR (Mn) | Labour (L), Mn | Capital Stock Growth (K) | Labour (L) Growth | Share of Capital Stock | Share of Labour | GDP Growth (Y) | Contribution of Capital Stock (K) | Contribution of Labour (L) | Contribution of TFP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ΔlnK | ΔlnL | ∝ | (1-∝) | ΔlnY | ∝ ΔlnK | (1-∝) ΔlnL | Δ lnTFP |
| 1998 | 15,354 | 2,231 | | 43,072 | 661 | | | 0.71 | 0.29 | | | | |
| 1999 | 15,391 | 1,912 | -14.3% | 42,344 | 692 | -1.7% | 4.8% | 0.71 | 0.29 | 0.2% | -1.2% | 1.4% | 0.1% |
| 2000 | 16,437 | 1,681 | -12.1% | 41,429 | 716 | -2.2% | 3.5% | 0.71 | 0.29 | 6.8% | -1.5% | 1.0% | 7.3% |
| 2001 | 17,164 | 1,882 | 11.9% | 40,771 | 763 | -1.6% | 6.6% | 0.71 | 0.29 | 4.4% | -1.1% | 1.9% | 3.7% |
| 2002 | 16,983 | 2,079 | 10.5% | 40,351 | 798 | -1.0% | 4.5% | 0.71 | 0.29 | -1.1% | -0.7% | 1.3% | -1.6% |
| 2003 | 16,528 | 2,517 | 21.1% | 40,395 | 680 | 0.1% | -14.8% | 0.71 | 0.29 | -2.7% | 0.1% | -4.3% | 1.5% |
| 2004 | 16,738 | 3,018 | 19.9% | 40,937 | 726 | 1.3% | 6.7% | 0.71 | 0.29 | 1.3% | 1.0% | 1.9% | -1.6% |
| 2005 | 17,399 | 3,501 | 16.0% | 41,928 | 755 | 2.4% | 4.1% | 0.71 | 0.29 | 4.0% | 1.7% | 1.2% | 1.0% |
| 2006 | 18,231 | 3,589 | 2.5% | 42,947 | 764 | 2.4% | 1.2% | 0.71 | 0.29 | 4.8% | 1.7% | 0.3% | 2.7% |
| 2007 | 18,899 | 4,727 | 31.7% | 45,041 | 917 | 4.9% | 20.0% | 0.71 | 0.29 | 3.7% | 3.5% | 5.8% | -5.6% |
| 2008 | 20,625 | 6,314 | 33.6% | 48,594 | 1,096 | 7.9% | 19.5% | 0.71 | 0.29 | 9.1% | 5.6% | 5.7% | -2.1% |
| 2009 | 21,917 | 5,956 | -5.7% | 51,570 | 1,193 | 6.1% | 8.9% | 0.71 | 0.29 | 6.3% | 4.3% | 2.6% | -0.7% |
| 2010 | 23,049 | 5,414 | -9.1% | 53,823 | 1,297 | 4.4% | 8.7% | 0.71 | 0.29 | 5.2% | 3.1% | 2.5% | -0.5% |
| 2011 | 23,940 | 5,914 | 9.2% | 56,438 | 1,473 | 4.9% | 13.6% | 0.71 | 0.29 | 3.9% | 3.4% | 3.9% | -3.5% |
| 2012 | 25,993 | 6,172 | 4.4% | 59,150 | 1,682 | 4.8% | 14.2% | 0.71 | 0.29 | 8.6% | 3.4% | 4.1% | 1.0% |
| 2013 | 27,332 | 6,935 | 12.4% | 62,459 | 1,864 | 5.6% | 10.8% | 0.71 | 0.29 | 5.2% | 4.0% | 3.1% | -2.0% |
| 2014 | 27,867 | 7,100 | 2.4% | 65,730 | 1,941 | 5.2% | 4.1% | 0.71 | 0.29 | 2.0% | 3.7% | 1.2% | -3.0% |
| 2015 | 29,282 | 7,181 | 1.1% | 68,882 | 2,075 | 4.8% | 6.9% | 0.71 | 0.29 | 5.1% | 3.4% | 2.0% | -0.3% |
| 2016 | 29,872 | 7,127 | -0.7% | 71,786 | 2,256 | 4.2% | 8.7% | 0.71 | 0.29 | 2.0% | 3.0% | 2.5% | -3.5% |
| Averages | | | **7.5%** | | | **2.9%** | **7.3%** | **0.71** | 0.29 | **3.8%** | **2.1%** | **2.1%** | **-0.4%** |
| *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | | | | | | | **54.44** | **55.78** | **-10.22** |

*Source: Measured by Author using NCSI Data*

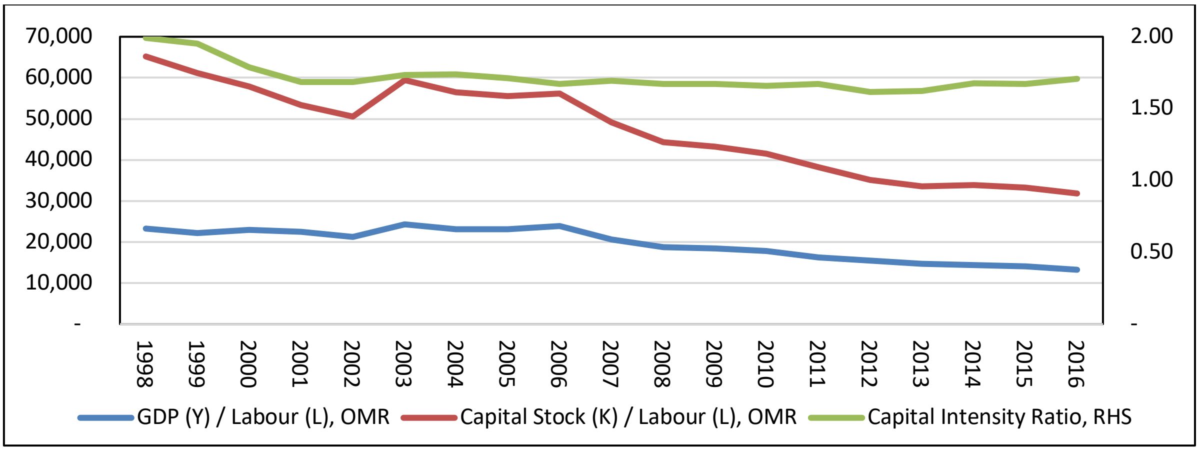
*Figure 3. 15: Oman's National Level Input Factors Contributions to Output Growth, During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

Figure (3.16) shows the CI at the national level during the period 1998–2016. The marginal downwards slope of CI indicates a slight overall increase in both capital efficiency and labour productivity in the economy. The average aggregate output growth and capital investment growth in Oman during the period were 3.8% and 2.9% per annum, respectively, whereas the average growth of labour was 7.3% per annum. This suggests that the labour growth outstripped the growth in aggregate output and capital investment growth, leading the CI to show an efficient trend.

*Figure 3. 16:Oman's Labour Productivity (Y/L), Capital Efficiency (K/L), and Capital Intensity (CI) Ratios at National level, During the period 1998–2016*




*Source: Measured by Author using NCSI Data*

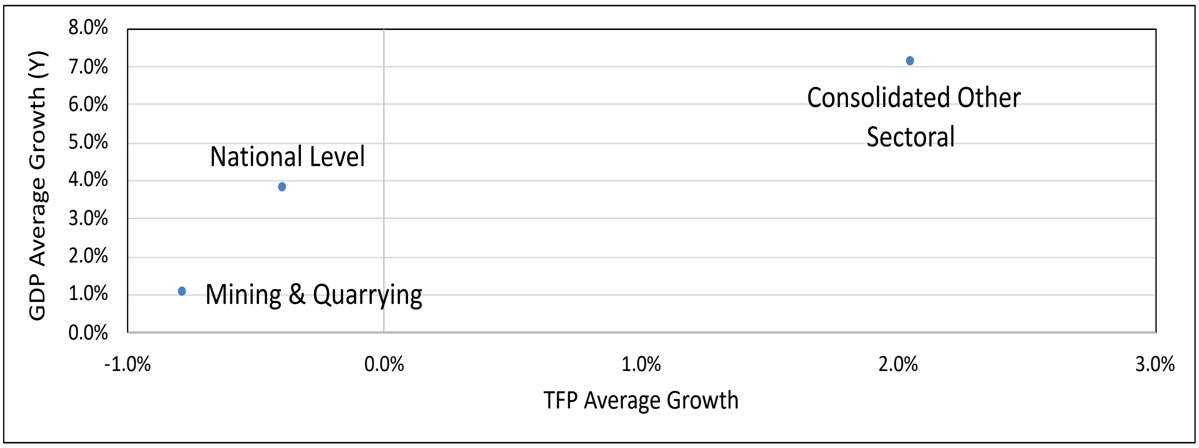
To analyse the role of the M&Q sector independently against the consolidated other sectors, we combined all thirteen sectors other than the M&Q sector, by adding their capital stock and labour, and taking averages of their capital and labour shares in order to estimate their input factors contributions to output growth. The results are shown in Table (3.7) and Figure (3.17). The M&Q capital stock contribution to the output growth was 136.5%, while that for the consolidated other sectors was 36.1%. The contribution of labour was 37.9% and 35.1%, respectively, while that of TFP was negative 74.4% and positive 28.8%, respectively. Hence, it seems that TFP did not contribute to the output growth in the M&Q sector, with that sector's growth seeming to depend heavily on capital stock accumulation during the period. In contrast, the TFP contribution was positive for the consolidated other sectors, suggesting that technology played a role in their output growth, alongside capital and labour. In addition, not only did the consolidated other sectors have a positive TFP contribution to the output growth, they also had the highest average output growth rate during the period: of 7.1% per annum, compared to 3.8% at the national level and 1.0% for the M&Q sector.

*Table 3. 7: Oman's Input Factors Contributions to Output Growth at National, M&Q Sector, and Consolidated Other Sectoral Levels, During the Period 1998–2016*

| Averages | Growth of Capital Stock (K)) | Growth of Labour (L) | Share of Capital Stock | Share of Labour | Growth of GDP (Y) | Contribution of Capital Stock (K) | Contribution of Labour (L) | Contribution of TFP |
|---|---|---|---|---|---|---|---|---|
| | ΔlnK | ΔlnL | ∝ | (1-∝) | ΔlnY | ∝ ΔlnK | (1-∝) ΔlnL | Δ lnTFP |
| National Level | 2.9% | 7.3% | 0.71 | 0.29 | 3.8% | 2.1% | 2.1% | -0.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 54.44 | 55.78 | -10.22 |
| Mining & Quarrying | 1.5% | 7.9% | 0.95 | 0.05 | 1.0% | 1.4% | 0.4% | -0.8% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 136.52 | 37.87 | -74.38 |
| Consolidated Other Sectoral | 3.9% | 7.3% | 0.66 | 0.34 | 7.1% | 2.6% | 2.5% | 2.0% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 36.07 | 35.08 | 28.84 |

*Source: Measured by Author using NCSI Data*

*Figure 3. 17: Oman's Average TFP Growth vs Average GDP Growth at National, M&Q Sector and Consolidated Other Sectoral Levels, During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

Figures (3.18) and (3.19) further confirms that the M&Q sector depends more heavily on capital stock than do the consolidated other sectors. The average capital stock per labour for the M&Q sector was OMR 1.59 million during the period 1998–2016, compared to just OMR 0.03 million for the consolidated other sectors. Further, the capital intensity of the consolidated other sectors decreased during the period,[51] which indicates an overall increase in capital efficiency and labour productivity. Whereas the CI of the M&Q sector showed a marginal increase,[52] which explains the decrease in capital efficiency and labour productivity. The decrease in capital efficiency can be explained in part by the fact that the M&Q sector's growth was mainly capital driven. As discussed earlier, the cost of extracting and processing M&Q products is increasing, meaning that large and increasing capital investments are being injected into the sector to sustain its value-addition in the economy.

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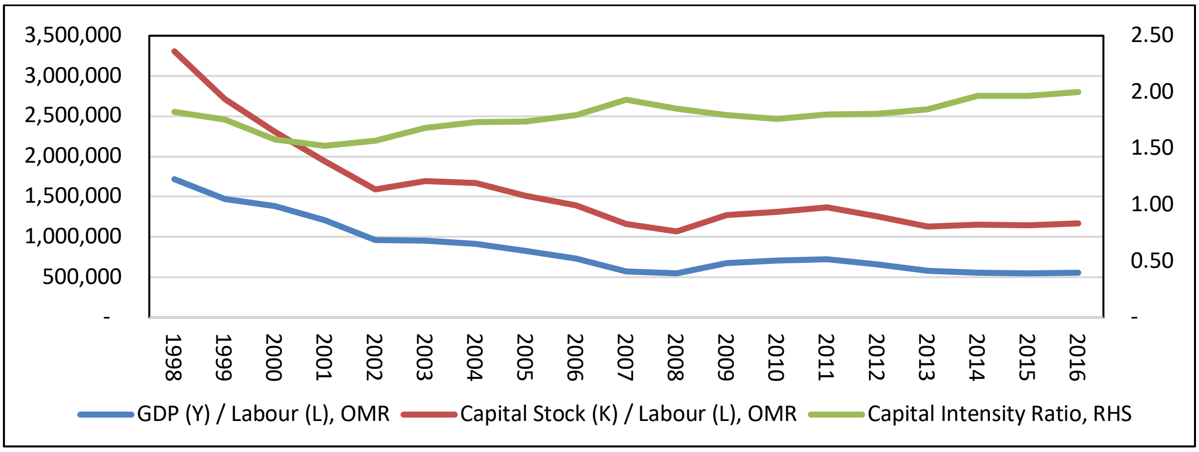
[51] The effect of the high labour growth of 7.3% in the consolidated sectoral activities during the period 1998–2016 was adjusted by the high output growth of 7.1% and capital contribution growth of 3.9%, meaning that the CI was decreasing.

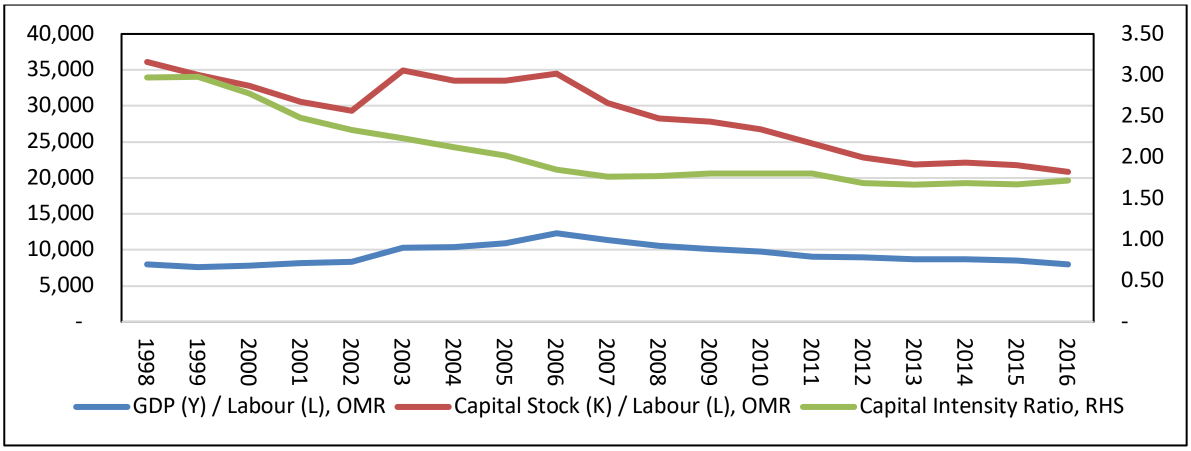
[52] The high labour growth of 7.9% in the M&Q sector during the period, as against its output growth of 1.0% indicates a negative effect on the capital efficiency and labour productivity in the sector, hence the CI was increasing.

*Figure 3. 18: Oman's M&Q sector's Labour Productivity (Y/L), Capital Efficiency (K/L), and Capital Intensity (CI) Ratios, During the period 1998–2016*




*Source: Measured by Author using NCSI Data*

*Figure 3. 19: Oman's Consolidated Other Sectoral Labour Productivity (Y/L), Capital Efficiency (K/L), and Capital Intensity (CI) Ratio, During the period 1998–2016*




*Source: Measured by Author using NCSI Data*

### 3.3.3.2 TFP on National and Main Consolidated Sectoral Levels

This section revisits the national and the M&Q sector's estimated average TFP contributions to the output growth results and presents them against the estimated results for the main consolidated sectors,[53] during the same period, 1998–2016.

[53] We decompose the consolidated other sectors discussed in the previous section into three main consolidated sectors: agriculture and fisheries, manufacturing and services.

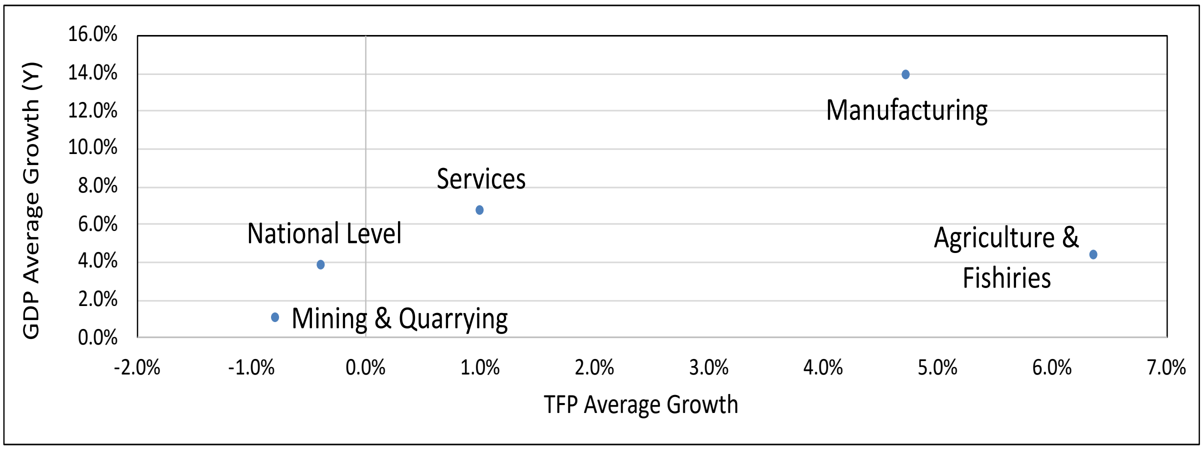
Table (3.8) shows that the TFP contributions to the output growth for the agriculture and fisheries, manufacturing and services sectors were 148.3%, 34.1% and 15.1%, respectively, whereas the contributions at the national and M&Q sector levels were negative contributions of 10.2% and 74.4%, respectively, as shown earlier. Hence, for all three main consolidated sectors, output did not grow just from capital and labour contributions, but from TFP contribution, which, as shown in Figure (3.20), resulted in positive productivity contributions to sectors' output growth during the period.

*Table 3. 8: Oman's Input Factors Contributions to Output Growth at National, and Major Consolidated Sectoral Levels, During the Period 1998–2016*

| Averages | Growth of Capital Stock (K)) | Growth of Labour (L) | Share of Capital Stock | Share of Labour | Growth of GDP (Y) | Contribution of Capital Stock (K) | Contribution of Labour (L) | Contribution of TFP |
|---|---|---|---|---|---|---|---|---|
| | ΔlnK | ΔlnL | ∝ | (1-∝) | ΔlnY | ∝ ΔlnK | (1-∝) ΔlnL | Δ lnTFP |
| National Level | 2.9% | 7.3% | 0.71 | 0.29 | 3.8% | 2.1% | 2.1% | -0.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 54.44 | 55.78 | -10.22 |
| Agriculture & Fishiries | -5.0% | 3.3% | 0.65 | 0.35 | 4.3% | -3.2% | 1.2% | 6.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | -75.29 | 26.96 | 148.33 |
| Mining & Quarrying | 1.5% | 7.9% | 0.95 | 0.05 | 1.0% | 1.4% | 0.4% | -0.8% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 136.52 | 37.87 | -74.38 |
| Manufacturing | 9.5% | 7.2% | 0.84 | 0.16 | 13.9% | 8.0% | 1.2% | 4.7% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 57.56 | 8.30 | 34.14 |
| Services | 3.3% | 7.7% | 0.47 | 0.53 | 6.7% | 1.6% | 4.1% | 1.0% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 23.6 | 61.3 | 15.1 |

*Source: Measured by Author using NCSI Data*

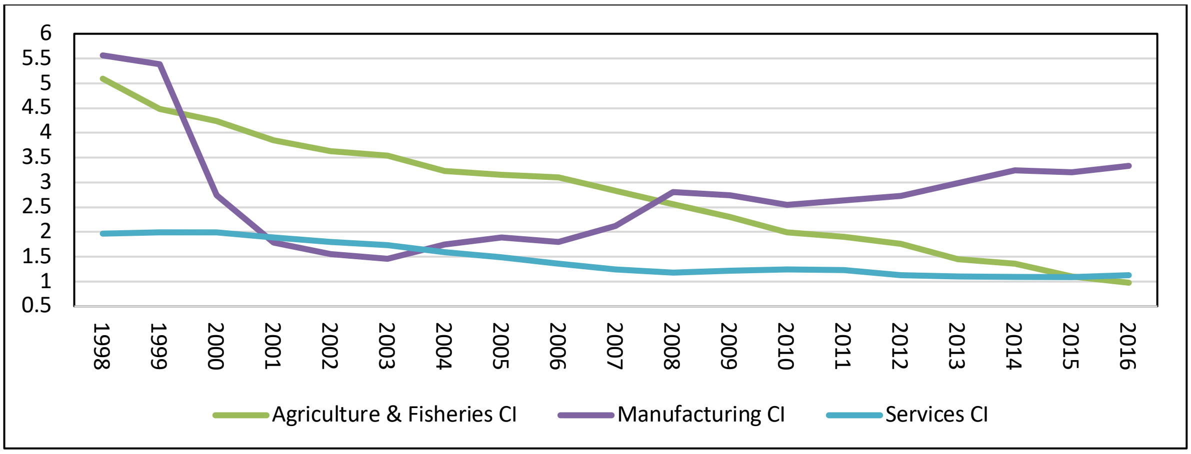
*Figure 3. 20: Oman's Average TFP Growth vs Average GDP Growth at National and Major Consolidated Sectoral Levels, During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

Figure (3.21) shows the capital intensity (CI) ratios for all three main consolidated sectors. It can be seen that the CI of the agriculture and fisheries sector decreased sharply during the period, probably as a result of the negative 5.0% per annum capital stock growth during the period. The manufacturing sector's CI, meanwhile, decreased sharply in the initial period, mainly due to the contribution of the LNG output, thereafter, started increasing from the year 2004. This increase indicates a decrease in capital efficiency and labour productivity, for which the main reason seems to be the significant average growth of 51.1% per annum in capital investment from the year 2004 until the end of the period, comfortably exceeding capital investment growth in all the other sectors,[54] and making the manufacturing sector capital inefficient. In contrast, the services CI showed a steady decline, which indicates an increase in capital efficiency and labour productivity performances during the period.

*Figure 3. 21: Oman's Capital Intensity of Major Consolidated Sectors, During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

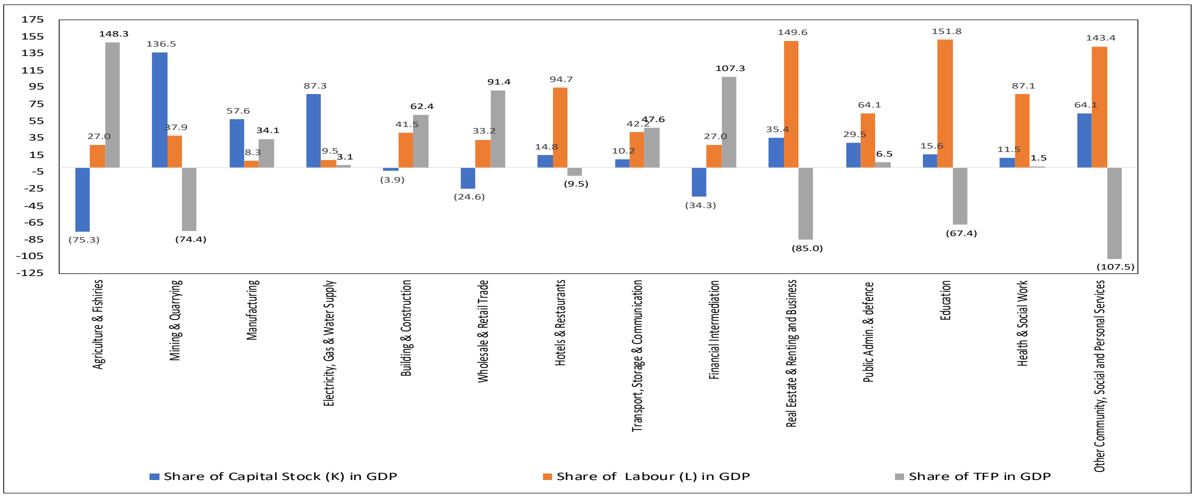
[54] Capital investment growth at the national level, and in the agriculture and fisheries, M&Q, and services sectors was 9.1%, (1.5)%, 9.6%, and 7.4%, respectively, for the same period.

### 3.3.3.3 TFP on National and Multi-Sectoral Levels

For further detailed analyses of the multi-sectoral input factors contributions to the output growth in Oman's economy, we segregated the economy into individual fourteen sectors.

As well as the TFP contribution to the output growth being negative at the national level during the period 1998–2016, five[55] out of fourteen sectors also had negative TFP contributions, as shown in Figure (3.22). Leaving aside the main government related and non-tradable[56] productive sectors, and also the wholesale & retail trade and transport, storage & communication sectors, which are directly linked to foreign trade and have no local content, the only remaining productive sectors in Oman's economy are agriculture and fisheries, manufacturing and financial intermediation. These sectors exhibited TFP contributions to their output growth of 148.3%, 34.1%, and 107.3%, respectively, as presented in Table (3.9). These positive productivity contributions to output growth suggest that these sectors could potentially drive future economic growth in Oman.

*Figure 3. 22: Oman's Multi-Sectoral Input Factors Contributions to Output Growth (%), During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

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[55] Other community, social and personal services; real estate & renting business; M&Q; education; and hotels & restaurants sectors.
[56] Building & construction; public administration & defence; electricity, gas & water supply; and health & social work sectors.

*Table 3. 9: Oman's Input Factors Contributions to Output Growth at National, and Multi-Sectoral Levels, During the Period 1998–2016*

| Averages | Growth of Capital Stock (K) | Growth of Labour (L) | Share of Capital Stock | Share of Labour | Growth of GDP (Y) | Contribution of Capital Stock (K) | Contribution of Labour (L) | Contribution of TFP |
|---|---|---|---|---|---|---|---|---|
| | ΔlnK | ΔlnL | ∝ | (1-∝) | ΔlnY | ∝ ΔlnK | (1-∝) ΔlnL | Δ lnTFP |
| National Level | 2.9% | 7.3% | 0.71 | 0.29 | 3.8% | 2.1% | 2.1% | -0.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 54.4 | 55.8 | -10.2 |
| 1 Agriculture & Fishieries | -5.0% | 3.3% | 0.65 | 0.35 | 4.3% | -3.2% | 1.2% | 6.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | -75.3 | 27.0 | 148.3 |
| 2 Mining & Quarrying | 1.5% | 7.9% | 0.95 | 0.05 | 1.0% | 1.4% | 0.4% | -0.8% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 136.5 | 37.9 | -74.4 |
| 3 Manufacturing | 9.5% | 7.2% | 0.84 | 0.16 | 13.9% | 8.0% | 1.2% | 4.7% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 57.6 | 8.3 | 34.1 |
| 4 Electricity, Gas & Water Supply | 10.8% | 5.0% | 0.81 | 0.19 | 10.0% | 8.7% | 1.0% | 0.3% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 87.3 | 9.5 | 3.1 |
| 5 Building & Construction | -1.0% | 10.7% | 0.51 | 0.49 | 12.6% | -0.5% | 5.2% | 7.9% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | -3.9 | 41.5 | 62.4 |
| 6 Wholesale & Retail Trade | -2.0% | 3.5% | 0.56 | 0.44 | 4.6% | -1.1% | 1.5% | 4.2% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | -24.6 | 33.2 | 91.4 |
| 7 Hotels & Restaurants | 2.0% | 12.3% | 0.49 | 0.51 | 6.6% | 1.0% | 6.3% | -0.6% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 14.8 | 94.7 | -9.5 |
| 8 Transport, Storage & Communication | 1.4% | 19.0% | 0.76 | 0.24 | 10.8% | 1.1% | 4.6% | 5.1% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 10.2 | 42.2 | 47.6 |
| 9 Financial Intermediation | -3.5% | 8.7% | 0.76 | 0.24 | 7.8% | -2.7% | 2.1% | 8.3% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | -34.3 | 27.0 | 107.3 |
| 10 Real Eestate & Renting and Business | 2.2% | 20.6% | 0.69 | 0.31 | 4.3% | 1.5% | 6.4% | -3.6% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 35.4 | 149.6 | -85.0 |
| 11 Public Admin. & defence | 12.9% | 4.2% | 0.13 | 0.87 | 5.7% | 1.7% | 3.6% | 0.4% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 29.5 | 64.1 | 6.5 |
| 12 Education | 10.5% | 11.4% | 0.10 | 0.90 | 6.7% | 1.1% | 10.2% | -4.5% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 15.6 | 151.8 | -67.4 |
| 13 Health & Social Work | 6.3% | 5.9% | 0.11 | 0.89 | 6.1% | 0.7% | 5.3% | 0.1% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 11.5 | 87.1 | 1.5 |
| 14 Other Community, Social and | 12.7% | 9.0% | 0.24 | 0.76 | 4.8% | 3.1% | 6.8% | -5.1% |
| | *Input Factors Contributing to GDP Growth (% GDP Growth)* | | | | | 64.1 | 143.4 | -107.5 |

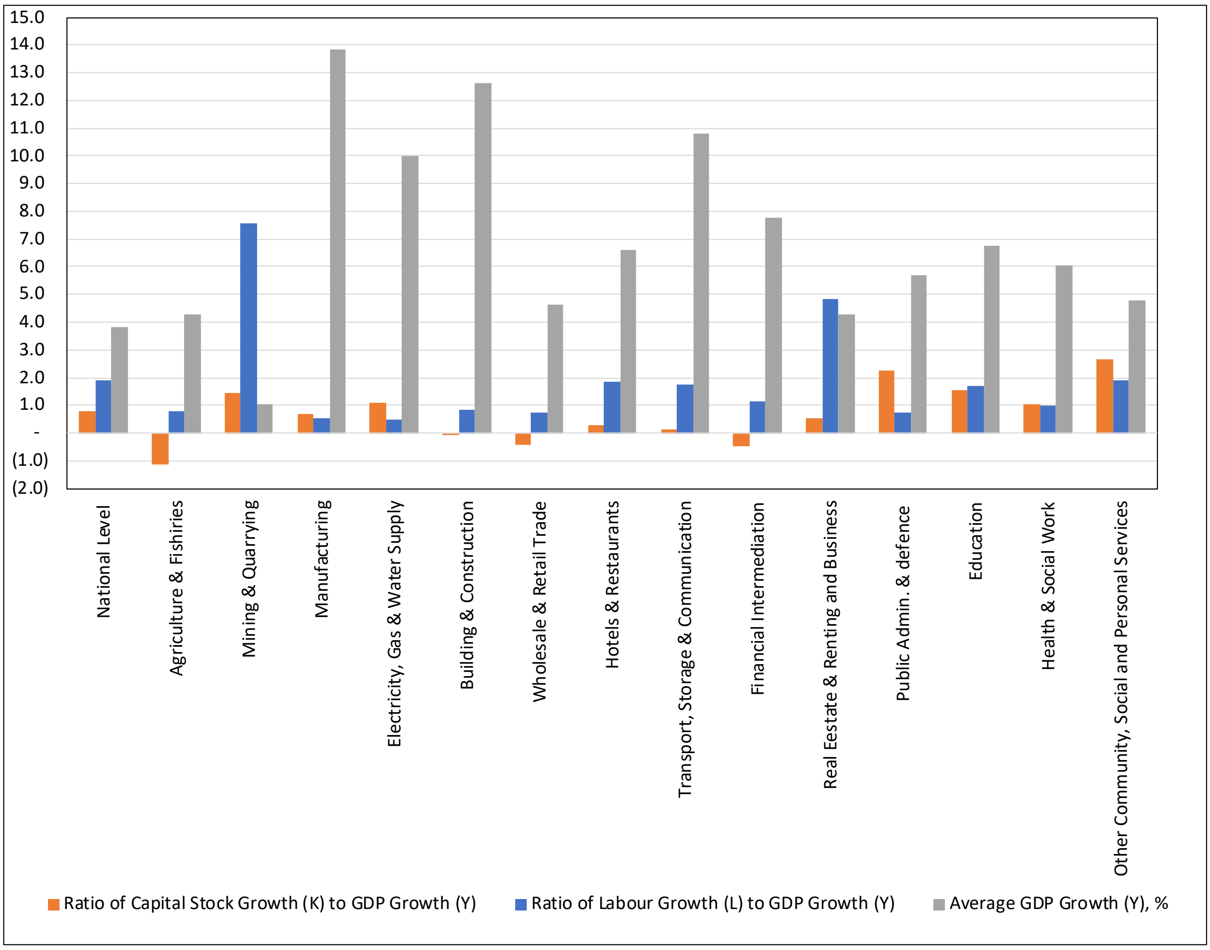
*Source: Measured by Author using NCSI Data*

### 3.3.4 Multi-Sectoral Input-Factors Allocation

As discussed in the literature review section, it is not only the level of accumulation of input factors in an economy that matters for output growth, but how these input factors are allocated across the various sectors of the economy. To analyse this, we divided the averages of capital stock growth and labour growth by the average output (GDP) growth, nationally and for each sector, for the period 1998–2016.

As shown in Figure (3.23), although the average GDP growth during the period was 3.8% per annum at the national level, the averages of capital stock and labour to GDP ratios were 0.8 and 1.92, respectively. This indicates that a large amount of labour was injected into Oman's economy compared to the economy's GDP growth (in fact, almost double). Moreover, Analysing the M&Q and manufacturing sectors as examples. GDP growth during the period was 1.0% and 13.8%, respectively, whereas their capital stock to GDP ratios were 1.4 and 0.7, and their labour to GDP ratios were 7.6 and 0.5, respectively. Although the two sectors require different input resources as capital and labour for their output growth, there seems to be a vast difference in their input resources against their GDP growth. This might indicate that misallocation of resources could have taken place, in the M&Q sector especially, since this would result in the sector's TFP contribution to its output growth being significantly negative during the period, as discussed in the previous section. The manufacturing sector, meanwhile, having a positive TFP contribution to its output growth, and the highest GDP growth, during the period, has received less input resources to its output growth.

*Figure 3. 23: Oman's Average Capital Stock and Labour Growth to Average GDP Growth Ratios at National and Multi-Sectoral Levels, During the Period 1998–2016*




*Source: Measured by Author using NCSI Data*

### 3.3.5 Measure of TFP Sensitivity

Since TFP growth coefficients are affected by the assumptions that are made as to the elasticity of capital stock and labour,[57] it is suggested that, in order to check for robustness of the results, a TFP growth sensitivity analysis should be estimated with different assumptions regarding the weight of the fastest growing factor of production, and regarding the degree of economies of scale (The World Bank, 2000).

[57] In our case we have used averages of labour and capital stock shares for each sector during the period.

To check and confirm our estimated results, therefore, we changed the values of the capital stock shares ($\propto$) for national and multi-sectoral levels during the period and measured the effect on the average TFP growth contribution to the output growth. This was achieved by increasing and decreasing the capital stock share by 10% in three different scenarios of economies of scales, i.e., Constant Return to scale (CRT), Increasing Return to scale (IRT) and Decreasing Return to scale (DRT).

The results showed that the overall sensitivity computation results are robust to our initial estimations. Table (3.10) shows the average TFP contribution to output growth at the national level to be mostly negative during the period for almost all the scenarios.[58] Table (3.11), meanwhile, shows computations of the average TFP growth contributions for all the different sectors in the economy under different scenarios.

*Table 3. 10: Sensitivity Analysis of Average TFP Contribution to Output Growth in Oman at National Level under Different Scenarios, During the Period 1998–2016*

| | Estimated $\propto$ | Increasing $\propto$ by 10% | Decreasing $\propto$ by 10% |
|---|---|---|---|
| Constant Return to Scale (CRT) = 1 | -10.2% | -2.0% | -18.4% |
| Increasing Return to Scale (IRT) = 1.2 | -21.4% | -10.4% | -32.3% |
| Decreasing Return to Scale (DRT) = 0.9 | -4.6% | 2.2% | -11.5% |

*Source: Measured by Author*

[58] Except in one scenario where the average TFP contribution to the output growth showed a slight positive result.

*Table 3. 11: Sensitivity Analysis of Average TFP Contribution to Output Growth in Oman at National and Multi-Sectoral Levels under Different Economies of Scale Scenarios, for the Period 1998–2016*

| CRT =1 | Averages | Estimated Shares of Capital Stock | Estimated Shares of Labour | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ∝ | (1-∝) | Actual | | | Increasing ∝ by 10% | | | Decreasing ∝ by 10% | | |
| | National Level | 0.71 | 0.29 | 54.4% | 55.8% | -10.2% | 59.9% | 42.1% | -2.0% | 49.0% | 69.4% | -18.4% |
| 1 | Agriculture & Fishiries | 0.65 | 0.35 | -75.3% | 27.0% | 148.3% | -82.8% | 22.0% | 160.9% | -67.8% | 32.0% | 135.8% |
| 2 | Mining & Quarrying | 0.95 | 0.05 | 136.5% | 37.9% | -74.4% | 150.2% | -34.1% | -16.1% | 122.9% | 109.8% | -132.7% |
| 3 | Manufacturing | 0.84 | 0.16 | 57.6% | 8.3% | 34.1% | 63.3% | 3.9% | 32.7% | 51.8% | 12.7% | 35.5% |
| 4 | Electricity, Gas & Wate | 0.81 | 0.19 | 87.3% | 9.5% | 3.1% | 96.1% | 5.5% | -1.5% | 78.6% | 13.6% | 7.8% |
| 5 | Building & Constructio | 0.51 | 0.49 | -3.9% | 41.5% | 62.4% | -4.3% | 37.2% | 67.1% | -3.5% | 45.8% | 57.7% |
| 6 | Wholesale & Retail Tra | 0.56 | 0.44 | -24.6% | 33.2% | 91.4% | -27.0% | 29.0% | 98.0% | -22.1% | 37.4% | 84.7% |
| 7 | Hotels & Restaurants | 0.49 | 0.51 | 14.8% | 94.7% | -9.5% | 16.3% | 85.6% | -1.9% | 13.3% | 103.8% | -17.1% |
| 8 | Transport, Storage & C | 0.76 | 0.24 | 10.2% | 42.2% | 47.6% | 11.2% | 28.9% | 59.9% | 9.2% | 55.6% | 35.2% |
| 9 | Financial Intermediati | 0.76 | 0.24 | -34.3% | 27.0% | 107.3% | -37.7% | 18.4% | 119.2% | -30.8% | 35.5% | 95.3% |
| 10 | Real Eestate & Renting | 0.69 | 0.31 | 35.4% | 149.6% | -85.0% | 39.0% | 116.3% | -55.3% | 31.9% | 182.9% | -114.8% |
| 11 | Public Admin. & defe | 0.13 | 0.87 | 29.5% | 64.1% | 6.5% | 32.4% | 63.1% | 4.5% | 26.5% | 65.0% | 8.4% |
| 12 | Education | 0.10 | 0.90 | 15.6% | 151.8% | -67.4% | 17.2% | 150.2% | -67.3% | 14.0% | 153.5% | -67.6% |
| 13 | Health & Social Work | 0.11 | 0.89 | 11.5% | 87.1% | 1.5% | 12.6% | 86.0% | 1.4% | 10.3% | 88.1% | 1.5% |
| 14 | Social and Personal Services | 0.24 | 0.76 | 64.1% | 143.4% | -107.5% | 70.5% | 138.9% | -109.3% | 57.7% | 147.9% | -105.6% |

| IRT =1.2 | Averages | Estimated Shares of Capital Stock | Estimated Shares of Labour | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ∝ | (1-∝) | Actual | | | Increasing ∝ by 10% | | | Decreasing ∝ by 10% | | |
| | National Level | 0.71 | 0.35 | 54.4% | 66.9% | -21.4% | 59.9% | 50.6% | -10.4% | 49.0% | 83.3% | -32.3% |
| 1 | Agriculture & Fishiries | 0.65 | 0.42 | -75.3% | 32.4% | 142.9% | -82.8% | 26.3% | 156.5% | -67.8% | 38.4% | 129.4% |
| 2 | Mining & Quarrying | 0.95 | 0.06 | 136.5% | 45.4% | -82.0% | 150.2% | -40.9% | -9.3% | 122.9% | 131.8% | -154.6% |
| 3 | Manufacturing | 0.84 | 0.19 | 57.6% | 10.0% | 32.5% | 63.3% | 4.7% | 32.0% | 51.8% | 15.2% | 33.0% |
| 4 | Electricity, Gas & Wate | 0.81 | 0.23 | 87.3% | 11.4% | 1.2% | 96.1% | 6.6% | -2.6% | 78.6% | 16.3% | 5.1% |
| 5 | Building & Constructio | 0.51 | 0.59 | -3.9% | 49.8% | 54.1% | -4.3% | 44.6% | 59.7% | -3.5% | 55.0% | 48.5% |
| 6 | Wholesale & Retail Tra | 0.56 | 0.53 | -24.6% | 39.9% | 84.7% | -27.0% | 34.8% | 92.2% | -22.1% | 44.9% | 77.2% |
| 7 | Hotels & Restaurants | 0.49 | 0.61 | 14.8% | 113.6% | -28.4% | 16.3% | 102.7% | -19.0% | 13.3% | 124.5% | -37.8% |
| 8 | Transport, Storage & C | 0.76 | 0.29 | 10.2% | 50.7% | 39.1% | 11.2% | 34.6% | 54.2% | 9.2% | 66.7% | 24.1% |
| 9 | Financial Intermediati | 0.76 | 0.29 | -34.3% | 32.4% | 101.9% | -37.7% | 22.1% | 115.5% | -30.8% | 42.6% | 88.2% |
| 10 | Real Eestate & Renting | 0.69 | 0.37 | 35.4% | 179.5% | -115.0% | 39.0% | 139.6% | -78.5% | 31.9% | 219.5% | -151.4% |
| 11 | Public Admin. & defe | 0.13 | 1.04 | 29.5% | 76.9% | -6.4% | 32.4% | 75.7% | -8.2% | 26.5% | 78.0% | -4.6% |
| 12 | Education | 0.10 | 1.08 | 15.6% | 182.2% | -97.8% | 17.2% | 180.2% | -97.4% | 14.0% | 184.2% | -98.3% |
| 13 | Health & Social Work | 0.11 | 1.07 | 11.5% | 104.5% | -15.9% | 12.6% | 103.2% | -15.8% | 10.3% | 105.8% | -16.1% |
| 14 | Social and Personal Services | 0.24 | 0.91 | 64.1% | 172.1% | -136.1% | 70.5% | 166.6% | -137.1% | 57.7% | 177.5% | -135.2% |

| DRT =0.9 | Averages | Estimated Shares of Capital Stock | Estimated Shares of Labour | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP | Share of Capital Stock (K) in GDP | Share of Labour (L) in GDP | Share of TFP in GDP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ∝ | (1-∝) | Actual | | | Increasing ∝ by 10% | | | Decreasing ∝ by 10% | | |
| | National Level | 0.71 | 0.26 | 54.4% | 50.2% | -4.6% | 59.9% | 37.9% | 2.2% | 49.0% | 62.5% | -11.5% |
| 1 | Agriculture & Fishiries | 0.65 | 0.32 | -75.3% | 24.3% | 151.0% | -82.8% | 19.8% | 163.1% | -67.8% | 28.8% | 139.0% |
| 2 | Mining & Quarrying | 0.95 | 0.05 | 136.5% | 34.1% | -70.6% | 150.2% | -30.7% | -19.5% | 122.9% | 98.8% | -121.7% |
| 3 | Manufacturing | 0.84 | 0.14 | 57.6% | 7.5% | 35.0% | 63.3% | 3.5% | 33.1% | 51.8% | 11.4% | 36.8% |
| 4 | Electricity, Gas & Wate | 0.81 | 0.17 | 87.3% | 8.6% | 4.1% | 96.1% | 4.9% | -1.0% | 78.6% | 12.2% | 9.2% |
| 5 | Building & Constructio | 0.51 | 0.44 | -3.9% | 37.4% | 66.6% | -4.3% | 33.5% | 70.9% | -3.5% | 41.3% | 62.3% |
| 6 | Wholesale & Retail Tra | 0.56 | 0.40 | -24.6% | 29.9% | 94.7% | -27.0% | 26.1% | 100.9% | -22.1% | 33.7% | 88.4% |
| 7 | Hotels & Restaurants | 0.49 | 0.46 | 14.8% | 85.2% | 0.0% | 16.3% | 77.0% | 6.7% | 13.3% | 93.4% | -6.7% |
| 8 | Transport, Storage & C | 0.76 | 0.22 | 10.2% | 38.0% | 51.8% | 11.2% | 26.0% | 62.8% | 9.2% | 50.1% | 40.8% |
| 9 | Financial Intermediati | 0.76 | 0.22 | -34.3% | 24.3% | 110.0% | -37.7% | 16.6% | 121.1% | -30.8% | 32.0% | 98.8% |
| 10 | Real Eestate & Renting | 0.69 | 0.28 | 35.4% | 134.7% | -70.1% | 39.0% | 104.7% | -43.7% | 31.9% | 164.6% | -96.5% |
| 11 | Public Admin. & defer | 0.13 | 0.78 | 29.5% | 57.7% | 12.9% | 32.4% | 56.8% | 10.8% | 26.5% | 58.5% | 14.9% |
| 12 | Education | 0.10 | 0.81 | 15.6% | 136.7% | -52.3% | 17.2% | 135.1% | -52.3% | 14.0% | 138.2% | -52.2% |
| 13 | Health & Social Work | 0.11 | 0.80 | 11.5% | 78.4% | 10.2% | 12.6% | 77.4% | 10.0% | 10.3% | 79.3% | 10.4% |
| 14 | Social and Personal Services | 0.24 | 0.68 | 64.1% | 129.0% | -93.1% | 70.5% | 125.0% | -95.4% | 57.7% | 133.1% | -90.8% |

*Source: Measured by Author*

## 3.4 Conclusion

The main objective of this chapter was to estimate and analyse the contributions of the input factors to the national and the multi-sectoral output growth in Oman's economy. This was achieved by estimating average growth contributions of capital stock, labour and TFP to the output growth (GDP), during the period 1998–2016.

1) The analysis of general stylized long-term growth variables showed that, as expected for resource-dependent developing countries, the GDP and GDP per capita growth rates increased rapidly in the early years after the discovery of M&Q resources. During the period 1998–2016, however, these measures remained broadly stable, with average GDP and GDP per capita growth rates of 3.8% and negative 1.0% per annum, respectively. Moreover, on average, the capital efficiency, labour productivity and capital productivity growth rates all declined during the period.
2) The analysis of the input factors contributions to the economy's output growth at the national and the multi-sectoral levels suggests the following:
    a) The output growth in Oman's economy was mainly driven by capital accumulation and labour contributions rather than productivity contribution; in fact, the productivity contribution to the economy's output growth was negative.
    b) The M&Q sector is the most dominant sector in Oman's economy in terms of aggregate output share, export share and share of capital investments. The findings showed that the sector has been significantly driven by the contribution of capital investments, with declining capital efficiency and labour productivity, rather than being driven by technology. Further, the capital investments upon which the sector depends are derived mainly from government revenue, which is in turn dependent on the M&Q sector's own revenue streams. Hence, as well

as being unproductive, inefficient and capital intensive, the M&Q sector uses its own revenue to sustain its own output.

c) Further analysis of the input factor contributions to the multi-sectoral output growth showed that the consolidated other sectoral[59] productivity contributions to the output growth were positive during the period. This could imply that the M&Q sector played a significant role during the period in decreasing the average productivity contribution share to the output growth at the national level. On the other hand, the fact that the consolidated other sectors had a positive productivity contribution to the output growth confirms the ability of these sectors to play a significant role in increasing and diversifying the output growth at the national level, in the absence of the M&Q sector.

d) In respect to other tradable sectors, excluding government activities, those that showed positive productivity contributions to the output growth were agriculture and fisheries, financial intermediation, and manufacturing, respectively. The agriculture and fisheries sector showed a positive productivity contribution to the output growth, but its average share in the economy's output (GDP) was small (1.4%) and grew only at 4.3% annually during the period.[60] In contrast, the manufacturing and financial intermediation sectors' average productivity contributions to the economy's output growth were 34.1% and 107.3%, with average growth rates of 13.9% and 7.8% annually during the period, respectively. Hence, the latter two sectors have significant potential for further growth and value addition to Oman's economy.

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[59] Excluding the M&Q sector.
[60] Refer to Figure (2.21) in Chapter (2).

# Chapter 4: Measurement of Oman’s Multi-Sectoral Interlinkages

The main objective of this chapter is to measure and analyse the multi-sectoral interlinkages in Oman’s economy. This will be achieved by applying different empirical models that have been used within the literature on Input-Output (IO) framework to identify the most dominant sectors in an economy in terms of inter-sectoral linkages. Identifying such sectors in Oman will enable Oman’s government to support these sectors as tradable sectors with the potential to take over from the Mining and Quarrying (M&Q) sector in the future, thus diversifying Oman’s economy and securing long-term economic growth. In the context of multi-sectoral linkages, the chapter also examines the possible impact of the Dutch disease phenomenon on Oman’s economy during the period 1998–2016, as an ailment supposedly arising from the M&Q sector boom.

This chapter will answer the following major questions:

1) Has Oman suffered from Dutch disease symptoms?
2) How do multi-sectoral backward and forward interlinkages in Oman’s economy compare with those in the economy of the USA?
3) Has the M&Q sector established linkages to other sectors in Oman’s economy?
4) What are the multi-sectoral relationships in Oman’s economy with respect to their demand, supply, and prices?
5) What would be the effect on Oman’s aggregate output if external demand shocks were to be applied on different sectors of the economy?
6) What would be the effect on Oman’s aggregate output if the M&Q sector was to be extracted from Oman’s economy?.

## 4.1 Literature Review

### 4.1.1 Linkage Theory

Linkage theory examines how one industry/sector in an economy influences another industry. It is an extension of Staple theory, which was developed in 1950s by Canadian economists to explain how income from abundant natural resources created a more diversified and sustainable productive economy in Canada. In the case of Canada, the theory explains how the export of raw commodities, such as agricultural products, minerals, and fish to Europe, induced the development of other industries that eventually led to economic development and sustainable growth in Canada (Watkins, 1963; Altman, 2003).

Linkage theory, meanwhile, was proposed by Hirschman (1958). He explored the role of intermediate goods in industrialization, which he called linkages, under the assumption that these play a key role in stimulating parts of an economy beyond the booming sector. For Hirschman, the main problem facing underdeveloped economies is not their lack of resources, but the inability to invest scarce resources in the money market economy. Hence expansion should give preference to projects that maximize induced decision making, i.e., concentrate on a few key sectors with strong linkages to the leading sector.

### 4.1.2 Linkages in an Input–Output Framework

Leontief (1986)[61] defined IO analysis as a method of systematically quantifying the mutual interrelationships among the various industries/sectors of a complex economic system. The concept was derived from the Soviet Union's Balance of the National Economy for the year

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[61] Wassily Leontief was a pioneer of IO analysis, for which he was awarded a Nobel Prize in Economics in 1973.

1923–1924. Subsequently, the IO framework became an important element in the construction of short-term Soviet planning, particularly the annual economic plan. In a different way, the annual plan was a particular aspect in the Soviet schema for achieving long-term economic growth (Sabiroglu and Bashirli, 2012).

In an IO system framework, production by a particular sector has two kinds of economic effects on other sectors in the economy. For example, if sector (j) increases its output this means there will be increased demand from sector (j) (as a purchaser) on the other sectors whose goods are used as production inputs of sector (j). This is the direction of causation in the usual demand-side model, and the term backward linkage (BL) is used to indicate this kind of interconnection of a particular sector with those upstream sectors from which it purchases inputs. On the other hand, increased output in sector (j) also means that additional amounts of product (j) are available to be used as inputs to other sectors for their own production; that is there will be increased supplies from sector (j) (as a seller) for the sectors that use good (j) in their production. This is the direction of causation in the supply-side model. The term forward linkage (FL) is used to indicate this kind of interconnection of a particular sector with those downstream sectors to which it sells its output. If the backward linkage of sector (i) is larger than that of sector (j), one might conclude that a dollar's worth of expansion of sector (i) output would be more beneficial to the economy than would an equal expansion in sector (j′s) output. Similarly, if the forward linkage of sector (j) is larger than that of sector (i), it could be said that a dollar's worth of expansion of the output of sector (j) is more essential to the economy than a similar expansion in the output of sector (i), from the point of view of the overall productive activity that it could support. Comparisons of the strengths of backward and forward linkages for different sectors in a single economy therefore provide a mechanism for identifying the leading sectors in that economy (those sectors that are most connected and therefore, in some sense, most important). In addition, if IO data are available for more than one time period, the evolution of these interconnections can be further studied. Also, examination of these measures for similar sectors in different countries provides one method of making international comparisons of the structure of production (Miller and Blair, 2011).

There have been numerous suggestions for differing definitions and refinements of these linkage and key sector measures, and others of economic connectedness (Miller and Blair, 2011). Hirschman and many other researchers have looked at the Leontief IO tables to test the linkage effects and to measure the production linkages of an economy.[62] They disagreed, however, as to the best methods for measuring the indirect effect of an industry. Yotopoulos and Nugent (1973) suggested the use of the inverse of the IO column sum to capture the total linkage effect; that is the sum of both backward and forward linkages and the indirect effects that result from such linkages. Rasmussen (1967) suggested using a weighted inverse of the row sums to measure the inter-sectoral linkages, or what is called an "index of sensitivity dispersion" to capture both the direct and indirect linkage effects. Jones (1976), however, argued that neither of these techniques captures total forward linkages. The total linkage effect used by Yotopoulos and Nugent captures direct and indirect effects on supplier industries but not user industries (the backward linkages only). On the other hand, Rasmussen's calculation, by using the sum of the rows, captures only the part of the forward linkage that is the total intermediate sales of an industry sector. To capture both direct and indirect linkage effects, Jones suggested calculating intermediate sales as a share of total sales, including final demand instead of intermediate inputs as a share of total inputs including value-added (Al-Saqri, 2010).

[62] IO tables are introduced more fully in section 4.1.4.

### 4.1.3 Empirical Studies That Have Made Use of Linkage Theory

Researchers differ about the multiplier effect of a primary sector, such as agriculture, on other sectors of an economy. Hirschman (1958) suggested that the agricultural sector has weak linkages to other sectors of the economy because it does not induce new investments or downstream industries. In his strategy, Hirschman suggested that policy planners should promote non-agriculture investment, industrial investment in particular, because of greater linkages to other sectors of the economy. Other researchers, however, suggested that agriculture can stimulate and induce other economic sectors and encourage economic development. For example, Vogel (1994) examined the strength of the forward and backward linkages of the agricultural sector and its role in encouraging industrialization using a social accounting matrix. He concluded that the sector had the potential to induce intersectoral linkages, especially in developing countries.[63]

Auty (2001, 1990) and Hirschman (1981) each investigated the production, fiscal, and consumption linkages of mining and petroleum industries. Hirschman stressed the importance of fiscal linkages for the mining and petroleum sector, while Auty researched the reasons behind failures in resource-based industrialization. Hausmann, Klinger and Lopez-Calix (2010) analysed the linkages in Algeria, Norway and Brazil, and showed the ability of these countries to build substantial upstream (forward) linkages from oil to other industries (Gelb, 2010). Ploeg (2011) showed that resource-abundant countries, the UAE, Botswana, Indonesia, and Malaysia, all managed to utilize their resources forward linkages efficiently and effectively to achieve economic diversification by establishing and promoting new industries.

[63] Since the size of the agricultural sector in developing countries tends to be bigger.

Sabiroglu and Bashirli (2012) used IO framework models to analyse the linkages for 25 different sectors and their Total Factor Productivity (TFP) growth rates[64] in Azerbaijan's economy.[65] They found that a marginal change in final demand has a significant impact on the M&Q sector, but its impact on total output and total supply was relatively low compared to other sectors. They explained this by the limited capacity of the M&Q sector directly to generate wealth and employment opportunities on a large scale; hence, they recommended that consideration should be given to policies to increase linkages between the M&Q sector and other sectors. Stilwell *et al.* (2000) also used IO techniques to analyse the effect of the M&Q sector on the South African economy. Their results showed that there were few linkages between the M&Q sector and the rest of the economy, and they also suggested that policies should be introduced to increase those linkages. Lei, Cui and Pan (2013), meanwhile, analysed the economic effects of various M&Q developments in China, using the basic hypotheses of IO economics and industrial linkage models. They showed that all the M&Q development industries had a strong positive impact on China's fixed asset investment and GDP, and on their downstream (i.e., forward linkages), but created only weak pull effects (i.e., backward linkages) in terms of national economic development.

### 4.1.4 Concepts and Applications of Input–Output Analysis

An IO system can be viewed as a simplified representation of the production side of an economy. It adopts a linear Leontief production function, which assumes proportionality between the inputs and outputs of an industry. Within this system, each industry requires

[64] To measure TFP growth in the IO framework, IO tables for a minimum of two different periods are required. Sabiroglu and Bashirli used IO tables for the years 2001 and 2006. In our case, since there is only one IO table that has been produced to date for Oman, for the year 2005, their model could not be used to measure the TFP growth.

[65] In 2006, M&Q represented 79.3% of Azerbaijan's total exports (compared to 81.0% in the same year in Oman). The GDP growth was 34.5%, mainly due to the heavy oil & gas extraction and their rapidly increasing prices.

different inputs to produce its output, with these inputs being procured from other domestic industries, or from suppliers of non-domestically produced inputs (intermediate imports). Analysis of an IO system demonstrates how industries are linked together through supplying inputs for the output of the economy. For example, let us consider the production of automobiles. We know that a range of raw materials, such as steel, electronic gadgets, plastic, glass etc., are needed to manufacture cars, and these are referred to as direct inputs in IO terminology. If one direct input moves up the supply chain, however, then one can realize that several other raw materials go into the production of these direct inputs; for instance, steel production requires water, iron ore, coal, electricity, etc. Those raw materials which are not used directly in the production of cars are known as indirect inputs. If the price of iron ore were to increase substantially, we can see that this would have an impact on (a) the number of cars produced, (b) the amount of electricity produced, and (c) the price of electricity. IO analysis is one of the few tools available to answer these types of questions in a systematic way (Stilwell *et al.*, 2000).

The IO models are mostly final demand driven planning tools,[66] which are designed to examine the inter-relationships among the productive sectors of an economy. They use IO tables which describe the complex process of production, the use of goods and services, and the way in which income and value-added are generated within various sectors of an economy.

In an IO table, the structure of an economy can be shown by the transaction flows across various sectors. A particular row of an IO table represents a sector that sells its final output to other sectors, while a column represents a sector that buys its required intermediate inputs from another given sector. All these intermediate transactions are recorded in the first quadrant (intermediate quadrant) of the table, which is referred to as the heart of the IO table. The system

[66] In Chapter (6), we will be looking at a supply side of the IO model (called Ghosh Model).

is closed by adding three other quadrants to the table. These are: (1) the final demand quadrant, which shows the sectoral distribution of household expenditure, government consumption, fixed capital formation/investments, and exports (i.e., the destination of sales that do not go to other sectors as intermediate inputs); (2) the primary inputs quadrant, where the sectoral distribution of wages, operating surplus, value-added, indirect taxes, subsidies and non-competitive imports are usually shown; and (3) the primary-input-to-final demand quadrant, which presents the value of various primary inputs directly linked to the final demand.

IO techniques have many applications, such as economic impact analysis (i.e., measuring the impact of a change in a sector's final demand on the production, income, value-added or employment of other sectors in the economy), measuring various backward and forward linkages indices, employment creation, income distribution, analysing the effective rate of protection, project appraisal, cost-benefit analysis, regional planning, energy analysis, and price-quantity relationships. In almost all of these applications one needs to calculate Leontief multipliers.[67]

### 4.1.5 Theoretical Structure of Input–Output Models

Assuming that an economy can be categorized into (n) sectors, the equations that identify the productions and sales of the output to each of the (n) sectors are:

$$X_1 = z_{11} + z_{12} + z_{13} + \cdots + z_{1n} + Y_1 = \sum_{j=1}^{n} z_{1j} + Y_1$$

$$X_2 = z_{21} + z_{22} + z_{23} + \cdots + z_{2n} + Y_2 = \sum_{j=1}^{n} z_{2j} + Y_2$$

. . . . . .

$$X_n = z_{n1} + z_{n2} + z_{n3} + \cdots + z_{nn} + Y_n = \sum_{j=1}^{n} z_{nj} + Y_n \tag{4.1}$$

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[67] For a detailed account of the theory and applications of the IO analysis refer to Parikh and Bulmer-Thomas (1984), Valadkhani (2003) and Miller and Blair (2011).

And, if generalized, the Supply (X) and Demand $(z, Y)$ balanced equation for the nation's production system can be written as:

$$X_i = z_{i1} + z_{i2} + z_{i3} + \cdots + z_{in} + Y_i = \sum_{j=1}^{n} z_{ij} + Y_i \qquad (4.2)$$

Where, $X_i$ is the gross-output of $i^{th}$ sector (row vector), $Y_i$ the total final demand[68] for sector $i's$ product, and $z_{ij}$ represents the intermediate inputs, being the flow of input from sector (i) to sector (j), (including itself, when j=i). Assuming an open economy, $Y_i$ includes ($i^{th}$) commodity's exports as a positive entry and imports ($M_i$) as a negative entry; thus ($z_{ij}$) is the total absorptions of the ($i^{th}$ ) commodity by the ($j^{th}$ ) sector inclusive of imports.

Leontief's greatest achievement was to provide, through the IO system, an empirical implementable general equilibrium system, where each intermediate input ($z_{ij}$) is only a function of total output ($X_j$):

$$z_{ij} = f_{ij}\left(X_j\right) \qquad (4.3)$$

The fundamental assumption in equation (4.3) is that the intermediate input flow from (i) to (j) depends entirely on the total output of sector (j), which results in ratios called technical coefficients:[69]

$$a_{ij} = {}^{z_{ij}}\!/_{X_j} \qquad (4.4)$$

In the Leontief model, once these technical coefficients are measured, they are assumed to be unchanging and viewed as measuring fixed relationships between a sector's output and its

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[68] Details about and a breakdown of the final demand will be discussed in section (4.4.2).
[69] Also called IO coefficients and direct input coefficients.

input. Also, substitution of intermediate inputs is not allowed, hence, changes in relative prices have no influence on technical coefficients.[70]

Using the technical coefficient relationship in equation (4.4), we can see that in the Leontief model this becomes:[71]

$$X_j = {}^{z_{1j}}/_{a_{1j}} = {}^{z_{2j}}/_{a_{2j}} = \cdots = {}^{z_{nj}}/_{a_{nj}} \qquad (4.5)$$

The main problem with the simple formulation above is that when a particular input (i) is not used in the production of (j) (i.e., $a_{ij} = 0$), the output becomes infinitely large. Therefore, a more appropriate production function is embodied in the model:[72]

$$X_j = \min\left({}^{z_{1j}}/_{a_{1j}}, {}^{z_{2j}}/_{a_{2j}}, \ldots, {}^{z_{nj}}/_{a_{nj}}\right) \qquad (4.6)$$

Where, (X and z) denotes the smallest of the numbers of X and $z$ For illustration, Figure (4.1) shows the graphical concept and structure of two sectors' fixed proportion Leontief production functions, where f ( $z_{ij}$ , $z_{ij}$) = min ( $z_{ij}$ , $z_{ij}$). To produce $X_2$ (for example), the minimum inputs of $z_{12}$ and $z_{22}$ are indicated by the red dot. Whereas, to produce $X_1$ and $X_3$ using $z_1$ and $z_2$ as inputs, where $X_3 > X_1$, larger inputs of $z_1$ and $z_2$ are required to produce $X_3$ than $X_1$, but the

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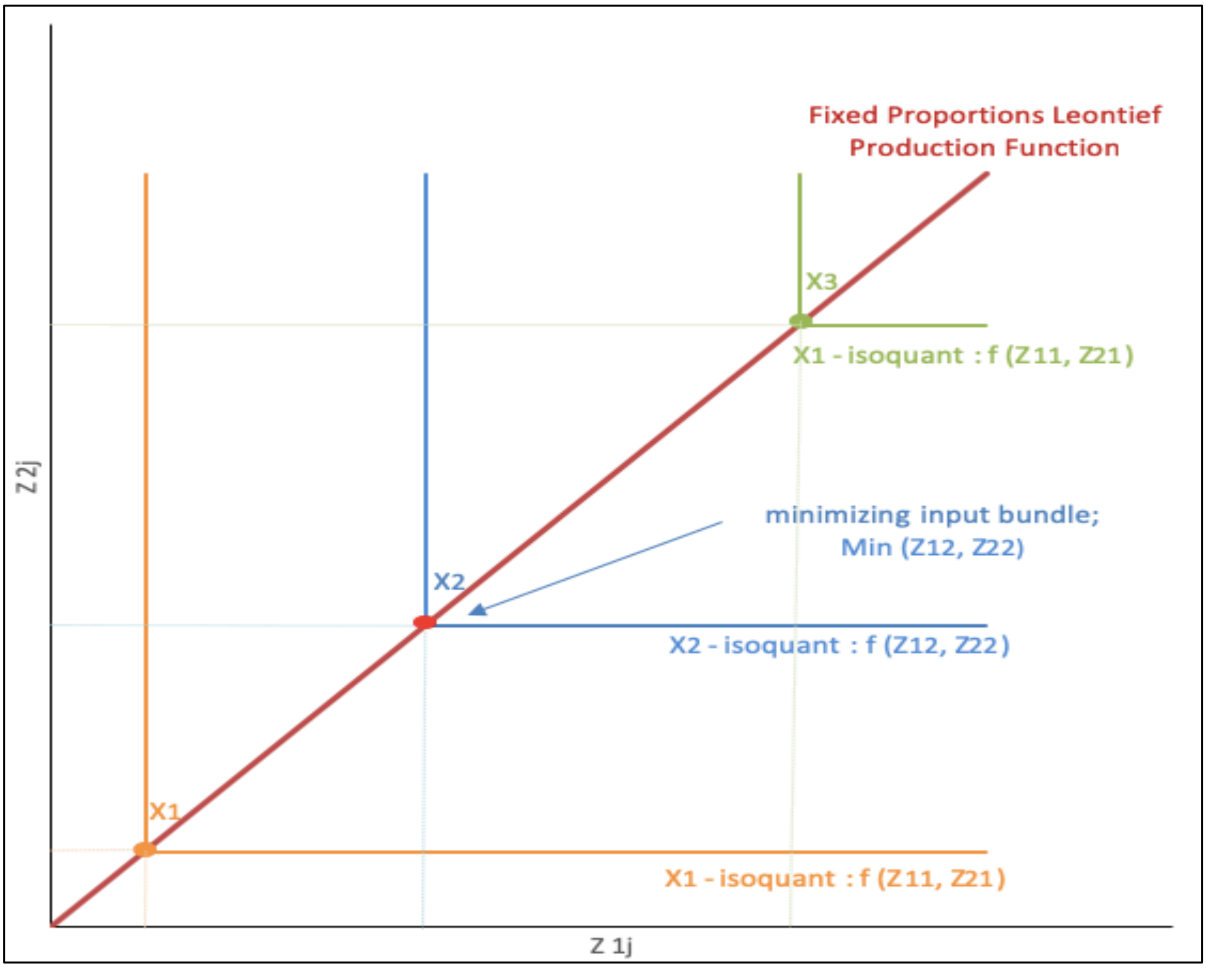
[70] Beside the prices, Leontief's formulation assumes that the relationship in equation (4.2) can be expressed in physical terms (quantity dimensions). Further justifications for this can be found in detail in Bulmer-Thomas (1982, page 55). The fact that Leontief's model neglects prices does not imply that changes in prices cannot be reflected when using Leontief's' approach. In essence, variations in prices can be evaluated, but changes in values and quantities are not simultaneous within this model. This is in fact one of the distinctive characteristics of IO analysis and Leontief's theoretical approach. It closely corresponds to the case of a competitive equilibrium where the supply curve is perfectly elastic and thus the overall situation, in terms of equilibrium quantities, is determined by the demand side (Guerra & Sancho, 2010).

[71] Ignoring the contributions of $Y_j$ and $M_j$, since our focus is on intermediate usages.

[72] This belongs to an important family of production function models, so-called fixed proportion production functions.

proportions of inputs $z_1$ to $z_2$ that are required for the production of both the outputs always remain the same.

*Figure 4. 1: Fixed Proportion Leontief Production Function, Geometry for a Two Sector Economy*




*Source: Customized by Author based on figure from Miller and Blair (2011)*

Once the notion of a set of fixed technical coefficients is acknowledged and accepted, substituting relationships in equation (4.1) we achieve:

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \cdots + a_{1n}X_n + Y_1 = \sum_{j=1}^{n} a_{1j}X_j + Y_1$$

$$X_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \cdots + a_{2n}X_n + Y_2 = \sum_{j=1}^{n} a_{2j}X_j + Y_2$$

. . . . . .

$$X_n = a_{n1}X_1 + a_{n2}X_2 + a_{n3}X_3 + \cdots + a_{nn}X_n + Y_n = \sum_{j=1}^{n} a_{nj}X_j + Y_n \qquad (4.7)$$

Again, if generalized, the Leontief supply and demand balanced equation (4.2) can be rewritten as:

$$\mathrm{X_i} = \sum_{\mathrm{j=1}}^{\mathrm{n}} a_{\mathrm{ij}}\mathrm{X_j} + \mathrm{Y_i} \tag{4.8}$$

Using the simple matrix format of equation (4.8) can be written as: [73]

$$\begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} a_{11} & \cdots & a_{1\mathrm{n}} \\ \vdots & \ddots & \vdots \\ a_{\mathrm{n}1} & \cdots & a_{\mathrm{nn}} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} + \begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix} \tag{4.9}$$

where A refers to the technical coefficient matrix = $\begin{bmatrix} a_{11} & \cdots & a_{1\mathrm{n}} \\ \vdots & \ddots & \vdots \\ a_{\mathrm{n}1} & \cdots & a_{\mathrm{nn}} \end{bmatrix}$,

The simple notation equation (4.9) can be presented as Y= $[1 - \mathrm{A}]$ X. Assuming the inverse of $[\mathrm{I} - \mathrm{A}]$ exists,[74] we get $\mathrm{X} = [\mathrm{I} - \mathrm{A}]^{-1}$ Y, where $[1 - \mathrm{A}]^{-1}$ is defined as the Leontief inverse matrix.

### 4.1.6 Limitations of Input–Output Framework Analysis

When using IO models for analysis, forecasting and policy recommendations, it is important to understand some of their main limitations and uncertainties. These limitations are mainly associated with a number of restrictive assumptions, which are briefly discussed here. First, as mentioned earlier, IO models assume a linear production function (or fixed technical coefficients) for each industry, ruling out the possibilities of economies of scale, externalities and substitutions among inputs. In other words, the proportion of inputs used in the production process are insensitive to the level of production: so, if 100 cars require 10 tons of steel, 200 cars will require 20 tons of steel. These models also assume linearity in the cyclical impact,

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[73] Most of the simple IO models are strictly linear and the structure of such models thus lend themselves to matrix algebra (Parikh and Bulmer-Thomas, 1984).

[74] A being non-negative, and its determinate is not zero (i.e., A not being singular and $[\mathrm{I} - \mathrm{A}]$ is singular).

meaning that the economy responds in exactly the same way in a boom phase as it does in a recession. Second, it is assumed that the economy operates with spare capacity and that there always exists un- and/or under-utilized resources to accommodate the multiplier effects. In other words, supply effects are virtually ignored, suggesting that the supply curve is perfectly elastic. For example, if government expenditure in a given year increases by, say ten per cent, based on this assumption it is possible to meet the extra demand through the present production capacity. On the other hand, if many resources are close to full utilization, the multiplier effects will ignore or mask (negative) displacement effects. In view of this fact, it would be useful to compare and contrast the sectoral capacity utilization rate, but that would be beyond the scope of this research.[75] Third, the models generate values of endogenous variables (i.e., output, income, value-added employment, and prices), but only for an initial equilibrium and when a new equilibrium aftershock is imposed. In other words, IO analysis does not convey information on the dynamic adjustment process, and only provides a snapshot of the structural characteristics of the economy.[76] Fourth, in IO models, it is assumed that the endogenous reaction (in terms of absolute value) of the sectoral output to a shut-down (or a negative one-unit shock) is exactly the same as the response that would accompany an expansion (proxied by a positive one-unit shock). In other words, unlike the real-world situation, if the final demand in a given year increases (say by ten per cent), the resulting change in output in other sectors (in terms of absolute value) would be exactly the same as a ten per cent decrease in the final demand of that sector (Valadkhani, 2003).

Besides the above general limitations, there are some specific limitations when using IO models for forecasting and policy analysis in resource-based countries. First, GDP estimates,

[75] Additional future research on this issue would be of value.
[76] The IO models used in this thesis therefore involve comparative statistics and, as such, the reported findings of this research should be considered with caution.

whether derived from IO techniques or from expenditure analysis, do not account for natural resource depletion. Consequently, GDP tends to exaggerate the wealth of economies, such as Oman, in which resource extraction plays a large part. Second, GDP measures may understate the value of production in economies with large informal sectors. Despite these limitations, virtually all developed countries, as well as many developing countries, use IO techniques for national income accounting (Stilwell *et al.*, 2000; Sabiroglu and Bashirli, 2012).

It should be noted that the restrictive assumptions in the IO analysis framework make generalizations more difficult and mean that the analysis results obtained could be less accurate, but the end findings remain to some extent indicative and powerful.

## 4.2 Interlinkages in Oman

In resource-dependent economies, debate has focused on the type of relationship that exists between the resource sectors and other sectors of the economy. In the case of Oman, that debate is concerned with the nature of relationship between the M&Q sector and other sectors in the economy, including agriculture and fisheries, manufacturing, financial intermediation, and services.

As discussed earlier in Chapter (2), since the discovery of the M&Q sector’s products and the start of the associated export boom, the economy has gone through a significant transformation. Articulating this in terms of the linkages hypothesis, the M&Q sector in Oman has four major linkages: fiscal, forward, backward and consumption linkages. These are discussed in turn below.

The fiscal linkage has played a major role in the expansion of the economy. Revenue from the M&Q exports passes directly to the government and is then utilized through government expenditure and investments to create and expand other sectors of the economy.

The forward linkages relate to how the M&Q sector's output was used as an intermediate input into the making of other goods. The sector's output was used to meet domestic market demands. This also supported the establishment of refining activities and a petrochemical industry in the country. The forward linkage also made important contributions to the development of the manufacturing sector, as seen in the growth of its share of GDP, discussed in Chapter (2).

The backward linkages refer to inputs created within the domestic economy to cater for the needs of the M&Q sector. As discussed in Chapter (2), the M&Q sector's average share of total capital investment was 32.4% during the period 1998–2016. These investments went back into the sector which then generated additional demand in other sectors, especially in the services sector.

The consumption linkages, meanwhile, refer to the increased consumption resulting from the revenues generated by M&Q exports. Linkage theory suggests that increased consumption may increase demand for imports, but also encourages local agents to manufacture consumer products to meet this increased demand (Al-Saqri, 2010).

## 4.3 Dutch Disease

One of the phenomena associated with Dutch disease[77] is that it causes re-allocation of resources (capital investment and labour) from other sectors of the economy to the booming sector. Analysing the effect of the Dutch disease on Oman will therefore support a better understanding of the multi-sectoral interlinkages in Oman's economy.

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[77] As discussed in the literature review of Chapter (3), section (3.1.1).

### 4.3.1 Dutch Disease Model

In the model proposed by Corden and Neary (1982), any small open economy consists of three sectors: a tradable booming sector, such as the M&Q sector in the case of Oman, a lagging tradable sector, such as the manufacturing sector in Oman, and a non-trading sector, which is usually defined as the services sector. In this scenario, the tradable sectors' products are subject to international market prices, and the non-tradable sectors' products are subject to domestic market forces. According to their theory, an abundant natural resource sector (booming sector) has two major economic impacts on an economy:

1) Resource movement effect: this takes place when the booming sector's demand for input factors increases. For example, in the case of a shift in labour from the manufacturing sector to the booming sector, the former's output will decline in the short-term and there will be de-industrialization in the long term.
2) Spending effect: this takes place when demand in the non-tradable sector, such as services, increases as a result of the income generated in, and the support needs of, the booming sector. This increase in demand for non-tradable sector goods and services results in labour shifting from the lagging tradable sector (the manufacturing sector in our example above) to the non-tradable sector. This second demand shift causes an indirect de-industrialization. In addition, this increases in demand for non-tradable sectors' goods and services increases their prices, which leads to an increase in the real exchange rate, causing further de-industrialization.

### 4.3.2 Oman and the Dutch Disease

Although there are many different ways to evaluate the effects of the Dutch disease phenomena on an economy, in our case, in order to investigate whether Oman has suffered from the Dutch disease or not, we will follow Al-Saqri (2010) in evaluating Dutch disease effects in Oman based on the following four core parameters:[78]

1) Exchange rate appreciation.
2) Decline in the manufacturing sector, and boom in the services sector.[79]
3) Shift in labour from the manufacturing sector to the services sector.

The above parameters will be compared with the respective parameters for the Kingdom of Saudi Arabia (KSA) since, like Oman, KSA is also a M&Q-dependent economy.[80]

#### 4.3.2.1 Exchange Rate Appreciations

As per the Dutch disease theory, the real exchange rate should appreciate as an effect of revenue inflow from the sector subject to the resource boom. As Figure (4.2) shows, the Omani Rial gradually depreciated until the year 2006, before appreciating for a couple of years and then remaining broadly stable for the rest of the period.[81] Almost the same trend was observed in KSA. This parameter, therefore, does not provide evidence for the presence of the Dutch disease in either Oman or KSA.

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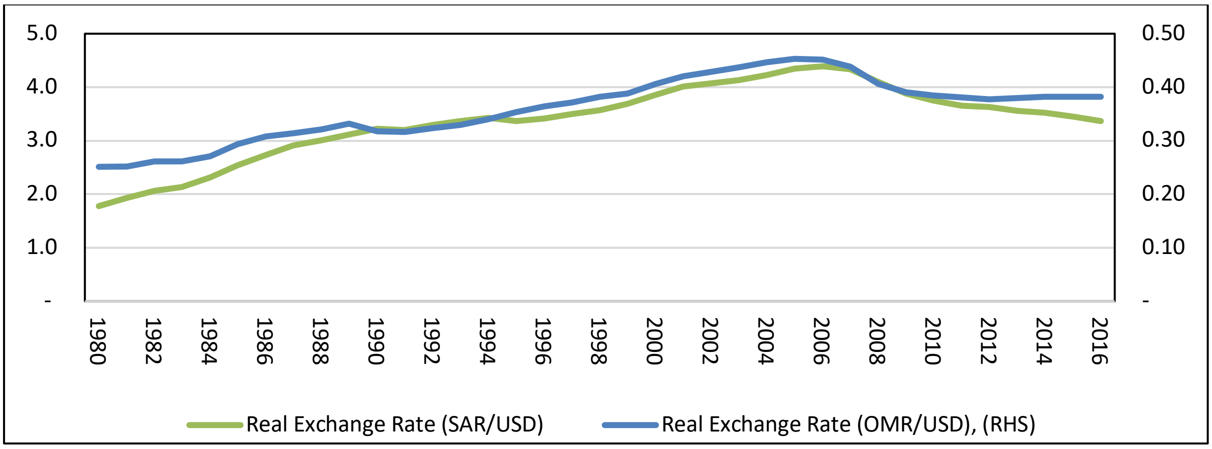
[78] The suggested parameters for the Dutch disease evaluation are only examples and are not intended to be seen as a complete record of policies for Dutch disease evaluation. The Dutch disease affects different countries in various ways. Further, the time frame for this study is limited to 19 years only, from 1998–2016.
[79] Considered as two parameters.
[80] Rodriguez (2006) also used the same parameters to evaluate the Dutch disease effects on KSA.
[81] Since the Omani Rial is pegged to the USA Dollar since 1972, fiscal policy is the only available option that could reduce the impact of a positive shock on the money supply on the domestic economy.

*Figure 4. 2 : Real Exchange Rate of OMR/USD and SAR/USD, During the Period 1980–2016*




*Source: Compiled by Author using Economic Research Service International Macroeconomic Data*

#### 4.3.2.2 Decline in the Manufacturing Sector and Boom in the Services Sector

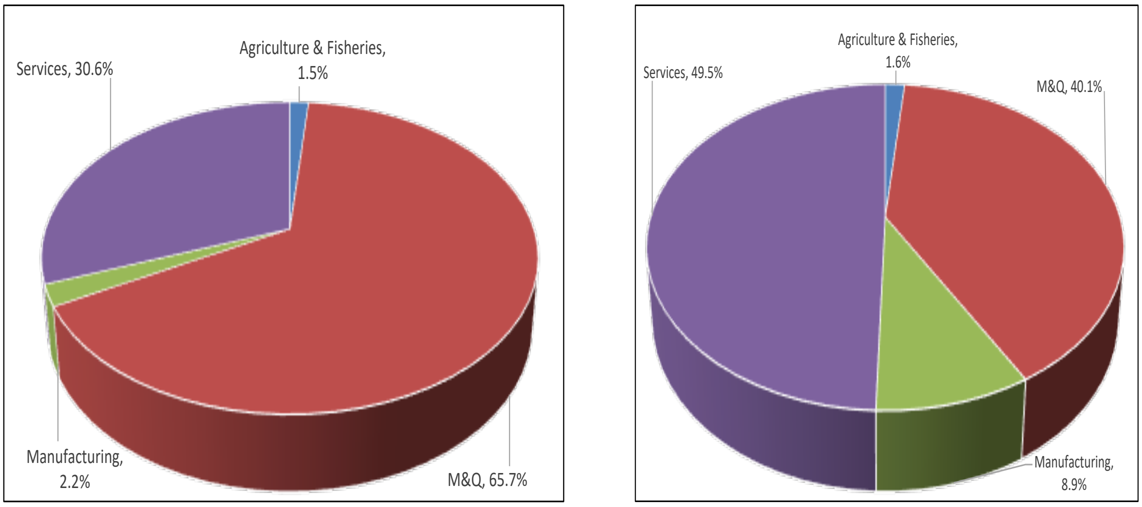
As per the theory, the GDP share of tradable sectors in the economy, such as manufacturing, decreases, while the GDP share of non-tradable sectors, such as services, increases. As Figure (4.3) shows[82] the GDP share of the manufacturing sector in Oman increased marginally from 2.2% in 1998 to 8.9% in 2016, with an average growth of 13.9% per annum during the period 1998–2016. During the same period, the services sector's GDP share increased from 30.6% to 49.5%, with an average growth of 6.7% per annum. The same effects took place in KSA during the same period, as shown in Figure (4.4). There, the GDP share of the manufacturing sector increased from 7.8% in 1998 to 12.0% in 2016, while that of the services sector increased from 31.2% to 44.9%. In both economies, although the services sector grew to become the dominant sector, this did not lead to de-industrialization since the manufacturing sector was also growing.

Therefore, this parameter (decline in the manufacturing sector), also does not provide evidence of the presence of the Dutch disease in Oman, or KSA. This finding, in fact, aligned with that of Hutchison (1994), who investigate the presence of the Dutch disease in the wake of energy

[82] To better understand the evolution and development of the various sectors, we have consolidated and analysed the data in the following four broad sectors: agriculture and fisheries, M&Q, manufacturing, and services.

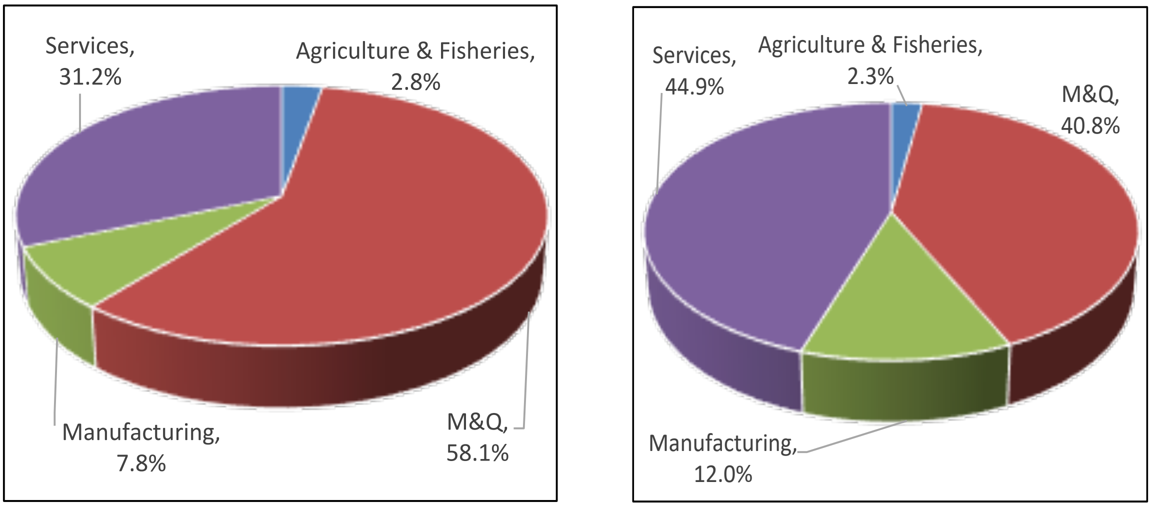
boom in Norway, the UK and Netherlands. Hutchison found that, although the manufacturing sector declined in Norway during the period of his investigation, it grew in both the UK and the Netherlands, which he attributed to the booming sector in the economy increasing aggregate demand, leading to growth in the manufacturing sector.

*Figure 4. 3 : Oman's Multi-sectoral GDP Composition, During the Years 1998 (LHS) and 2016*




*Source: Compiled by Author using NCSI Data*

*Figure 4. 4: KSA's Multi-sectoral GDP Composition, During the Years (LHS) 1998 and 2016*




*Source: Compiled by Author using Saudi Arabian Monetary Agency (SAMA) Data*

#### 4.3.2.3 Shift of Labour from the Manufacturing Sector to the Services Sector

Another attribute of the theory is a shift of labour from tradable to non-tradable sectors, as it becomes cheaper to import than to produce domestically due to the appreciating local currency and consumer inflation. As Figure (4.5) shows, the share of labour held by the services sector in Oman increased from 78.0% in 1998 to 83.3% in 2016, with an average growth of 7.7% per annum during the period. During the same period, the share of labour held by the manufacturing sector decreased marginally from 11.7% to 11.0%, with an average growth of 7.2% per annum. Although the share of labour held by the manufacturing sector has decreased slightly, this does not imply that labour has moved from tradable to non-tradable sectors, because the aggregate average growth of labour in the economy during the same period was 7.3% per annum, almost the same as both sectors' growth during the same period. The other significant tradable sector, agriculture and fisheries, experienced a decline in its labour share from 9.4% in 1998 to 4.7% in 2016, although its average growth during the period was 3.3% per annum.

In KSA, meanwhile, the opposite trend occurred, as shown in Figure (4.6). The share of labour held by the services sector decreased from 82.5% in 2005[83] to 76.7% in 2016, while all the labour shares held by all the tradable sectors increased during the same period. Again, therefore, this parameter does not provide evidence for the presence of the Dutch disease in Oman, or KSA.

Indeed overall, neither the Oman nor the KSA economies appear to exhibit symptoms of the Dutch disease during the period, based on the parameters tested. This conclusion aligns with those of Al-Saqri (2010) and Rodriguez (2006), who found very similar results for both countries.

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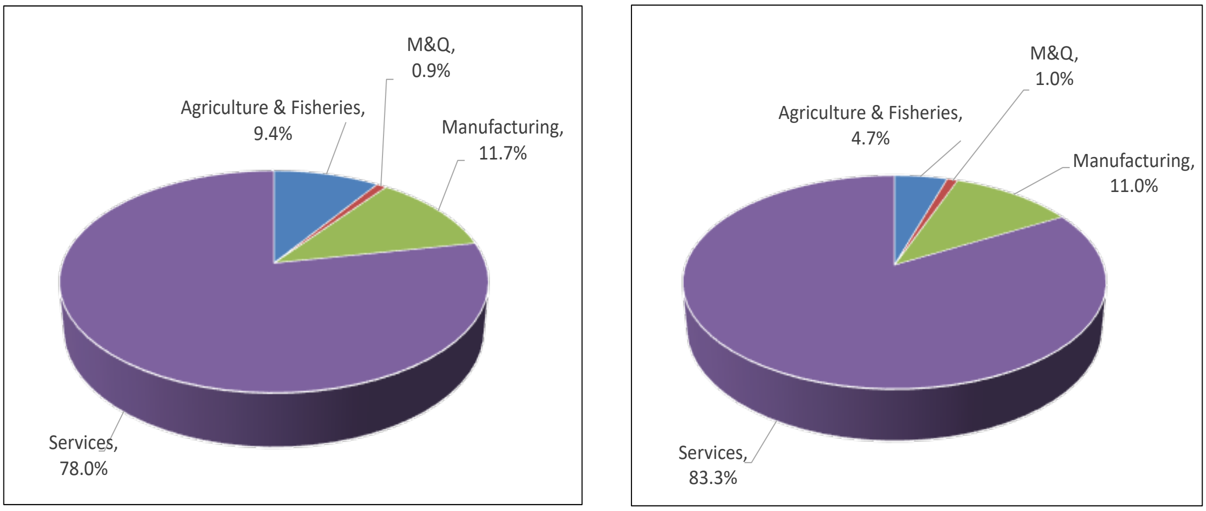
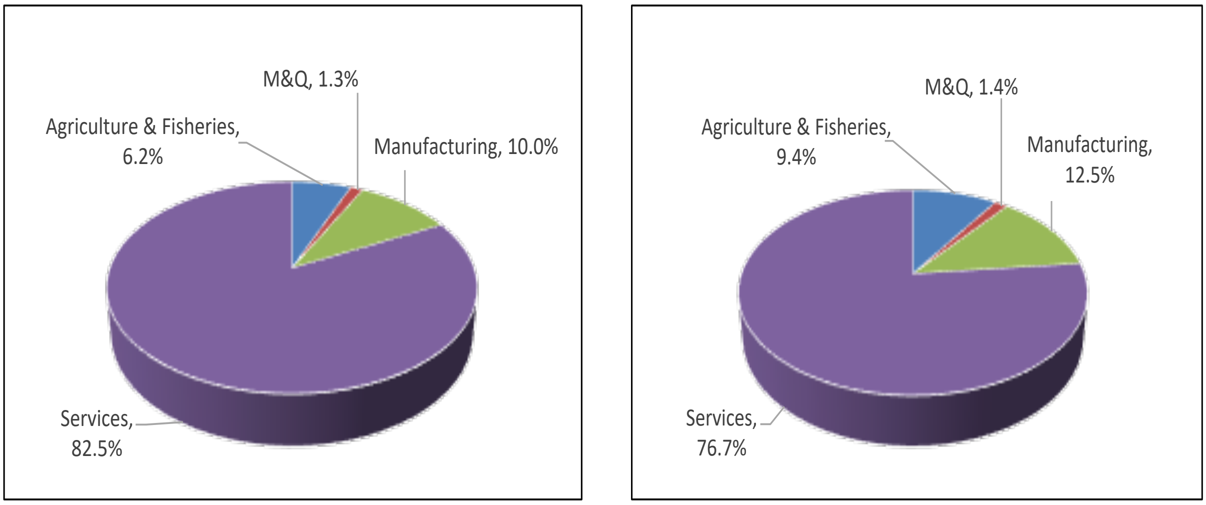
[83] Multi-sectoral labour data for KSA were available only from 2005 onwards.

*Figure 4. 5 : Oman's Multi-sectoral Labour Composition, During the Years 1998 (LHS) and 2016*




*Source: Compiled by Author using NCSI Data*

*Figure 4. 6: KSA's Multi-sectoral Labour Composition, During the Years 2005 (LHS) and 2016*




*Source: Compiled by Author using Saudi Arabian Monetary Agency (SAMA) Data*

## 4.4 Methodologies and Empirical Models Analysis

This section aims to present the empirical models, their methodologies, and results within the IO framework so as to measure the multi-sectoral interlinkages in Oman's economy. The main empirical models that have been used in this section are:

1) Direct backward and forward linkages,
2) Direct and indirect backward and forward linkages,

3) Linkages between final demand and total output, final demand and total supply, and value-added ratios and prices,
4) Demand shocks model, and
5) Hypothetical extraction model (shut-down).

To measure the multi-sectoral linkages using the above empirical models, we use the only multi-sectoral (32 sectors) IO table that has been developed for Oman: for the year 2005 by GTAP (Green, 2011).

We define below the main symbols used in those different models within this section:

$\mathrm{X_i}$ = Gross-output of $\mathrm{i^{th}}$ sector (row vector)

$\mathrm{X_j}$ = Gross-output of $\mathrm{j^{th}}$ sector (column vector)

$\mathrm{z_{ij}}$ = Intermediate inputs from sector i to j sector (intermediate consumption)

$a_{\mathrm{ij}}$ = Intermediate inputs ratios from sector i to j sector (technical coefficient)

$\mathrm{Y_i}$ = Final demand of $\mathrm{i^{th}}$ sector

$\mathrm{V_j}$ = Value-added (GDP) of $\mathrm{j^{th}}$ sector

$\mathrm{C_i}$ = Consumption of $\mathrm{i^{th}}$ sector

$\mathrm{I_i}$ = Investment of $\mathrm{i^{th}}$ sector

$\mathrm{G_i}$ = Government expenditure of $\mathrm{i^{th}}$ sector

$\mathrm{E_i}$ = Exports of $\mathrm{i^{th}}$ sector

$\mathrm{M_i}$ = Imports of $\mathrm{i^{th}}$ sector

$\mathrm{A^T}$ = Transpose matrix

$\mathrm{L_i}$ = Labour of $\mathrm{i^{th}}$ sector

$A_i$ = Total factor productivity (TFP) of $i^{th}$ sector

I = Identity matrix.

### 4.4.1 Direct Backward and Forward linkages Model

Using the intermediate quarter of the IO table we measure the production linkages, Backward Linkages (BL) and Forward Linkages (FL), of the 32 sectors in Oman' economy. To compare the differences in the economic structure of Oman in the year 2005, as captured by the multi-sectoral IO linkages, we use the 33-sector IO table for the USA, also for the year 2005.[84]

#### 4.4.1.1 Structures of the Economies of Oman and the USA

##### 4.4.1.1.1 Methodology

Before comparing multi-sectors production linkages within each economy, it is worth attempting to visualize the overall IO structure of the multi-sectoral linkages in both the economies. To achieve this, we use the technical coefficient matrixes (A) from Oman and the USA IO tables. We present and analyse two different scenarios for the technical coefficients' ratios, $a_{ij} > 0.1$ and $a_{ij} > 1.0$, for both the economies.

##### 4.4.1.1.2 Interpretation of Findings

The results are shown in Figure (4.7), where the columns of the IO matrix are the producing sectors, and the rows are the sectors whose outputs are used as inputs by other sectors.[85] Thus, a dot in the matrix indicates that the column sector uses some of the row sector's output as an input, and a blank space indicates that there is no significant connection between the two sectors. Comparing the matrices, it is apparent that, in Oman, there are only few sectors which

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[84] Retrieved from The Organization for Economic Co-operation and Development (OECD), https://data.oecd.org.

[85] Imported intermediate inputs have been incorporated in ($a_{ij}$) in the technical coefficients in Figure (4.2), and all upcoming measures of backward and forward linkages.

supply to other sectors, while most of the other sectors are quite isolated, in other words their output is not used as an input by many other sectors. By contrast, in the USA, the matrices are much denser for both the scenarios, which indicate that a much larger number of sectors supply to many other sectors in the USA economy. This explains that the overall inter-sectoral linkages in the USA are much more interconnected to each other than in Oman's economy.

#### 4.4.1.2 Direct Backward and Forward Linkages

##### 4.4.1.2.1 Methodology

We use the technical coefficient matrixes (A) from the IO tables for Oman and the USA to measure the production linkages, Direct Backward Linkages (DBL) and Direct Forward Linkages (DFL).

The DBL for the $j^{th}$ sector is measured by summing the column ratios of its technical coefficients (intermediate inputs ratios):

$$\mathrm{DBL_j} = \sum_{\mathrm{i}=1}^{\mathrm{n}} a_{\mathrm{ij}} \tag{4.10}$$

Whereas the DFL for the $i^{th}$ sector is measured by summing the row ratios of its technical coefficients (intermediate demands ratios):

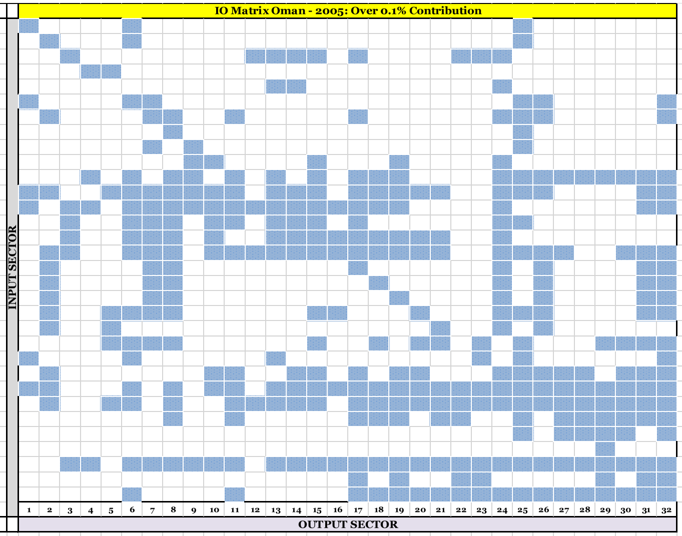
$$\mathrm{DFL_i} = \sum_{\mathrm{j}=1}^{\mathrm{n}} a_{\mathrm{ij}} \tag{4.11}$$

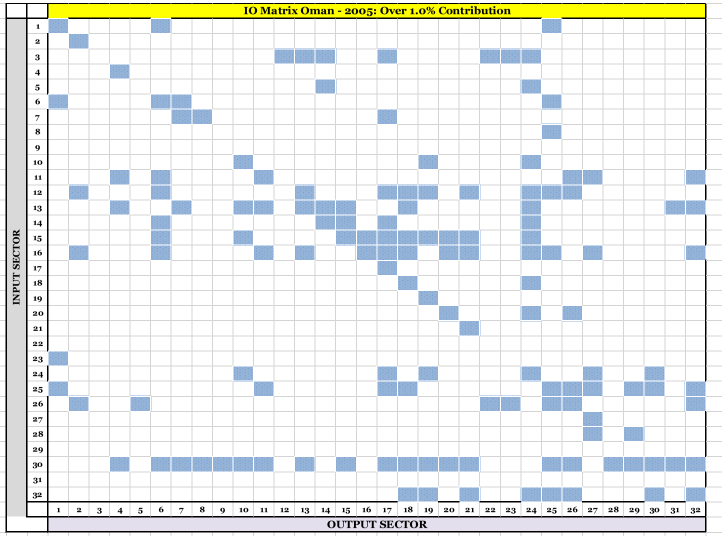
Various measures, and normalizations of these measures, have been proposed and used in empirical studies.[86] We use Rasmussen's (1956) degree of dispersion within the IO framework.

[86] As has been discussed in section (4.1.2).

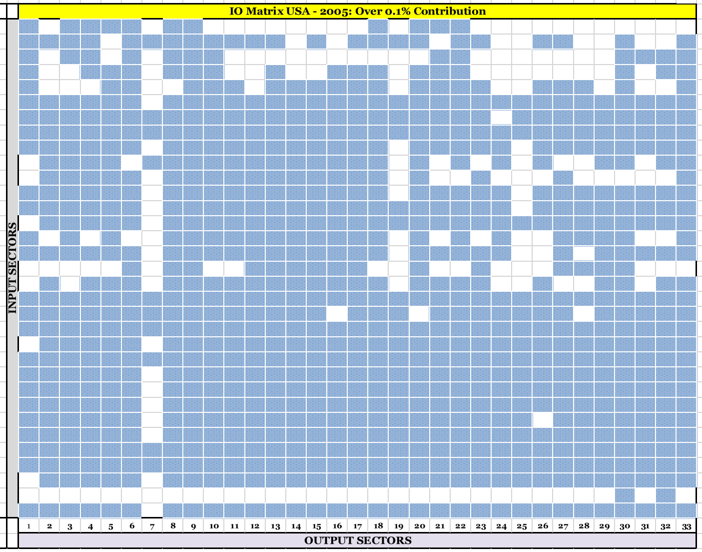
*Figure 4. 7: Representation of Technical Coefficient Ratios of Oman and USA in the Year 2005*

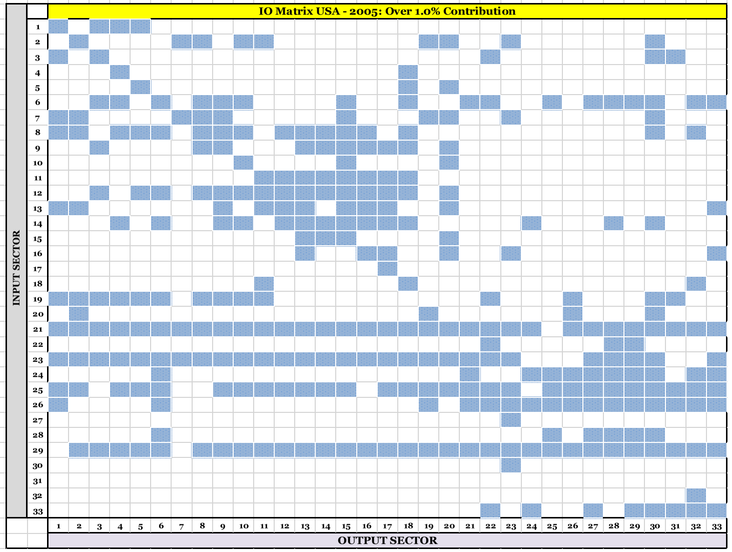
| | Sectors |
|---|---|
| 1 | Agriculture and livestock |
| 2 | Fishing |
| 3 | Extraction of crude petroleum & natural gas |
| 4 | Service activities; incidental to oil & gas extraction |
| 5 | Other mining & quarrying |
| 6 | Manufacture of food products and beverages |
| 7 | Manufacture of textiles |
| 8 | Manufacture of wearing apparel, dressing &dyeing of fur |
| 9 | Manufacture of leather luggage & hand bags |
| 10 | Manufacture of wood & w. products except furniture |
| 11 | Manufacture of paper and paper products, publishing |
| 12 | Manufacture of coke, petroleum products & nuclear fuel |
| 13 | Manufacture of chemicalls, rubber & plastic products |
| 14 | Manufacture of other non-metallic mineral products |
| 15 | Manufacture of basic metals |
| 16 | Manufacture of fabricated metal products |
| 17 | Manufacture of machinery and equipment |
| 18 | Manufacture of electric machinery and apparatus |
| 19 | Manufactures nec |
| 20 | Manufacture of motor vehicles, trailers and semitrailers |
| 21 | Manufacture of other transport equipment, n.e.c. |
| 22 | Electricity and gas |
| 23 | Water works and supply |
| 24 | Construction |
| 25 | Wholesale & retail trade, restaurants & hotels |
| 26 | Transport and storage |
| 27 | Communication |
| 28 | Financial institutions |
| 29 | Insurance |
| 30 | Real estate |
| 31 | Public aministration, defence, education, health |
| 32 | Recreational & cultural services |




| | |
|---|---|
| 1 | Agriculture, hunting, forestry &fishing |
| 2 | Mining & quarrying |
| 3 | Food products, beverages & tobacco |
| 4 | Textiles, textile products, leather & footwear |
| 5 | Wood and products of wood and cork |
| 6 | Pulp, paper, paper products, printing & publishing |
| 7 | Coke, refined petroleum products and nuclear fuel |
| 8 | Chemicals and chemical products |
| 9 | Rubber and plastics products |
| 10 | Other non-metallic mineral products |
| 11 | Basic metals |
| 12 | Fabricated metal products |
| 13 | Machinery and equipment, nec |
| 14 | Computer, Electronic and optical equipment |
| 15 | Electrical machinery and apparatus, nec |
| 16 | Motor vehicles, trailers and semi-trailers |
| 17 | Other transport equipment |
| 18 | Manufacturing nec; recycling |
| 19 | Electricity, gas and water supply |
| 20 | Construction |
| 21 | Wholesale and retail trade; repairs |
| 22 | Hotels and restaurants |
| 23 | Transport and storage |
| 24 | Post and telecommunications |
| 25 | Financial intermediation |
| 26 | Real estate activities |
| 27 | Renting of machinery and equipment |
| 28 | Computer and related activities |
| 29 | R&D and other business activities |
| 30 | Public administration, &defence |
| 31 | Education |
| 32 | Health and social work |
| 33 | Other community, social and personal services |




*Source: Measured by Author using Oman and USA 2005 Input-Output Tables*

The power of dispersion (or measure of dispersion) describes the relative extent to which an increase in final demand for the products of industry (j) is dispersed throughout the system of industries. The power of dispersion of sector (j) is composed of the unweighted sum of the elements of column (j), divided by the number of sectors and standardized by the average of all elements of matrix (A). Hence, the measure of dispersion, or the so-called Direct Backward Linkage Index (DBLI) becomes:

$$\mathrm{DBLI_j} = \frac{\frac{1}{\mathrm{n}} \sum_{\mathrm{i=1}}^{\mathrm{n}} a_{\mathrm{ij}}}{\left(\frac{1}{n^2}\right) \sum_{\mathrm{i=1}}^{\mathrm{n}} \sum_{j=1}^{n} a_{\mathrm{ij}}} \tag{4.12}$$

The numerator of the ratio $\mathrm{DBLI_j}$ denotes the average increase in an economy's output when a unit increase is induced in the final demand for products of sector (j). In making international comparisons of multi-sectoral linkage patterns, the average degree of sectoral interdependences for the whole economy when final demands increase by unity, must be considered, hence, standardization of $\mathrm{DBL_j}$ by the average $a_{\mathrm{ij}}$ in the denominator (Parikh and Bulmer-Thomas, 1984; Dijck, Linnemann and Verbruggen, 1987; Kamaruddin, Rashid and Jusoff, 2008). Besides, the value of the power of dispersion for an imaginary sector that equals exactly the average value of backward linkages in an economy is 1. Consequently, if $\mathrm{DBLI_j}$ is greater than 1, it implies that sector (j) has above-average backward linkage effects, whereas if $\mathrm{DBLI_j}$ is less than 1, it can be stated that the sector (j) is operating in relative isolation from other sectors (Dijck, Linnemann and Verbruggen, 1987).

A dispersion measure for the Direct Forward Linkages Index, $\mathrm{DFLI_i}$ is denoted by Rasmussen as the sensitivity of dispersion:

$$\mathrm{DFLI_i} = \frac{\frac{1}{\mathrm{n}} \sum_{\mathrm{j=1}}^{\mathrm{n}} a_{\mathrm{ij}}}{\left(\frac{1}{n^2}\right) \sum_{\mathrm{i=1}}^{\mathrm{n}} \sum_{j=1}^{n} a_{\mathrm{ij}}} \tag{4.13}$$

The numerator of the ratio $DFLI_i$ refers to the $i^{th}$ row sum, which in turn measures the total impact on the sector (i) when the final demand for all sectors increased by unity. Hirschman (1958) interpreted a high $DFLI_i$ (greater than 1) as meaning that the particular sector (i) has to increase its output by more than other sectors for each unit increase in final demand. If the impact is large, it is suggested that increasing investment in this particular sector would induce output in all other sectors, as users take advantage of the increased availability of inputs (Kamaruddin, Rashid and Jusoff, 2008).

#### 4.4.1.2.2 Interpretation of Findings

Table (4.1) shows that the five sectors with the highest ranking of DBLI in Oman's economy are manufacture of coke; refined petroleum products and nuclear fuel; construction; electricity and gas; manufacture of food products and beverages; and finally, manufacture of paper and paper products, with direct backward linkage indexes of 2.43, 2.18, 2.14, 1.78 and 1.62, respectively. If we focus on tradable sectors that could in the long run support economic growth away from the M&Q sector, out of the fifteen sectors having a DBLI above one, eight are tradable sectors, and seven of those are related to manufacturing activities. It is worth mentioning here that the M&Q[87] sector has the lowest DBLI and is the last in the hierarchy, with an index of 0.06.

Turning to DFLI, the five sectors with the highest levels of DFLI in Oman's economy are services activities incidental to oil and gas extraction; other M&Q; manufacture of other non-metallic mineral products; manufacture of wood & products of wood & cork, except furniture; and finally, manufacture of basic metals, with indexes of 3.25, 2.50, 2.12, 2.11 and 1.92, respectively. Out of the ten sectors having a DFLI above one, seven are tradable sectors, six of

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[87] The M&Q sector is defined in Oman's IO table as extraction of crude petroleum and natural gas (No.3).

which are related to manufacturing activities. Again, the M&Q sector had a low DFLI of 0.44 with a ranking of 24.

Considering the USA economy, Table (4.2) shows that the five sectors with the highest levels of DBLI are motor vehicles; trailers and semi-trailers; food products, beverages and tobacco; basic metals; wood and products of woodwork and cork; and finally, coke, refined petroleum products and nuclear fuel, with DBLI of 1.45, 1.40, 1.38, 1.34 and 1.31, respectively. Again, out of the 16 sectors having a DBLI ratio above average, all are tradable sectors and almost all are related to manufacturing activities. Again, the M&Q sector is below the average, with a ranking of 20 and a DBLI of 0.93. In the USA, the five sectors with the highest levels of DFLI are M&Q; basic metals; wood and products of wood and cork; other non-metallic products; and finally, fabrication of metal products, with indexes of 2.73, 2.20, 2.07, 1.84 and 1.76, respectively. Interestingly, the M&Q sector leads the direct forward linkages in the USA economy, unlike in Oman. This will be further discussed in the next section.

*Table 4. 1: Oman's 32 Sectors' Direct Backward (DBLI) and Direct Forward (DFLI) Linkages Indexes for the Year 2005*

| | | ***DBLI*** | | ***DFLI*** | |
|---|---|---|---|---|---|
| **Sector** | **No.** | **Sum of Columns** | **Ranking** | **Sum of Rows** | **Ranking** |
| Agriculture and livestock | 1 | 1.43 | 7 | 0.96 | 12 |
| Fishing | 2 | 0.49 | 24 | 0.68 | 19 |
| Extraction of crude petroleum & natural gas | 3 | 0.06 | 32 | 0.44 | 24 |
| Service activities; incidental to oil & gas extraction | 4 | 1.41 | 8 | 3.25 | 1 |
| Other mining & quarrying | 5 | 0.17 | 31 | 2.50 | 2 |
| Manufacture of food products and beverages | 6 | 1.78 | 4 | 0.82 | 14 |
| Manufacture of textiles | 7 | 0.48 | 25 | 1.02 | 11 |
| Manufacture of wearing apparel, dressing &dyeing of fur | 8 | 0.60 | 23 | 0.58 | 21 |
| Manufacture of leather luggage & hand bags | 9 | 0.20 | 29 | 0.49 | 23 |
| Manufacture of wood & w. products except furniture | 10 | 0.67 | 22 | 2.11 | 4 |
| Manufacture of paper and paper products, publishing | 11 | 1.62 | 5 | 1.86 | 6 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | 2.43 | 1 | 1.29 | 10 |
| Manufacture of chemicalls, rubber & plastic products | 13 | 1.39 | 9 | 0.77 | 16 |
| Manufacture of other non-metallic mineral products | 14 | 1.00 | 16 | 2.12 | 3 |
| Manufacture of basic metals | 15 | 1.28 | 11 | 1.92 | 5 |
| Manufacture of fabricated metal products | 16 | 0.69 | 20 | 1.69 | 7 |
| Manufacture of machinery and equipment | 17 | 0.78 | 19 | 0.40 | 28 |
| Manufacture of electric machinery and apparatus | 18 | 0.93 | 18 | 0.52 | 22 |
| Manufactures nec | 19 | 1.30 | 10 | 0.81 | 15 |
| Manufacture of motor vehicles, trailers and semitrailers | 20 | 1.08 | 15 | 0.68 | 20 |
| Manufacture of other transport equipment, n.e.c. | 21 | 0.68 | 21 | 0.42 | 25 |
| Electricity and gas | 22 | 2.14 | 3 | 0.16 | 30 |
| Water works and supply | 23 | 0.98 | 17 | 0.13 | 31 |
| Construction | 24 | 2.18 | 2 | 0.74 | 18 |
| Wholesale & retail trade, restaurants & hotels | 25 | 1.11 | 14 | 0.40 | 27 |
| Transport and storage | 26 | 1.45 | 6 | 0.93 | 13 |
| Communication | 27 | 1.24 | 12 | 0.76 | 17 |
| Financial institutions | 28 | 0.19 | 30 | 0.27 | 29 |
| Insurance | 29 | 0.32 | 27 | 0.40 | 26 |
| Real estate | 30 | 0.37 | 26 | 1.44 | 8 |
| Public aministration, defence, education, health | 31 | 0.29 | 28 | 0.05 | 32 |
| Recreational & cultural services | 32 | 1.24 | 13 | 1.37 | 9 |
| Maximum | | 2.43 | | 3.25 | |
| Minimum | | 0.06 | | 0.05 | |
| Arithmetic mean (Average) | | 1.00 | | 1.00 | |
| Median | | 0.99 | | 0.77 | |
| Variance | | 0.39 | | 0.58 | |
| Standard Deviation | | 0.62 | | 0.76 | |

*Source: Measured by Author*

*Table 4. 2: USA's 33 Sectors' Direct Backward (DBLI) and Direct Forward (DFLI) Linkages Indexes for the Year 2005*

| Sector | No. | DBLI Sum of Columns | DBLI Ranking | DFLI Sum of Rows | DFLI Ranking |
|---|---|---|---|---|---|
| Agriculture, hunting, forestry and fishing | 1 | 1.08 | 14 | 1.42 | 8 |
| Mining and quarrying | 2 | 0.93 | 20 | 2.73 | 1 |
| Food products, beverages and tobacco | 3 | 1.40 | 2 | 0.64 | 25 |
| Textiles, textile products, leather and footwear | 4 | 1.23 | 8 | 0.82 | 23 |
| Wood and products of wood and cork | 5 | 1.34 | 4 | 2.07 | 3 |
| Pulp, paper, paper products, printing and publishing | 6 | 1.06 | 15 | 1.20 | 15 |
| Coke, refined petroleum products and nuclear fuel | 7 | 1.31 | 5 | 1.30 | 11 |
| Chemicals and chemical products | 8 | 1.29 | 6 | 1.25 | 13 |
| Rubber and plastics products | 9 | 1.26 | 7 | 1.73 | 6 |
| Other non-metallic mineral products | 10 | 1.13 | 12 | 1.84 | 4 |
| Basic metals | 11 | 1.38 | 3 | 2.20 | 2 |
| Fabricated metal products | 12 | 1.09 | 13 | 1.76 | 5 |
| Machinery and equipment, nec | 13 | 1.18 | 10 | 1.43 | 7 |
| Computer, Electronic and optical equipment | 14 | 0.97 | 17 | 1.24 | 14 |
| Electrical machinery and apparatus, nec | 15 | 1.19 | 9 | 1.29 | 12 |
| Motor vehicles, trailers and semi-trailers | 16 | 1.45 | 1 | 0.98 | 22 |
| Other transport equipment | 17 | 1.14 | 11 | 0.54 | 28 |
| Manufacturing nec; recycling | 18 | 1.02 | 16 | 0.66 | 24 |
| Electricity, gas and water supply | 19 | 0.96 | 19 | 1.00 | 20 |
| Construction | 20 | 0.96 | 18 | 0.31 | 30 |
| Wholesale and retail trade; repairs | 21 | 0.65 | 29 | 1.01 | 19 |
| Hotels and restaurants | 22 | 0.88 | 23 | 0.39 | 29 |
| Transport and storage | 23 | 0.91 | 21 | 1.15 | 16 |
| Post and telecommunications | 24 | 0.82 | 25 | 1.00 | 21 |
| Financial intermediation | 25 | 0.88 | 22 | 1.11 | 18 |
| Real estate activities | 26 | 0.65 | 30 | 0.63 | 26 |
| Renting of machinery and equipment | 27 | 0.78 | 26 | 1.15 | 17 |
| Computer and related activities | 28 | 0.60 | 32 | 1.32 | 10 |
| R&D and other business activities | 29 | 0.63 | 31 | 1.35 | 9 |
| Public administration and defence; compulsory social security | 30 | 0.85 | 24 | 0.14 | 32 |
| Education | 31 | 0.49 | 33 | 0.18 | 31 |
| Health and social work | 32 | 0.75 | 28 | 0.05 | 33 |
| Other community, social and personal services | 33 | 0.76 | 27 | 0.58 | 27 |
| Maximum | | 1.45 | | 2.73 | |
| Minimum | | 0.49 | | 0.05 | |
| Arithmetic mean (Average) | | 1.00 | | 1.00 | |
| Median | | 0.97 | | 1.15 | |
| Variance | | 0.07 | | 0.37 | |
| Standard Deviation | | 0.26 | | 0.61 | |

*Source: Measured by Author*

### 4.4.1.3 Direct and Indirect Backward and Forward Linkages

#### 4.4.1.3.1 Methodology

Unfortunately, DBLI and DFLI do not fully identify the sectors in an economy that have potential for further investment and expansion capacity, because the direct linkages do not take into account the indirect effect of stimuli given to the economy if the investment in that particular sector goes ahead. In order to account for all the ripple effects within the economy (direct and indirect effects), a better approach would be to measure the Direct and Indirect Backward (DIBLI) and Forward Linkages Indexes (DIFLI) by summing the columns and rows, respectively, of the $[1-\mathrm{A}]^{-1}$ matrix (i.e., the Leontief inverse matrix), (Miller and Blair, 2011).

Hence, to measure the effect of both the direct and indirect backward and forward linkages in the economies of Oman and the USA we use the same methods used in section 4.4.1.2, but instead of using technical coefficients $a_{\mathrm{ij}}$ from matrixes (A) in equations (4.12 and 4.13), we use the derived coefficients of the Leontief inverse matrix $[1-\mathrm{A}']^{-1}$ derived from the 2005 IO tables for Oman and the USA.

#### 4.4.1.3.2 Interpretation of Findings

Table (4.3) shows that the five sectors with the highest ranking of DIBLI in Oman's economy are construction; manufacture of food products and beverages; manufacture of paper and paper products; agriculture and livestock; and finally, manufacture of coke, refined petroleum products and nuclear fuel, with DIBLI of 1.45, 1.39, 1.31, 1.24 and 1.22, respectively. Out of fifteen sectors having a DIBLI above one, eight are tradable sectors, and seven of those are related to manufacturing activities. Again, the M&Q sector had the lowest DIBLI, of 0.70. The analysis therefore confirms the findings of the literature review that the M&Q sector is operating in relative isolation from other sectors in Oman's economy.

The five sectors of Oman's economy with the highest sum of rows (DIFLI), meanwhile, are M&Q; manufacture of basic metals; real estate; manufacture of food products and beverages; and, finally, manufacture of coke, refined petroleum products and nuclear fuel, with DIFLI of 2.44, 1.86, 1.67, 1.37 and 1.33, respectively. The M&Q sector has the highest DIFLI, 2.44, which indicates that it is the major supplier to the other sectors in the economy. Out of the eleven sectors having a DIFLI above one, seven are tradable sectors, and six of those are related to manufacturing activities.

Now, considering the economy of the USA, Table (4.4) shows that the five sectors with the highest sum of columns (DIBLI) are motor vehicles, trailers and semi-trailers; basic metals; food products, beverages and tobacco; wood and products of woodwork and cork; and finally, chemicals and chemical products, with DIBLI of 1.37, 1.25, 1.23, 1.21 and 1.17, respectively. In the USA economy, although the M&Q sector does not have the lowest DIBLI, as is the case in Oman, it does have a below average index of 0.95 and a ranking of 19. It seems, therefore, that in both the economies, the M&Q sector does not play a strong and dynamic role in promoting the backward linkages with other sectors, and hence works almost in isolation.

The five sectors with the highest ranking of DIFLI in the USA economy, meanwhile, are wholesale and retail trade; R&D and other business activities; M&Q; financial intermediation; and finally, basic metals, with indexes of 2.65, 2.34, 1.85, 1.77 and 1.40, respectively.

Whereas in Oman, the M&Q sector's DIFLI is the highest in the economy, in the USA, it is the third-placed sector. In both the economies, meanwhile, the DIBLI of the M&Q sector is below the average. This suggests that, in both these economies, the M&Q sector has a dominant forward linkage effect on other sectors of the economy. These findings align with those of Lei, Cui and Pan (2013) for China's economy.

*Table 4. 3: Oman's 32 Sectors' Direct and Indirect Backward (DIBLI) and Forward (DIFLI) Linkages Indexes for the Year 2005*

| | | ***DIBLI*** | | ***DIFLI*** | |
|---|---|---|---|---|---|
| **Sector** | **No.** | **Sum of Columns** | **Ranking** | **Sum of Rows** | **Ranking** |
| Agriculture and livestock | 1 | 1.24 | 4 | 0.94 | 13 |
| Fishing | 2 | 0.83 | 24 | 0.74 | 24 |
| Extraction of crude petroleum & natural gas | 3 | 0.70 | 32 | 2.44 | 1 |
| Service activities; incidental to oil & gas extraction | 4 | 1.08 | 12 | 0.76 | 21 |
| Other mining & quarrying | 5 | 0.74 | 29 | 0.87 | 18 |
| Manufacture of food products and beverages | 6 | 1.39 | 2 | 1.37 | 4 |
| Manufacture of textiles | 7 | 0.82 | 25 | 0.84 | 19 |
| Manufacture of wearing apparel, dressing &dyeing of fur | 8 | 0.84 | 23 | 0.69 | 30 |
| Manufacture of leather luggage & hand bags | 9 | 0.73 | 31 | 0.69 | 31 |
| Manufacture of wood & w. products except furniture | 10 | 0.88 | 22 | 0.92 | 14 |
| Manufacture of paper and paper products, publishing | 11 | 1.31 | 3 | 1.24 | 6 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | 1.22 | 5 | 1.33 | 5 |
| Manufacture of chemicalls, rubber & plastic products | 13 | 1.19 | 7 | 1.18 | 7 |
| Manufacture of other non-metallic mineral products | 14 | 0.96 | 17 | 0.90 | 16 |
| Manufacture of basic metals | 15 | 1.13 | 9 | 1.86 | 2 |
| Manufacture of fabricated metal products | 16 | 0.92 | 18 | 1.07 | 9 |
| Manufacture of machinery and equipment | 17 | 0.92 | 19 | 0.72 | 25 |
| Manufacture of electric machinery and apparatus | 18 | 0.99 | 16 | 0.75 | 23 |
| Manufactures nec | 19 | 1.12 | 10 | 0.78 | 20 |
| Manufacture of motor vehicles, trailers and semitrailers | 20 | 1.03 | 15 | 0.92 | 15 |
| Manufacture of other transport equipment, n.e.c. | 21 | 0.90 | 21 | 0.72 | 26 |
| Electricity and gas | 22 | 1.17 | 8 | 0.71 | 27 |
| Water works and supply | 23 | 0.91 | 20 | 0.71 | 28 |
| Construction | 24 | 1.45 | 1 | 1.02 | 11 |
| Wholesale & retail trade, restaurants & hotels | 25 | 1.05 | 14 | 1.07 | 10 |
| Transport and storage | 26 | 1.22 | 6 | 1.09 | 8 |
| Communication | 27 | 1.09 | 11 | 0.89 | 17 |
| Financial institutions | 28 | 0.74 | 30 | 0.76 | 22 |
| Insurance | 29 | 0.77 | 28 | 0.69 | 32 |
| Real estate | 30 | 0.80 | 26 | 1.67 | 3 |
| Public aministration, defence, education, health | 31 | 0.77 | 27 | 0.70 | 29 |
| Recreational & cultural services | 32 | 1.08 | 13 | 0.96 | 12 |
| Maximum | | 1.45 | | 2.44 | |
| Minimum | | 0.70 | | 0.69 | |
| Arithmetic mean (Average) | | 1.00 | | 1.00 | |
| Median | | 0.97 | | 0.90 | |
| Variance | | 0.04 | | 0.15 | |
| Standard Deviation | | 0.21 | | 0.39 | |

*Source: Measured by Author*

*Table 4. 4: USA's 33 Sectors' Direct and Indirect Backward (DIBLI) and Forward (DIFLI) Linkages Indexes for the Year 2005*

| | | ***DIBLI*** | | ***DIFLI*** | |
|---|---|---|---|---|---|
| **Sector** | **No.** | **Sum of Columns** | **Ranking** | **Sum of Rows** | **Ranking** |
| Agriculture, hunting, forestry and fishing | 1 | 1.04 | 14 | 0.93 | 15 |
| Mining and quarrying | 2 | 0.96 | 19 | 1.85 | 3 |
| Food products, beverages and tobacco | 3 | 1.23 | 3 | 0.73 | 21 |
| Textiles, textile products, leather and footwear | 4 | 1.11 | 10 | 0.63 | 28 |
| Wood and products of wood and cork | 5 | 1.21 | 4 | 0.76 | 20 |
| Pulp, paper, paper products, printing and publishing | 6 | 1.01 | 16 | 1.00 | 10 |
| Coke, refined petroleum products and nuclear fuel | 7 | 1.13 | 9 | 0.94 | 14 |
| Chemicals and chemical products | 8 | 1.17 | 5 | 1.33 | 6 |
| Rubber and plastics products | 9 | 1.17 | 6 | 0.81 | 17 |
| Other non-metallic mineral products | 10 | 1.06 | 13 | 0.67 | 23 |
| Basic metals | 11 | 1.25 | 2 | 1.40 | 5 |
| Fabricated metal products | 12 | 1.10 | 12 | 1.06 | 9 |
| Machinery and equipment, nec | 13 | 1.15 | 8 | 0.98 | 12 |
| Computer, Electronic and optical equipment | 14 | 0.97 | 18 | 1.00 | 11 |
| Electrical machinery and apparatus, nec | 15 | 1.15 | 7 | 0.63 | 29 |
| Motor vehicles, trailers and semi-trailers | 16 | 1.37 | 1 | 0.95 | 13 |
| Other transport equipment | 17 | 1.10 | 11 | 0.59 | 31 |
| Manufacturing nec; recycling | 18 | 1.02 | 15 | 0.64 | 27 |
| Electricity, gas and water supply | 19 | 0.95 | 20 | 0.78 | 19 |
| Construction | 20 | 1.00 | 17 | 0.67 | 24 |
| Wholesale and retail trade; repairs | 21 | 0.79 | 30 | 2.65 | 1 |
| Hotels and restaurants | 22 | 0.92 | 22 | 0.64 | 26 |
| Transport and storage | 23 | 0.95 | 21 | 1.23 | 7 |
| Post and telecommunications | 24 | 0.86 | 25 | 0.91 | 16 |
| Financial intermediation | 25 | 0.89 | 24 | 1.77 | 4 |
| Real estate activities | 26 | 0.79 | 29 | 1.19 | 8 |
| Renting of machinery and equipment | 27 | 0.84 | 27 | 0.62 | 30 |
| Computer and related activities | 28 | 0.75 | 32 | 0.72 | 22 |
| R&D and other business activities | 29 | 0.77 | 31 | 2.34 | 2 |
| Public administration and defence; compulsory social security | 30 | 0.90 | 23 | 0.67 | 25 |
| Education | 31 | 0.71 | 33 | 0.59 | 32 |
| Health and social work | 32 | 0.84 | 28 | 0.51 | 33 |
| Other community, social and personal services | 33 | 0.85 | 26 | 0.78 | 18 |
| Maximum | | 1.37 | | 2.65 | |
| Minimum | | 0.71 | | 0.51 | |
| Arithmetic mean (Average) | | 1.00 | | 1.00 | |
| Median | | 1.00 | | 0.81 | |
| Variance | | 0.03 | | 0.25 | |
| Standard Deviation | | 0.16 | | 0.50 | |

*Source: Measured by Author*

### 4.4.2 Linkages between Final Demand, Total Output, Total Supply, Value-added and Prices

In this model, we use a multipliers' approach to measure the linkages within Oman's 32 sectors with respect to their final demand and total output, final demand and total supply, and value-added ratios and prices.

#### 4.4.2.1 Final Demand and Total Output Model

##### 4.4.2.1.1 Methodology

As discussed earlier, by means of an IO framework, $X_i = \sum_{j=1}^{n} z_{ij} + Y_i$ and $X_j = \sum_{i=1}^{n} z_{ij} + V_j$. Thus, $\sum_{i=1}^{n} X_i = \sum_{i=1}^{n} \sum_{j=1}^{n} z_{ij} + \sum_{i=1}^{n} Y_j$ and $\sum_{j=1}^{n} X_j = \sum_{i=1}^{n} \sum_{j=1}^{n} z_{ij} + \sum_{j=1}^{n} V_j$, and since $X_i = X_j$, then $\sum_{i=1}^{n} X_i$ (total output) $= \sum_{j=1}^{n} X_j$ (total input). And since $\sum_{i=1}^{n} \sum_{j=1}^{n} z_{ij}$, being the total intermediate consumption in the system, then, finally, $\sum_{i=1}^{n} Y_j$ (GDP expenditure approach) $=$ $\sum_{j=1}^{n} V_j$ ( (GDP income approach). Having the technical coefficients (equation 4.4) $a_{ij} = z_{ij} / X_j$ from the IO table, we can rewrite these identities in the form of $z_{ij} = a_{ij} X_j$, and by placing them in the above equation we get $X_i = \sum_{j=1}^{n} a_{ij} X_j + Y_i$. Using the matrix and vector forms we define $A = (a_{ij})$[88] and then $X = AX + Y$, and hence, $Y = [1 - A] X$. On the other hand, we receive $X = [1 - A]^{-1} Y$, where $[1 - A]^{-1} = B$, hence; $X = BY$ and $B = \left(b_{ij}\right)$.

We are interested in the sum of columns ($\sum_{i=1}^{n} b_{ij}$) and sum of rows ($\sum_{j=1}^{n} b_{ij}$), since these multipliers give us the relationships between final demand and total output. Let's assume $Y_i$ of sector (i) demand increases by one unit, with all other final demands unchanged for other sectors, the total effect on the production system, or gross increase in output of all sectors, is

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[88] In this model, while measuring the technical coefficients ($a_{ij}$), we do not incorporate the imported intermediate goods. These will be discussed and incorporated in the model in the next section.

captured by the expression ($\sum_{i=1}^{n} b_{ij}$). Thus, the column sum of the Leontief inverse shows the direct and indirect effects on the economy of a unit change in final demand for the sector shown at the head of column. In other words, the maximum value among the sum of columns shows the sector whose final demand has the most impact on the overall intersectoral structure, i.e., on the total output in comparing with other sectors.

Similarly, the sum of the rows of the Leontief inverse ($\sum_{j=1}^{n} b_{ij}$) shows the total effect on the ($i^{th}$) sector when each sector's final demand increases by unity. In other words, the maximum value among the sum of rows indicates that the output of this sector is more affected by the change in final demand.

##### 4.4.2.1.2 Interpretation of Findings

Table (4.5) shows that the five sectors with the highest levels in the sum of columns ($\sum_{i=1}^{n} b_{ij}$) are manufacture of coke, refined petroleum products and nuclear fuel; construction; electricity and gas; transport and storage; and finally, service activities incidental to oil and gas extraction excluding surveying, with multipliers of 1.78, 1.76, 1.72, 1.64 and 1.54, respectively. This means that one unit increase in the final demand of manufacture of coke, refined petroleum products and nuclear fuel, for example, causes 1.78 units of increase in the economy's gross-output. It is worth mentioning here, the M&Q sector had the lowest multiplier, of 1.02, of all the sectors in the economy.

Since our focus is on the tradable sectors, on the basis that these sectors can best promote the economy,[89] the five tradable sectors with the highest multipliers are manufacture of coke, refined petroleum products and nuclear fuel; manufacture of chemicals, rubber & plastic products; manufacture of paper and paper products, publishing; agriculture and livestock; and

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[89] Out of a total of 32 sectors, 22 are tradable and the rest are non-tradable.

finally, manufacture of food products and beverages, with multipliers of 1.78, 1.51, 1.43, 1.42 and 1.42, respectively. Almost all the tradable sectors[90] with multipliers higher than the average (1.32) are directly linked to manufacturing activities. It is worth mentioning here that the M&Q sector has the smallest multiplier among the sum of columns (1.02), hence has the least effect on the economy's gross-output when its demand increases by one unit. Sabiroglu and Bashirli (2012) arrived at similar results in their work on Azerbaijan.[91]

The five sectors with the highest levels in the sum of rows ($\sum_{j=1}^{n} b_{ij}$), meanwhile, are M&Q; real estate; manufacture of basic metals; manufacture of coke, refined petroleum products and nuclear fuel; and finally, transport and storage, with multipliers of 3.34, 2.38, 1.80, 1.64 and 1.59, respectively. This means that if the final demand for all sectors increased by one unit, the M&Q sector would demonstrate the highest increase of gross-output of 3.34 units. Again, Sabiroglu and Bashirli (2012) found very similar results: the M&Q sector had high ranks of 3 and 5, in years 2001 and 2006, respectively, out of the 25 sectors they tested in Azerbaijan. This clearly shows the reliance and the interlinkage effect of the M&Q sector on other sectors and the whole economy.

Focusing once more on non-M&Q tradable sectors, the five tradable sectors with the highest row sum ratios are manufacture of basic metals; manufacture of coke, refined petroleum products and nuclear fuel; manufacture of paper and paper products, publishing, manufacture of food products and beverages; and finally, manufacture of chemicals, rubber & plastic products, with multipliers of 1.8, 1.64, 1.37, 1.32 and 1.27, respectively. These are all related to manufacturing activities and almost all having ratios above the average.

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[90] Fifteen sectors have above average score, out of which seven are tradable, and six of those related to manufacturing activities.

[91] Azerbaijan and Oman have almost similar economic structures, being M&Q resource-based economies.

### 4.4.2.2 Final Demand and Total Supply Model

#### 4.4.2.2.1 Methodology

From the IO table, one can arrive at a new equilibrium; $X_i + M_i = \sum_{j=1}^{n} z_{ij} + C_i + I_i + G_i + E_i$, which is obtained by considering $Y_i = C_i + I_i + G_i + (E_i - M_i)$ in equation $X_i = \sum_{j=1}^{n} z_{ij} + Y_i$. If the final demand (without import substitution) is defined as D, and used as equation $D_i = C_i + I_i + G_i + E_i$. We drive $X_i + M_i = \sum_{j=1}^{n} z_{ij} + D_i$, then $\sum_{i=1}^{n}(X_i + M_i)$ (total supply) = $(\sum_{i=1}^{n}\sum_{j=1}^{n} z_{ij} + \sum_{i=1}^{n} D_j)$ (total demand). According to supply, we can obtain the next coefficients; $a'_{ij} = z_{ij}/\,(X_j + M_j)$, so $z_{ij} = a'_{ij}\,(X_j + M_j)$. Using the matrix and vector forms we define $A' = (a'_{ij})$ and then $X + M = A'(X + M) + D$. Then $D = [1 - A'](X + M)$, hence, $(X + M) = [1 - A']^{-1}\,D$. Then substituting $[1 - A']^{-1} = B'$, where $B' = (b'_{ij})$, we can rewrite $X + M = B'D$.

Again, we are interested in the sum of columns $(\sum_{i=1}^{n}(b'_{ij}))$, and sum of rows, $(\sum_{j=1}^{n}(b'_{ij}))$, which gives us the relationship between final demand and total supply. The highest value among the sum of columns, Max $(\sum_{i=1}^{n}(b'_{ij}))$, indicates that the demand (D) for this sector has more effect on total supply than do the other sectors. The highest value among the sum of rows, Max $(\sum_{j=1}^{n}(b'_{ij}))$, means that the supply of this sector is most affected by the change in demand.

#### 4.3.2.2.2 Interpretation of Findings

Table (4.5) shows that the first five sectors with the highest levels in the sum of columns, $(\sum_{i=1}^{n}(b'_{ij}))$, are construction; electricity and gas; manufacture of coke, refined petroleum products and nuclear fuel; transport and storage; and finally, service activities incidental to oil and gas extraction excluding surveying, with multipliers of 1.73, 1.72, 1.71, 1.63 and 1.53, respectively. Four of these five are non-tradable sectors, and indeed only five out the of thirteen multipliers that were above average (1.28) belonged to tradable sectors, although four of those five were engaged in manufacturing related activities. Hence, any change in demand within Oman's economy's leads to further supply from the non-tradable sectors. It is also worth mentioning here that the M&Q sector has the lowest multiplier (1.02) of all 32 sectors. These results are similar to those of Sabiroglu and Bashirli (2012) for Azerbaijan, who found that the M&Q sector had ratios below the arithmetic means for both the years (2001 and 2006).

The first five sectors with the highest levels in the sum of rows ($\sum_{j=1}^{n}(b'_{ij})$) are M&Q; real estate; manufacture of basic metals; transport and storage; and finally, manufacture of coke, refined petroleum products and nuclear fuel, with multipliers of 3.13, 2.28, 1.57, 1.56 and 1.54, respectively. This means that a marginal change in final demand had a bigger effect on supply within these sectors, with the M&Q sector being at the top of the hierarchy. This also concurs with Sabiroglu and Bashirli's (2012) findings, in the fact that the M&Q sector had the second highest ranking in both the years 2001 and 2006 in Azerbaijan. In our study, out of nine sectors that have multipliers above the average (1.28), apart from the M&Q sector, only two others are tradable sectors (manufacture of basic metals, and manufacture of coke, refined petroleum products and nuclear fuel). This reconfirms that an increase in demand increases the supply in the non-tradable sectors in Oman's economy, instead of in the non-M&Q tradable sectors.

#### 4.4.2.3 Value-added Ratios and Prices Model

##### 4.4.2.3.1 Methodology

Any static IO system implies the existence of linear relationships between the prices of all products and the value-added in all sectors per unit of their respective outputs (Leontief, 1986). Dividing the value-added ($V_j$) by the input ($X_j$) we get the value-added ratio ($V_i$) for each sector. Denoting (P) as the price vector of the original system and (V) as the vector of value-added per unit of output in its (n) different sectors, the basic relationships between two sectors comes to be as $V = [1 - A^T]$ P. Where, $A^T$ is the transpose matrix. Hence, we can rewrite Leontief's price model as $P = [1 - A^T]^{-1} V$. As earlier, defining $[1 - A^T]^{-1} = B''$ and $B'' = (b''_{ij})$, then $P = B''V$.

We are again interested in the sum of columns, $(\sum_{i=1}^{n}(b''_{ij}))$, and sum of rows, $(\sum_{j=1}^{n}(b''_{ij}))$ to estimate our multipliers. The sector with the highest value among the sum of columns, max $(\sum_{i=1}^{n}(b''_{ij}))$, is the one in which the change in the value-added ratio has the greatest impact on the general price level. The sector with the highest value among the sum of rows, max $(\sum_{j=1}^{n}(b''_{ij})$, meanwhile, is the one in which prices are most affected by the change in value-added ratios.

#### 4.4.2.3.2 Interpretation of Findings

Table (4.5) shows that the five sectors with the highest levels in the sum of columns are M&Q; real estate; manufacture of basic metals; manufacture of coke, refined petroleum products and nuclear fuel; and finally, transport and storage, with multipliers of 3.34, 2.38, 1.8, 1.64 and 1.59, respectively. Hence, a one unit increase in the value-added ratio in the M&Q sector will result in a 3.34 unit increase in the general price levels in Oman's economy. This also shows the dramatic effect that changes in the international price of the M&Q sector's products have on overall pricing levels in the economy. When the international prices of the M&Q products increase, the ratio of the sector's value addition increases (assuming the production is fixed). Sabiroglu and Bashirli (2012) analysis came to very similar conclusions in the case of Azerbaijan, showing that the M&Q sector was ranked third and fifth, in 2001 and 2006, respectively.

The five sectors with the highest levels in the sum of rows, meanwhile, are manufacture of coke, refined petroleum products and nuclear fuel; construction; electricity and gas; transport and storage; and finally, service activities incidental to oil and gas extraction excluding surveying, with multipliers of 1.78, 1.76, 1.72, 1.64 and 1.54, respectively. This means, for example, that a one unit increase in the value-added ratios of all sectors will provoke a price of 1.78 units in the manufacture of coke, refined petroleum products and nuclear fuel. This probably reflects the fact that this sector uses by-products from the M&Q sector, and is therefore particularly sensitive to the value-added ratios, given that the M&Q sector is dominant in the value-addition percentages (53.6%, in 2005).

As discussed in section 4.3 in respect to Dutch disease, in resource-abundant countries, real exchange rate appreciation tends to reduce relative prices for products for non-M&Q tradable sectors (i.e., manufacturing, agriculture and fisheries, etc.) relative to prices for the products of non-tradable sectors (i.e., construction and services), so that labour and capital are withdrawn from the non-M&Q tradable sectors and flow into the non-tradable sectors. From an export point of view, however, an increase in the relative prices of non-M&Q tradable sectors depresses and further reduces the competitiveness of all the non-M&Q tradable sectors' products in the export markets (Mikesell, 1997). Considering this, out of the fifteen sectors having a sum of row multipliers above average (1.32), seven are non-M&Q tradable sectors, suggesting that any increases in the value-added ratios in Oman's economy have a direct impact in terms of price increases in these non-M&Q tradable sectors.

*Table 4. 5: Oman’ s Input-Output Linkages of Final Demand, Total Output, Total Supply, Value-Added and Prices, in the year 2005*

| | | *Final Demand and Total Output* | | | | *Final Demand and Total Supply* | | | | *Value-added Ratios and Prices* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sector** | **No.** | Sum of Columns | Ranking | Sum of Rows | Ranking | Sum of Columns | Ranking | Sum of Rows | Ranking | Sum of Columns | Ranking | Sum of Rows | Ranking |
| Agriculture and livestock | 1 | 1.42 | 10 | 1.18 | 15 | 1.34 | 11 | 1.14 | 15 | 1.18 | 15 | 1.42 | 10 |
| Fishing | 2 | 1.15 | 25 | 1.07 | 23 | 1.14 | 23 | 1.06 | 23 | 1.07 | 23 | 1.15 | 25 |
| Extraction of crude petroleum & natural gas | 3 | 1.02 | 32 | 3.34 | 1 | 1.02 | 32 | 3.13 | 1 | 3.34 | 1 | 1.02 | 32 |
| Service activities; incidental to oil & gas extraction | 4 | 1.54 | 5 | 1.12 | 20 | 1.53 | 5 | 1.11 | 20 | 1.12 | 20 | 1.54 | 5 |
| Other mining & quarrying | 5 | 1.08 | 29 | 1.16 | 17 | 1.05 | 31 | 1.14 | 16 | 1.16 | 17 | 1.08 | 29 |
| Manufacture of food products and beverages | 6 | 1.42 | 11 | 1.32 | 10 | 1.29 | 13 | 1.25 | 11 | 1.32 | 10 | 1.42 | 11 |
| Manufacture of textiles | 7 | 1.11 | 27 | 1.12 | 19 | 1.08 | 28 | 1.10 | 21 | 1.12 | 19 | 1.11 | 27 |
| Manufacture of wearing apparel, dressing &dyeing of fur | 8 | 1.16 | 22 | 1.02 | 30 | 1.15 | 22 | 1.02 | 30 | 1.02 | 30 | 1.16 | 22 |
| Manufacture of leather luggage & hand bags | 9 | 1.07 | 31 | 1.01 | 32 | 1.06 | 30 | 1.01 | 32 | 1.01 | 32 | 1.07 | 31 |
| Manufacture of wood & w. products except furniture | 10 | 1.16 | 23 | 1.15 | 18 | 1.09 | 27 | 1.11 | 18 | 1.15 | 18 | 1.16 | 23 |
| Manufacture of paper and paper products, publishing | 11 | 1.43 | 9 | 1.37 | 9 | 1.27 | 14 | 1.27 | 10 | 1.37 | 9 | 1.43 | 9 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | 1.78 | 1 | 1.64 | 4 | 1.71 | 3 | 1.54 | 5 | 1.64 | 4 | 1.78 | 1 |
| Manufacture of chemicalls, rubber & plastic products | 13 | 1.51 | 7 | 1.27 | 12 | 1.38 | 8 | 1.21 | 12 | 1.27 | 12 | 1.51 | 7 |
| Manufacture of other non-metallic mineral products | 14 | 1.25 | 19 | 1.22 | 13 | 1.20 | 19 | 1.20 | 13 | 1.22 | 13 | 1.25 | 19 |
| Manufacture of basic metals | 15 | 1.35 | 14 | 1.80 | 3 | 1.23 | 16 | 1.57 | 3 | 1.80 | 3 | 1.35 | 14 |
| Manufacture of fabricated metal products | 16 | 1.18 | 21 | 1.22 | 14 | 1.10 | 25 | 1.20 | 14 | 1.22 | 14 | 1.18 | 21 |
| Manufacture of machinery and equipment | 17 | 1.26 | 18 | 1.04 | 27 | 1.24 | 15 | 1.04 | 26 | 1.04 | 27 | 1.26 | 18 |
| Manufacture of electric machinery and apparatus | 18 | 1.28 | 16 | 1.05 | 24 | 1.23 | 17 | 1.04 | 24 | 1.05 | 24 | 1.28 | 16 |
| Manufactures nec | 19 | 1.40 | 12 | 1.10 | 22 | 1.34 | 10 | 1.09 | 22 | 1.10 | 22 | 1.40 | 12 |
| Manufacture of motor vehicles, trailers and semitrailers | 20 | 1.27 | 17 | 1.16 | 16 | 1.22 | 18 | 1.13 | 17 | 1.16 | 16 | 1.27 | 17 |
| Manufacture of other transport equipment, n.e.c. | 21 | 1.22 | 20 | 1.04 | 29 | 1.19 | 20 | 1.03 | 29 | 1.04 | 29 | 1.22 | 20 |
| Electricity and gas | 22 | 1.72 | 3 | 1.05 | 25 | 1.72 | 2 | 1.04 | 25 | 1.05 | 25 | 1.72 | 3 |
| Water works and supply | 23 | 1.34 | 15 | 1.05 | 26 | 1.34 | 12 | 1.04 | 27 | 1.05 | 26 | 1.34 | 15 |
| Construction | 24 | 1.76 | 2 | 1.48 | 7 | 1.73 | 1 | 1.45 | 7 | 1.48 | 7 | 1.76 | 2 |
| Wholesale & retail trade, restaurants & hotels | 25 | 1.38 | 13 | 1.53 | 6 | 1.37 | 9 | 1.46 | 6 | 1.53 | 6 | 1.38 | 13 |
| Transport and storage | 26 | 1.64 | 4 | 1.59 | 5 | 1.63 | 4 | 1.56 | 4 | 1.59 | 5 | 1.64 | 4 |
| Communication | 27 | 1.51 | 6 | 1.31 | 11 | 1.51 | 6 | 1.30 | 9 | 1.31 | 11 | 1.51 | 6 |
| Financial institutions | 28 | 1.08 | 30 | 1.11 | 21 | 1.08 | 29 | 1.11 | 19 | 1.11 | 21 | 1.08 | 30 |
| Insurance | 29 | 1.12 | 26 | 1.01 | 31 | 1.12 | 24 | 1.01 | 31 | 1.01 | 31 | 1.12 | 26 |
| Real estate | 30 | 1.16 | 24 | 2.38 | 2 | 1.16 | 21 | 2.28 | 2 | 2.38 | 2 | 1.16 | 24 |
| Public aministration, defence, education, health | 31 | 1.09 | 28 | 1.04 | 28 | 1.09 | 26 | 1.04 | 28 | 1.04 | 28 | 1.09 | 28 |
| Recreational & cultural services | 32 | 1.48 | 8 | 1.40 | 8 | 1.48 | 7 | 1.38 | 8 | 1.40 | 8 | 1.48 | 8 |
| Maximum | | 1.78 | | 3.34 | | 1.73 | | 3.13 | | 3.34 | | 1.78 | |
| Minimum | | 1.02 | | 1.01 | | 1.02 | | 1.01 | | 1.01 | | 1.02 | |
| Arithmetic mean (Average) | | 1.32 | | 1.32 | | 1.28 | | 1.28 | | 1.32 | | 1.32 | |
| Median | | 1.28 | | 1.16 | | 1.23 | | 1.14 | | 1.16 | | 1.28 | |
| Variance | | 0.046 | | 0.22 | | 0.04 | | 0.18 | | 0.22 | | 0.05 | |
| Standard Deviation | | 0.21 | | 0.47 | | 0.21 | | 0.42 | | 0.47 | | 0.21 | |

*Source: Measured by Author*

### 4.4.3 Demand Shocks Model

In this section, we will use a model within the IO framework to investigate the relationship between economic structure and aggregate gross-output sensitivity to the external demand shocks of different sectors in Oman's economy. As with the other models we have applied, this will also allow us to identify the sectors (especially the non-M&Q tradable sectors) whose demand has the most impact on the economy's aggregate gross-output; pointing the way to possible policy options to promote these specific sectors through further resource allocation and expansion.

#### 4.4.3.1 Methodology

To have a focused analysis and understanding of the main sectors in Oman's economy, we combine and consolidate the 32 sectors in the 2005 IO table for Oman, to eleven main sectors.[92]

Using and rearranging equation (4.9), we achieve:

$$\begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}^{-1} \begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix} \tag{4.14}$$

From the IO table we know the gross-output of every sector ($X_i$) and the aggregate gross-output (X). By varying the demand of any particular sector ($\Delta Y_1$), sector (1) for example, one can easily calculate the effect of this change on the sector's gross-output ($\Delta X_1$), and also the change in the economy's aggregate gross-output ($\Delta X$) which is the result of the changes in sector's (1) output itself and in other sectors' outputs due to the inter-sectoral linkage effects.

[92] Mainly we combine all the different manufacturing activities into one sector and recreate the IO table with 11 main sectors.

In this model, our focus is on the propagation and aggregate effects of domestic shocks. Accordingly, we do not consider imported shocks, although we do allow for external spill-overs of internal shocks.

#### 4.4.3.2 Interpretation of Findings

Prior to investigating the change in multi-sectoral demands on the economy's aggregate gross-output, it is worth looking at the output structure of the economy based on Oman's IO table for the year 2005. This is shown in Table (4.6), along with the contributions of the main sectors. The table shows that the main tradable sectors[93] that contributed to the value-added (GDP) are M&Q, manufacturing, financial intermediation, and agriculture and fisheries, with ratios of 38.9%, 13.7%, 2.9%, and 1.0%, respectively, and with respect to their total exports of 82.0%, 11.0%, 0%, and 0.6%, respectively.

Using equation (4.14), and by increasing the demand of different sector/sectors,[94] we measure the change in Oman's aggregate gross-output. This is repeated using four different scenarios, as shown in Table (4.7). In order to make the inter-scenarios comparable, we assume an arbitrary change of OMR 1.0 Mn in the exogenous demand variable ($Y_i$) of each scenario and simulate the effects on the sector's own production due to the change in its demand, and the change in the other sectors' gross-outputs due to linkage effects, and finally, on the aggregate gross-output of the economy. Each scenario could be presented as a policy option, as follows:

1) Increase in M&Q sector: increasing the demand in the M&Q sector could be presented as an increase in its export demand and/or an increase in the international market prices for its products. The increase in demand generates an overall aggregate gross-output

[93] As mentioned earlier, in this research we consider wholesale, retail trade, hotels & restaurants as non-tradable sectors.
[94] Decreasing the demand will provide the same effect to output but with a negative sign.

production of OMR[95] 1,020,219, which represents a 5.8% increase in aggregate gross-output. This overall production increase is the result of the initial direct increase in the M&Q to satisfy its increased demand, and the production increase of the latter and all other sectors due to the linkage effects. The direct production increase in the M&Q sector (its own production effect) generates OMR 1,007,322, which includes the initial stimulus to satisfy the initial demand of OMR 1.0 Mn, and OMR 7,322 as a second-round effect, which represents 36.2%.[96] The linkage effects to other sectors, meanwhile, generate a production increase of OMR 12,897, which represents a 63.8% increase. The fact that the increase in gross-output is almost twice as large when multi-sectoral linkages are incorporated explains and confirms our earlier findings that the M&Q sector has strong forward sectoral linkages.[97]

2) Increase demand in non-M&Q tradable sectors: this scenario could also be considered as a diversification scenario, since we are considering only the main non-M&Q tradable sectors in Oman's economy (agriculture and fisheries, manufacturing and financial intermediation), increasing all three sectors' combined demand[98] by OMR 1.0 Mn. That increase generates an overall production of OMR 1,0365,177, which equates to a 7.8% increase in aggregate gross-output (slightly higher than in scenario 1). The direct production increase in the three sectors generates OMR 147,843 (excluding OMR 1.0 Mn), which represents a 40.5% increase, whereas the multi-sectoral linkage effect generates OMR 217,334 production increase, which represents 59.5%. Again, this shows a strong multi-sectoral linkage between these combined sectors and other sectors in the economy.

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[95] All figures are in million (Mn), Omani Rial (OMR).
[96] Measured as (7,322 / (1,020,219 – 1,000,000)) = 36.2%.
[97] The same results were obtained in sections (4.4.1.3.2) and (4.4.2.1.2).
[98] Thus, increasing each sector's demand by c. 40%.

3) Increase in non-tradable sectors: although we are not focusing on promoting the non-tradable sectors in Oman’s economy, since they cannot be considered either for future economic growth or diversification of the economy, as discussed earlier, the objective of this scenario is to estimate the effect of their demand on the aggregate gross-output as an indication of their direct production and interlinkage effects in the economy. Increasing the major non-tradable sectors’ combined demand (electricity & water supply; building & construction; transport storage & communication; and public administration & defence & education & health).[99] The increase generates an overall production of OMR 1,496,721, which represents an 8.5% increase in aggregate gross-output (higher than in scenarios 1 and 2). The direct production increase in the three sectors generates OMR 141,794 (excluding OMR 1.0 Mn), which represents 28.5%, whereas the linkage to other sectors generates a production increase of OMR 354,928, which represents 71.5%. The fact that the production ratio is higher for indirect linkages than for the direct linkages (and by even more that the main non-M&Q tradable sector’s ratio) explains that the non-trading sectors in Oman’s economy have strong linkages to other sectors of the economy.
4) Increase in each sector independently: in this scenario we increase each individual sector’s demand by OMR 1.0 Mn at a time (while keeping the other sectors’ demand unchanged):
    a) The five sectors with the highest effect on aggregate gross-output due to an increase in their demands are building & construction; transport storage & communication; electricity & water; other community, social & personal activities & private households; and finally, manufacturing, with increases in

[99] Increasing each of these sectors’ demand by c. 40%.

aggregate gross-output ratios of 10.1%, 9.0%, 8.8%, 8.4%, and 8.1%, respectively. Four out of these five sectors are non-tradable sectors.

b) The sectors with the highest ranking in production due to linkages are electricity & water; wholesale, retail trade, hotels & restaurants; financial intermediation; public administration & defence & education & health; and finally, other community, social & personal activities & private households, with ratios of their production due to linkages of 99.3%, 92.3%, 92.2%, 89.3, and 83.0%, respectively. Again, four out of these five are non-tradable sectors, hence we can say that the non-trading sectors have stronger linkages to other sectors in the economy.

c) The M&Q sector had the lowest effect, of 5.8%, on the aggregate gross-output when its demands was increased as compared to other sectors, explains and confirms our earlier findings that the M&Q sector has weak backward linkages and operates in relative isolation from other sectors in the economy.[100]

d) Finally, the sectors with the highest aggregate gross-output effects within the non-M&Q tradable sectors are manufacturing, agriculture and fisheries, and financial intermediation, respectively.

[100] The same results were obtained in sections (4.4.1.3.2) and (4.4.2.1.2).

*Table 4. 6: Oman Economy' s Output Structure, in the Year 2005*

| Sectors | NO. | Value- Added (VA) OMR (,000) | % | Total Output (TOP) OMR (,000) | VA/TOP % | Value Added/Labour OMR (,000) | Imports OMR (,000) | % | Imports/Domestic Supply % | Exports OMR (,000) | % | Exports/Total Procution % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture & Fisheries | 1 | 137,882 | 1.0 | 192,460 | 71.6 | 2.1 | 32,041 | 3.5 | 58.7 | 36,741 | 0.6 | 19.1 |
| Minning & Quarrying | 2 | 5,447,666 | 38.9 | 6,371,453 | 85.5 | 486.4 | 55,221 | 6.1 | 6.0 | 5,438,698 | 82.0 | 85.4 |
| Manufacturing | 3 | 1,921,528 | 13.7 | 3,064,907 | 62.7 | 24.7 | 824,103 | 90.4 | 72.1 | 729,836 | 11.0 | 23.8 |
| Electricity & Water Supply | 4 | 588,266 | 4.2 | 616,385 | 95.4 | 235.3 | | | | | | |
| Building & Construction | 5 | 1,300,858 | 9.3 | 1,683,454 | 77.3 | 7.0 | | | | | | |
| Wholesale, Retail Trade, Hotels & Restaurants | 6 | 956,335 | 6.8 | 1,090,588 | 87.7 | 6.4 | | | | | | |
| Transport Storage & Communication | 7 | 906,014 | 6.5 | 1,235,272 | 73.3 | 131.3 | | | | | | |
| Financial Intermediation | 8 | 399,987 | 2.9 | 436,343 | 91.7 | 160.0 | | | | | | |
| Real Estate & Business Activities | 9 | 403,461 | 2.9 | 723,738 | 55.7 | 46.4 | | | | | | |
| Publich Admin &Defence +Education + Health | 10 | 1,747,101 | 12.5 | 1,773,048 | 98.5 | 11.4 | | | | 425,267 | 6.4 | 24.0 |
| Other community, Social & Personal Activities + Pvt. Households | 11 | 208,379 | 1.5 | 360,171 | 57.9 | 2.3 | | | | | | |
| | | 14,017,476 | 100 | 17,547,819 | 79.9 | 18.6 | 911,365 | 100 | | 6,630,543 | 100 | 37.8 |

*Source: Measured by Author using Oman' s Input-Output Table for the year 2005*

*Table 4. 7: Oman Economy's Demand Shocks Scenarios, in the Year 2005*

| | | | Scenario 1 | | | Scenario 2 | | | Scenario 3 | | | Scenario 4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sectors | NO. | Base X OMR (,000) | ΔY OMR (,000) | ΔX OMR (,000) | (ΔX / X) - | ΔY OMR (,000) | ΔX OMR (,000) | (ΔX / X) - | ΔY OMR (,000) | ΔX OMR (,000) | (ΔX / X) - | ΔY OMR (,000) | ΔX OMR (,000) | (ΔX / X) - | Ranking | Direct Effect | Linkage Effect |
| Agriculture & Fisheries | 1 | 192,460 | | 73 | | 50,000 | 61,775 | | | 1,541 | | | 1,386,915 | 7.9% | 6 | 19.2% | 80.8% |
| Minning & Quarrying | 2 | 6,371,453 | 1,000,000 | 1,007,322 | | | 157,700 | | | 158,500 | | | 1,020,219 | 5.8% | 11 | 36.2% | 63.8% |
| Manufacturing | 3 | 3,064,907 | | 7,606 | | 800,000 | 934,618 | | | 133,912 | | | 1,417,538 | 8.1% | 5 | 38.3% | 61.7% |
| Electricity & Water Supply | 4 | 616,385 | | 808 | | | 3,083 | | 250,000 | 252,021 | | | 1,542,518 | 8.8% | 3 | 0.7% | 99.3% |
| Building & Construction | 5 | 1,683,454 | | 591 | | | 5,743 | | 250,000 | 316,246 | | | 1,778,239 | 10.1% | 1 | 31.2% | 68.8% |
| Wholesale, Retail Trade, Hotels & Restaurants | 6 | 1,090,588 | | 456 | | | 14,001 | | | 15,283 | | | 1,373,354 | 7.8% | 7 | 7.7% | 92.3% |
| Transport Storage & Communication | 7 | 1,235,272 | | 1,108 | | | 6,702 | | 250,000 | 320,334 | | | 1,573,899 | 9.0% | 2 | 40.4% | 59.6% |
| Financial Intermediation | 8 | 436,343 | | 43 | | 150,000 | 151,451 | | | 7,176 | | | 1,078,674 | 6.1% | 10 | 7.8% | 92.2% |
| Real Estate & Business Activities | 9 | 723,738 | | 1,616 | | | 24,354 | | | 18,492 | | | 1,157,200 | 6.6% | 8 | 25.7% | 74.3% |
| Publich Admin &Defence +Education + Health | 10 | 1,773,048 | | 388 | | | 466 | | 250,000 | 253,192 | | | 1,092,228 | 6.2% | 9 | 10.7% | 89.3% |
| Other community, Social & Personal Activities + Pvt. Households | 11 | 360,171 | | 209 | | | 5,285 | | | 20,024 | | | 1,479,788 | 8.4% | 4 | 17.0% | 83.0% |
| | | **17,547,819** | **1,000,000** | **1,020,219** | **5.8%** | **1,000,000** | **1,365,177** | **7.8%** | **1,000,000** | **1,496,721** | **8.5%** | **1,000,000** | | | | | |

*Source: Measured by Author using Oman's Input-Output Table for the year 2005*

### 4.4.4 Hypothetical Extraction Model

The objective of the hypothetical extraction model approach is to quantify by how much the aggregate gross-output of a multi-sectoral economy would change if a particular sector is removed from that economy. Although, the direct importance of a sector in terms of output can easily be measured by its level of output, the indirect contribution of a sector to total aggregate gross-output is not simply observable unless its multi-sectoral effect is taken into account (Valadkhani, 2003; Miller and Blair, 2009). For example, if a sector is almost divorced from other sectors (i.e., with few backward linkages), and/or its output is mainly exported with very few domestic intermediate uses, it can then be argued that its indirect contribution effect on aggregate gross-output would be small. As a result, the total contribution (direct and indirect) of this sector to total output would be similar in magnitude to its direct contribution. On the other hand, if a sector is well integrated with other sectors in the economy, with high and evenly distributed multi-sectoral linkages, then the shut-down of this sector/industry would have severe adverse repercussions on the other sectors of the economy in terms of output. Even if we substitute the domestically-produced inputs of this sector with an equal amount of homogeneous imported inputs, due to the inter-relationship between sectors, the significance of this sector goes beyond its own output share in the economy (Valadkhani, 2003).

#### 4.4.4.1 Methodology

Using the IO system framework as in Section 4.4.3, we measure each of the main tradable sectors' direct and indirect extraction effects on Oman economy's gross-output. We follow $[1 - \mathrm{A}']\,\mathrm{X} = \mathrm{Y}$ in matrix form:

$$\left[\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}\right] \begin{bmatrix} \mathrm{X}_1 \\ \mathrm{X}_2 \\ \mathrm{X}_3 \\ \vdots \\ \mathrm{X}_n \end{bmatrix} = \begin{bmatrix} \mathrm{Y}_1 \\ \mathrm{Y}_2 \\ \mathrm{Y}_3 \\ \vdots \\ \mathrm{Y}_n \end{bmatrix} \qquad (4.15)$$

In order to measure the direct and indirect effects of a particular sector, say sector (1), it is assumed that sector (1) is shut down, meaning that it neither produces using other sectors' intermediate inputs nor provides any intermediate inputs to other sectors in the economy. This can be imposed in the following manner:

$$\left[\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & \cdots & 0 \\ 0 & a_{22} & a_{23} & \cdots & a_{2n} \\ 0 & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}\right] \begin{bmatrix} X_1^* \\ X_2^* \\ X_3^* \\ \vdots \\ X_n^* \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \vdots \\ Y_n \end{bmatrix} \qquad (4.16)$$

Removing sector (1) from the IO system, however, will result in an unbalanced IO table. Hence, the following assumptions should be considered. First, the other n-1 sectors which had previously used some intermediate inputs from sector (1), can outsource the required intermediate inputs from abroad through imports ($a'_{1n}$). Second, the shutdown of this sector does not have any effect on the technology of the existing industries, which continue to operate. Third, it is also assumed that the distribution of the remaining sectors' final demand ($Y_1, Y_2, \ldots Y_n$) remains unchanged.

From an IO table one knows the gross-output produced by sector (1) before its shutdown ($X_1$), and also the final demand in the other (n-1) sectors. We can therefore rewrite the above matrix equation in such a way that only pre-determined variables appear on the right-hand side:

$$\left[\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 \\ 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} 0 & a'_{12} & a'_{13} & \cdots & a'_{1n} \\ 0 & a_{22} & a_{23} & \cdots & a_{2n} \\ 0 & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix}\right] \begin{bmatrix} Y_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} (1 - a'_{11})X_1 \\ Y_2 + a'_{21}X_1 \\ Y_3 + a'_{31}X_1 \\ \vdots \\ Y_n + a'_{n1}X_1 \end{bmatrix} \qquad (4.17)$$

The other (n-1) sectors now import their required inputs from abroad rather than purchasing them from sector (1). Knowing the ($X_1$) as being the initial gross-output of sector (1), and that ($\Delta Y_2 = \Delta Y_3 = \cdots = \Delta Y_n = 0$), we can calculate ($\Delta X_1$), i.e. the hypothetical removal indirect effect of sector (1), and any other specific sector ($\Delta X_i$), from the IO system as follows:

$$\begin{bmatrix} \Delta Y_1 \\ \Delta X_2 \\ \Delta X_3 \\ \vdots \\ \Delta X_n \end{bmatrix} = \begin{bmatrix} 1 & -a'_{12} & -a'_{13} & \dots & -a'_{1n} \\ 0 & (1-a_{22}) & -a_{23} & \dots & -a_{2n} \\ 0 & -a_{32} & (1-a_{33}) & \dots & -a_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 0 & -a_{n2} & -a_{n3} & \cdots & (1-a_{nn}) \end{bmatrix}^{-1} \begin{bmatrix} (1-a'_{11})X_1 \\ Y_2 + a'_{21}X_1 \\ Y_3 + a'_{31}X_1 \\ \vdots \\ Y_n + a'_{n1}X_1 \end{bmatrix} \tag{4.18}$$

Knowing the initial gross-output ($X_i$) of a particular sector, and its indirect extraction effect ($\Delta X_i$), we can calculate the total effect of the removal of that particular sector on the economy's gross-output (total sector's extraction effect on gross-output = $X_i + \Delta X_i$).

#### 4.4.4.2 Interpretation of Findings

Since our focus is on the main tradable sectors in Oman's economy, we use this extraction (shutdown) model on these sectors, one at a time, and measure their direct and indirect effects on the economy's aggregate gross-output, using Oman's 2005 multi-sectoral IO table.

The results tabulated in Table (4.8) show that the agriculture and fisheries sector has the largest indirect effect as a percentage of its own direct output (15.0%), if extracted from the economy, thereafter, comes M&Q, manufacturing and financial intermediation, respectively. Clearly, the sector that has the largest direct and indirect effects on the aggregate gross-output of the economy if extracted, is the M&Q sector (41.1%). Since the M&Q sector is the most dominant sector in Oman's economy, with a value addition (GDP) share of 38.9%, a total export share of 82.0%, and a 78.8% share of total government revenues, this outcome is to be expected.

The manufacturing sector, having the second rank, also shows a significant effect when extracted from the economy, however; leading to a 19.3% reduction in Oman's aggregate gross-output.

*Table 4. 8: Oman's Tradable Multi-Sectoral Direct and Indirect Impacts of Hypothetical Shut-Down on Economy's Aggregate Gross-output*

| Sectors | Sr. No. | Direct (Xi) OMR, Mn (A) | Indirect (△Xi) OMR, Mn (B) | Total OMR, Mn © | (A/TOP) | (B/TOP) | (B/A) | (C/TOP) | Ranking |
|---|---|---|---|---|---|---|---|---|---|
| Agriculture & Fisheries | 1 | 192,460 | 28,936 | 221,396 | 1.1% | 0.2% | 15.0% | 1.3% | 4 |
| Minning & Quarrying | 2 | 6,371,453 | 852,338 | 7,223,791 | 36.2% | 4.8% | 13.4% | 41.1% | 1 |
| Manufacturing | 3 | 3,064,907 | 326,174 | 3,391,082 | 17.4% | 1.9% | 10.6% | 19.3% | 2 |
| Financial Intermediation | 8 | 436,343 | 31,216 | 467,559 | 2.5% | 0.2% | 7.2% | 2.7% | 3 |
| Total OutPut (TOP), (OMR, Mn) | | | | 17,579,035 | | | | | |

*Source: Measured by Author using Oman's Input-Output Table for the year 2005*

## 4.5 Conclusion

The main objectives of this chapter were to measure and analyse the multi-sectoral interlinkages in Oman's economy, so as to be able to identify the main potential non-M&Q tradable sectors that could be further promoted and invested-in by Oman's government for future economic growth.

1) In respect to the possible occurrence of the Dutch disease in Oman's economy due to the windfall gains from the M&Q sector, analyses of exchange rates, multi-sectoral growth and labour movement showed that the economy did not exhibit the characteristics of the Dutch disease. Whereas the conventional model of the Dutch disease effects on economies predicts that the exchange rate should display a gradual appreciation, in reality, the Omani Rial exhibited a gradual depreciation against the USA dollar in real terms. Similarly, under a Dutch disease scenario, one would expect to see movement of labour from a declining manufacturing sector to a booming services sector. In practice, however, although there was an increasing workforce in the services sector, the manufacturing sector continued to grow, albeit in a subdued way. Overall, other productive sectors of the economy, such us manufacturing and agriculture and

fisheries, could not gain as much benefit from the M&Q sectors boom as the (non-tradable) services sector.

2) The analysis of the overall view of the multi-sectoral interlinkages structure in Oman's economy showed that only a few sectors have interlinkages with each other, as compared to another developed country, the USA.[101]

3) The analysis of the forward and backward linkage models in Oman's economy, showed that, although the M&Q sector has a leading role (forward linkages) in promoting other sectors and hence the economy, its backward linkages with other sectors are very weak. This indicates that the M&Q sector is almost working in isolation from other sectors in the economy. Moreover, the forward and backward linkages analysis showed that the non-M&Q tradable sectors are the sectors with the strongest linkages in Oman's economy, especially so for the various manufacturing activities.

4) The analysis of the multiplier models approach showed that any increase in the economy's final demand has a significant impact on the M&Q sector's output and supply, but the impact on the economy's gross-output is relatively low when its demand was increased. Moreover, any increase in the M&Q sector's value-added shows a large positive increasing effect on the economy's prices. An increase in the demand from the non-M&Q tradable sectors, meanwhile, has a significant impact on both the output of those sectors and the economy's output as a whole, and this is especially true for the manufacturing activities. Moreover, any increase in multi-sectoral value-added (GDP) shows significant price increase in those non-M&Q tradable sectors. The analysis also showed that any increase in non-tradable sectors' demands has a significant impact on the economy's gross-output and on those sectors' supply.

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[101] Both these economies multi-sectoral network structures will be discussed in more detail in the next chapter.

5) The analysis of the multi-sectoral demand shocks model showed that increasing the M&Q sector's demand in Oman's economy does not have significant effect on the economy's gross-output as compared to other sectors,[102] as was also confirmed above using the multiplier models. Moreover, we found that the non-tradable sectors overall have a greater impact on the output when their demand is increased, mainly through the inter-sectoral linkage effects. The non-M&Q tradable sector with the largest effect on the economy's gross-output when its demand is increased, however, was the consolidated manufacturing activities sector.
6) Similar results were obtained using the extraction model. Once again, excluding the M&Q sector, the consolidated manufacturing activities sector, being a non-M&Q tradable sector, has the greatest effect on the economy's gross-output when it is extracted from Oman's economy.

These analyses suggest, therefore, that to grow Oman's economy in a sustainable way in the long term, policy considerations should be given to utilizing the M&Q sector's resources to further increase its backwards linkages with other sectors of the economy. In addition, policy should focus on promoting and developing the non-M&Q tradable sectors, especially the different manufacturing activities, while taking steps to avoid a drastic change in the value-added ratios so as to prevent a large increase in prices within the non-M&Q tradable sectors.[103]

[102] Refer to Table (4.7), the M&Q had the lowest ranking.
[103] Increases in non-M&Q tradable sector prices on the one hand support and limit the movement of resources (labour and capital) to non-tradable sectors, but on the other hand negatively affect the competitiveness of non-M&Q tradable sectors and might increase import substitution.

# Chapter 5: Measure of Oman's Multi-Sectoral Network Structure, Output-Multipliers, and Productivity Performances

In Chapters (3) and (4) we managed to identify which non-Mining and Quarrying (M&Q) tradable sectors in Oman's economy experienced positive Total Factor Productivity (TFP) growth and their productivities contributed positively to the output growth during the period 1998–2016, and the ones that had the highest inter-sectoral linkages in the year 2005. This was achieved using the aggregate growth accounting framework and a variety of Input-Output (IO) analysis methods, respectively.

This chapter builds on these same lines: seeking to identify and analyse the main non-M&Q tradable sectors in Oman's economy that are dominant in the multi-sectoral production network structure, have large production multipliers, and large TFP contributions. This is achieved using a range of empirical models within the IO framework, applied to Oman's 2005 IO table. The same empirical models are also applied to the USA's economy, in order to compare Oman's multi-sectoral performances with those of the USA in the same year.

Moreover, the chapter also measures and analyses TFP and TFP growth at national and multi-sectoral levels during the period 1998–2016, but instead of using the aggregate growth accounting framework, as used earlier, a theoretical framework is used. The results obtained from both these frameworks are then compared and analysed.

As mentioned earlier, identifying the leading non-M&Q tradable and productive sectors with the most potential for future growth will help guide Oman's government as to where to invest in order to diversify the economy away from the M&Q sector and its stream of revenues and best support future output growth.

This chapter will answer the following main questions:

1) Which sectors have the most dominant position within Oman's production network structure?
2) Which sectors have the most extensive output linkage multipliers in Oman's economy?
3) Which non-M&Q tradable sectors in Oman's economy had the most positive TFP and TFP growth during the period 1998–2016?
4) What overall policies could be adopted by Oman's government to foster linkages and induce faster economic growth?.

## 5.1 Literature Review

### 5.1.1 Multi-Sectoral Production Network

In an economy that is composed of several sectors, any perturbation affecting a single sector would have some impact on the economy's output. Furthermore, if these sectors are linked through IO trade relationships, then a shock could propagate through the system, possibly leading to significant output variability. While this argument has long been explored in the real business cycle literature, both theoretically and empirically (Roson and Sartori, 2016), a number of papers have revisited the issue, proposing new approaches and perspectives. For instance, Gabaix (2011) argued that the distribution of sectors in an economy is typically fat-tailed. A fat-tailed distribution is where a few large sectors have multiple connections to many other sectors, and under these circumstances any shocks to those large sectors would have a significant effect on aggregate outputs.

Acemoglu *et al.* (2012) considered a set of IO relationships among the sectors in terms of a network. They found that how microeconomic shocks—affecting a particular sector or technology along the supply chain network—propagate through the economy at the macro level depends on some specific network characteristics between sectors. They argued that it is not the mere existence of large IO flows that amplifies sectoral shocks, but rather the existence of relatively few dominant suppliers of intermediate factors. Any shock affecting these dominant central sectors would propagate easily to the rest of the economy. They proposed to interpret the IO structure as a (weighted) network, where the nodes correspond to the sectors and the links to the nodes represent trade flows. The relative importance of a sector as a supplier for the other sectors in the economy is captured by the sum of weights of all outgoing links between these sectors.[104]

Understanding the IO structure of production networks, therefore, can help identify the origins of aggregate fluctuations, and thus inform policy makers on how to prepare for and recover from adverse shocks that disrupt these production chains (Carvalho, 2014).

### 5.1.2 Multi-Sectoral Output-Multipliers and Productivities

One of the main debates in economics, in the context of explaining cross-country differences in income per capita, is on how important differences in factor endowments, such as physical and human capital stocks, are related to aggregate productivity differences. The standard method to address this question is to specify an aggregate production function for value-added (GDP). Given data on GDP and factor endowments and the mapping imposed between them, one can back out productivity as a residual that explains the differences.[105]

These aggregate TFP differences arise from two main sources; those due to differences in the use of technologies and the efficiency at which they are operated, and those due to differences in the IO structure of the various sectors of the economy that determine how different sectors' TFPs add-up at the country level.

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[104] In network theory, this is called the degree of a node.
[105] We have used the same methodology (a growth accounting exercise) to measure the TFP growth at national and multi-sectoral levels in Chapter (3).

The first source has been the focus of a large literature on endogenous growth and technology adoption, which basically ignores that the output is also affected by the economy's sectoral structure. The literature focusing on the second source, meanwhile, has mainly been in the field of development economics, initiated by Hirschman (1958), who long emphasized that economic structure, through the multi-sectoral IO linkages, is of first-order importance to understand cross-country income differences.

The IO linkages between various sectors in an economy determine each sector's importance, or weight, in respect to aggregate productivity, and can be effectively summarized using the distribution of sectors' IO output-multipliers. The output-multiplier of a sector depends on the number of sectors to which it supplies, as well as on the intensity with which its output is used as an input by other sectors. Hence, the output-multiplier of a sector measures by how much aggregate income changes if the productivity of that particular sector changes by one percent. In other words, TFP levels in sectors with high output-multipliers have a larger impact on aggregate outputs than sectors with low output-multipliers.

Ciccone (2002) and Jones (2011) have also highlighted the role of IO linkages in respect to aggregate income levels. That work has been continued recently by Fadinger, Ghiglino, and Teteryatnikova (2018), who showed that the IO structure of an economy, and its interaction with sectors' TFP levels, are of first-order importance for explaining cross-country income differences.

Bartelme and Gorodnichenko (2015) constructed a database of IO tables covering a broad spectrum of countries and times. They documented a strong relationship between the strength of industry linkages and aggregate productivity, estimating TFP gains averaging at roughly 10% for middle and low-income countries by increasing the use of intermediate inputs, strengthening linkages, and increasing productivity and other key indicators of development and welfare. They also showed that the strength of linkages, measured as the Average Output-

Multiplier (AOM), is strongly and positively related to measured output per worker. A one standard deviation increase in AOM was associated with a 15%–35% increase in output per worker, most of which they claimed to be stemmed from gains in productivity rather than accumulated factors of production.

Roson and Sartori (2016) investigated the relationship between economic structure and aggregate sensitivity to sector productivity shocks within 57 industries in 109 countries by varying the multifactor productivity of the value-added aggregates, corresponding to the productivity of a hypothetical single primary factor. This process allowed them to get an estimate of the standard error of the real GDP. They found that the variability of the output (GDP) induced by idiosyncratic sector shocks is basically determined by the level of industrial concentration in these countries. Interestingly, they found that, out of the 109 countries tested, Oman had the highest output variability. More precisely, Oman displayed the highest sensitivity of national income to domestic productivity shocks, under the assumption that the shocks affecting sectors are independently and identically distributed, and that they affect all primary factors (value-added composite) in a uniform way.

## 5.2 Theoretical Framework of Input–Output Model

In this section we discuss the theoretical framework steps performed by Jones (2011) and Fadinger, Ghiglino, and Teteryatnikova (2018), since the reminder of our analysis builds on these.

### 5.2.1 Economy Structure

Consider a static, open and a small multi-sectoral economy, with $(n)$ competitive sectors, each producing a distinct good that can be used either for final consumption within its own production or as an input for the production of another sector. The technology of sector

$(i \in 1{:}n)$ is a Cobb-Douglas production function, with a constant return to scale, and produces a gross-output $(X_i)$ as:

$$X_i = TFP_i \, (K_i^{\propto_i} \, L_i^{1-\propto_i})^{1-\sigma_i-\lambda_i} \, \{b_{1i}^{\sigma_{1i}} \, b_{2i}^{\sigma_{2i}} \dots b_{ni}^{\sigma_{ni}}\} \, \{m_{1i}^{\lambda_{1i}} \, m_{2i}^{\lambda_{2i}} \dots m_{ni}^{\lambda_{ni}}\} \tag{5.1}$$

Where, $TFP_i$ is the exogenous total factor productivity of sector (i), and $K_i$ and $L_i$ are values of the capital stock and labour used by sector (i), respectively. Two kinds of intermediate goods are used in production: $b_{ji}$ is the value of domestic goods (j) used by sector (i), and $m_{ji}$ is the value of the imported intermediate goods (j) used by sector (i). The parameters $\propto_i$ and $1 - \propto_i$ are shares of the capital stock and labour in the inputs, respectively, and the parameters $\sigma_i$ and $\lambda_i$ are the shares of domestic and imported goods, respectively. The associated values of these parameters in this production function satisfy:

$\sigma_i = \sum_{j=1}^{n} \sigma_{ji}$, $\lambda_i = \sum_{j=1}^{n} \lambda_{ji}$ and $0 < \propto_i < 1$, so the production function features constant returns to scale.

We assume imported intermediate goods are the same as domestic, so that they are perfect substitutes. Hence, the equation (5.1) becomes:

$$X_i = TFP_i \, (K_i^{\propto_i} \, L_i^{1-\propto_i})^{1-a_i} \, \{(b_{1i} + m_{1i})^{a_{1i}} \, (b_{2i} + m_{2i})^{a_{2i}} \dots (b_{ni} + m_{ni})^{a_{ni}}\} \tag{5.2}$$

Where $a_{1i}$ represents the share of good 1 (domestic and imported) in the production technology in sector (i), and $a_i = \sum_{j=1}^{n} a_{ji} \in (0,1)$ is the total shares of intermediate goods in the gross-output of sector (i).

Moreover, if we define (z) as being the total values of domestic (b) and imported (m) goods, then $(z = b + m)$, and we achieve:

$$X_i = TFP_i \, (K_i^{\propto_i} \, L_i^{1-\propto_i})^{1-a_i} \quad \{z_{1i}^{a_{1i}} \, z_{2i}^{a_{2i}} \dots z_{ni}^{a_{ni}}\} \tag{5.3}$$

Given the Cobb-Douglas technology in equation (5.3), and competitive markets, $a_{ji}$ also corresponds to the entries of the technical coefficient matrix (A).[106]

Every good domestically produced by sector (i) can be used either for final consumption ($Y_i$), or as an intermediate input ($z_{ij}$). Hence, the demand side balanced equation can be written as:

$$X_i = \sum_{j=1}^{n} z_{ij} + Y_i \qquad i = 1{:}\,n \qquad (5.4)$$

Further, if the final consumption goods are aggregated into a single final good through another Cobb-Douglas function:

$$Y = y_1^{1/n} \dots y_n^{1/n} \qquad (5.5)$$

This aggregate final good[107] is fully consumed by households[108] $(C)$ , so where $(Y = C)$. Also, the supply of capital stock ($K_i$) and labour ($L_i$) are assumed to be exogenous and fixed at 1. Then, there would be a unique equilibrium, where the logarithm of GDP per capital, $y = \log(Y)$, is given by:[109]

$$y = \sum_{i=1}^{n} \mu_i \lambda_i + \sum_{i=1}^{n} \sum^{n}_{\substack{j=1, \\ \text{s.t. } a_{ji} \neq 0}} \mu_i a_{ji} \log a_{ji} + \sum_{i=1}^{n} \mu_i (1 - a_i) \log(1 - a_i) - \log n \qquad (5.6)$$

where:

$\mu = \{\mu_i\}_i = \frac{1}{n}\,[I - A']^{-1}$, n x1 vector of output-multipliers.[110]

$\lambda = \{\lambda_i\}_i = \{\log \mathrm{TFP}_i\}_i$, n x1 vector of sectors' log-productivity coefficients.

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[106] As discussed in Chapter (4), section (4.1.5). The proof is provided in Appendix (1).
[107] The symmetry in the exponent of the final consumption, implies consumption demand for all goods equally. This is useful, since it will allow the focus to be only on the interaction effects between the sectors' IO network structure and productivities, leaving aside the impact of linkages on the final demand.
[108] The householders' consumption is constrained by their budget ($C = w + r\,k$), so no further decision from their side is required.
[109] For further details and proofs refer to Fadinger, Ghiglino, and Teteryatnikova (2016).
[110] The vector of sectors' output-multipliers is determined by the features of the IO matrix through a Leontief inverse matrix $[1 - A']^{-1}$, for further details refer to Burres (1994).

The equation (5.6) represents the aggregate GDP per capita as a log-linear function of the aggregate impact of the sectors via the IO structure, and thus represents aggregate productivity levels and the impact of the IO coefficients ($a_{ji}$). It also highlights two important facts, that the aggregate output is an increasing function of a sector's productivity ($\lambda_i$), and that the impact of each sector's productivity on aggregate output is proportional to the value of the sector's output-multiplier ($\mu_i$).

### 5.2.2 Multi-Sectoral Network and Output-Multipliers

The interdependence of multi-sectoral production technologies through the network of intersectoral trade offers some insights into the meaning of the Leontief inverse matrix $[1-A]^{-1}$ and the vector of sectors' output-multipliers ($\mu$). A typical element ($l_{ji}$) of the Leontief inverse matrix can be interpreted as a percentage increase in the output of sector (i) following a one percent increase in the productivity of sector (j). As discussed in Chapter (4), this result takes into account all direct and indirect effects at work, such as the effect of an increase of productivity in sector $(1)$, that makes sector $(2)$ more efficient and via this raises the output in sector $(3)$ (Fadinger, Ghiglino, and Teteryatnikova, 2018).

Then, multiplying the Leontief inverse matrix by the weights $(\frac{1}{n})$ and (vectors of $1$), we can calculate the productivity effect of sector (j) on the output of all other sectors in the economy:

$$\mu = \frac{1}{n}\,[1-A]^{-1}\,1 \tag{5.7}$$

Thus, a typical element of the resulting vector of output-multipliers reveals how a one percent increase in the productivity of a particular sector affects the overall value-added (GDP) in the economy. For clarity, let's consider a one-sector economy, where the output-multiplier is given by $(\frac{1}{1-a})$, where $a$ is the share of intermediate input in the production of that sector. Thus, if the share of intermediate input in output is, for example, 50% ($a = 0.5$), then a one percent increase in the TFP of that particular sector will lead to a two percent increase in the output of the economy. The effect of a sector's TFP improvement on aggregate output becomes extremely large when intermediate inputs increase ($\alpha$ →100%, 1) and get close to one, when ($\alpha$ →0%, 0) (Jones, 2011). Moreover, as it is worth mentioning here that, vector of output-multipliers is closely related to the Bonacich centrality vector, corresponding to the intersectoral network of the economy. This means that sectors that are more central in the network of intersectoral trade have larger output-multipliers, and hence play a more important role in determining aggregate output in the economy (Fadinger, Ghiglino, and Teteryatnikova, 2018).

Although the output-multiplier approach does not take the size of the sector into account, it does have a number of attractive features as a summary measure of linkages. For example, it is increasing in ($a_{ji}$) and decreasing in $X_j$. It is sensitive to the position of coefficients in the IO matrix, as well as their magnitude, because it takes both direct and indirect effects on output into account.

## 5.3 Methodologies and Analysis of Empirical Models

This section sets out the empirical models used, their methodologies, and the analysis of their results. The empirical models used are:

1) Multi-sectoral production networks,
2) Multi-sectoral output-multipliers, and
3) Multi-Sectoral TFP and TFP growth estimations.

### 5.3.1 Multi-Sectoral Production Network Effects Model

#### 5.3.1.1 Methodology

Considering a static multi-sectoral economy, with (n) competitive sectors, as discussed in section 5.2.1. In the Cobb–Douglas production question (5.3), the first term shows the contribution from primary factors to production and the second term shows the contributions of intermediate inputs deployed in the production. The element in this first term is $\mathrm{TFP_i}$, which is a sector-specific productivity disturbance, shifting the frontier of production possibilities of sector (i) in a random fashion. This is the only source of uncertainty in this simple economy. If it is assumed further that these productivity shocks are independent across producers of goods in the economy. The absence of any exogenous correlating device, that is the lack of any aggregate technology shocks, allows us to focus solely on our interest: the interconnections across production technologies in the form of intermediate input flows. Thus, these interconnections between production nodes come into play only with the second term of the production, which reflects the contribution of the intermediate inputs from the sector itself, and from other sectors in the economy. Hence, consistent with Carvalho (2014), the focus is only on the term $(\prod_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{z_{ji}}^{a_{\mathrm{ji}}})$.

We use this methodology to visualize the multi-sectoral production network structure, and to investigate and analyse the network structure of the sectoral input flows in Oman. We also apply the same methodology to the economy of the USA in order to compare the structures of the two economies.

### 5.3.1.2 Interpretation of Findings

To visualize and compare the multi-sectoral production network structures and input flows between Oman and the USA, we use Oman's 32-, and the USA's 33-sectors 2005 IO tables[111] in Gephi software and compare our results.[112] Figures (5.1 and 5.2) show the production network structures corresponding to Oman and the USA, respectively, where each node in the network corresponds to a sector in the IO table. Larger nodes closer to the centre of the network represent sectors supplying inputs to many other sectors (the dominant sectors).

As presented in Table (5.1), the key statistics summarizing the production network structures of Oman and the USA are:

a) Trade cover: considering only those transactions above 1.0% for a sector's total input purchases, we account for 86.5% of the total value of intermediate input trade within Oman, as compared to 84.9% in USA.

b) Network density:[113] only 120 out of a possible 1024 sectors have input transactions above 1.0% of a sector's total input purchases, yielding a network density of 11.7% in Oman, as compared to 30.2% for USA.

c) Average degree of the network:[114] in Oman this was 8.2 sectors (which represents 25.5% out of the total of 32 sectors), whereas in the USA it was 22.1 sectors (which represents 66.9% out of the total of 33 sectors).

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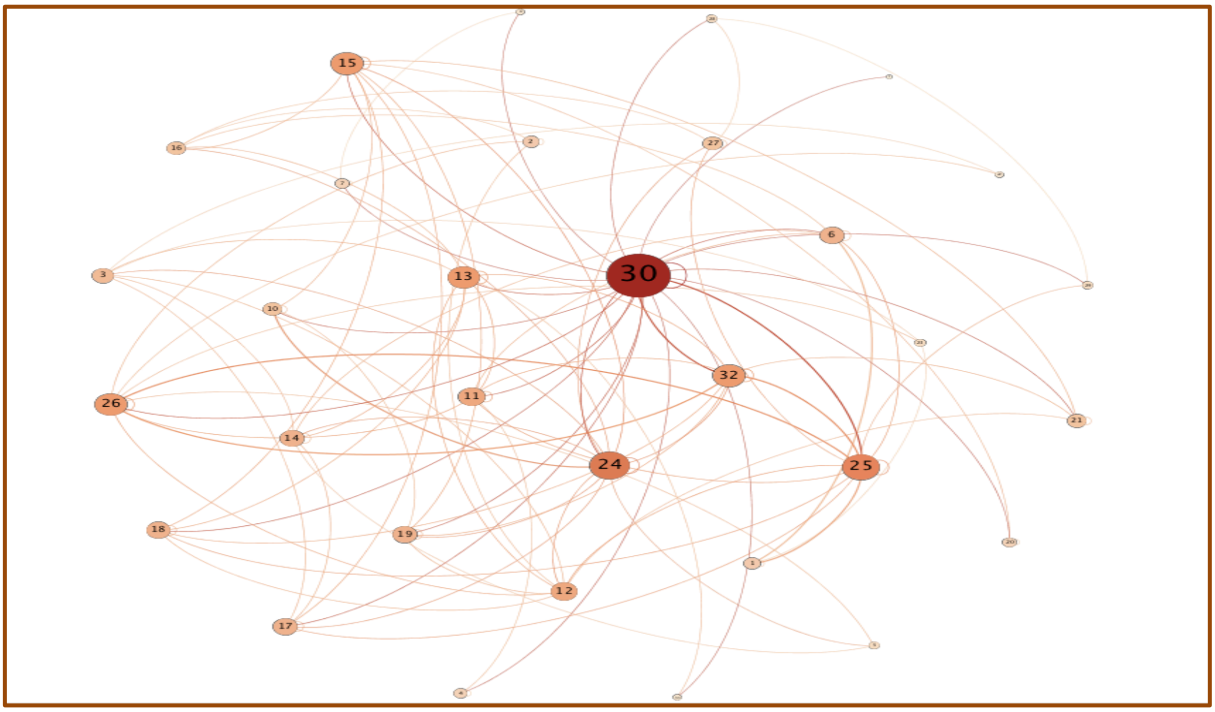
[111] The 2005 IO table for the USA was retrieved from the OECD https://data.oecd.org.

[112] For the purposes of this comparison, we only consider a link to be present if the associated input transaction ($a_{ji}$) is above 1.0% of the sector's total input purchase.

[113] Network density is defined by the fraction of edges that are present in the network relative to the total number of possible edges ($n^2$).

[114] The degree of a node is the number of relations (edges) it has independently of its in or out relation. It is the sum of edges for a node.

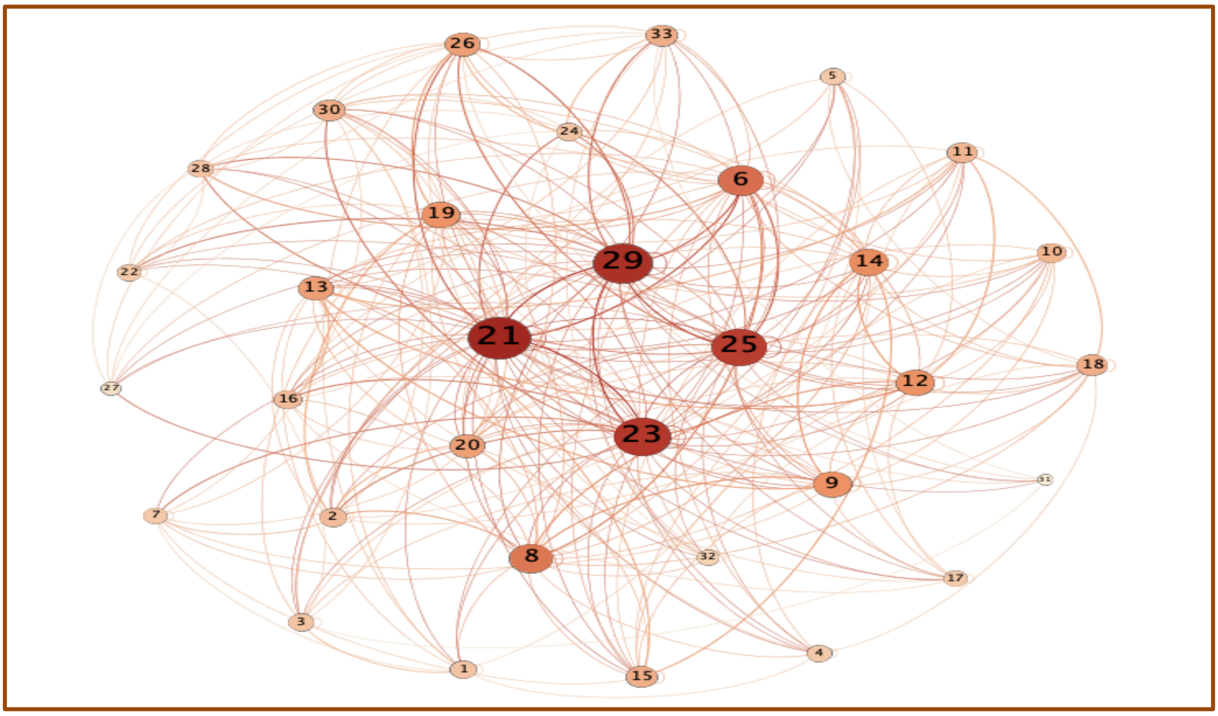
*Figure 5. 1: Oman's Production Network Structure for the Year 2005*




*Source: Created by Author using Gephi software*

*Notes: Each node in the network corresponds to a sector. Each edge corresponds to an input-supply relation between two sectors. Larger nodes closer to the centre of the network represent sectors supplying inputs to many other sectors.*

*Figure 5. 2: The USA's Production Network Structure for the year 2005*




*Source: Created by Author using Gephi software*

d) Weighted outdegree:[115] in Oman this was 7.5 sectors, while in the USA it was 19.9 sectors.

e) Average clustering: in Oman this was 40.1%, whereas in the USA it was 69.4%,

f) Average closeness centrality: in Oman this was 0.50, whereas in the USA it was 0.68.

Both economies have central sectors whose products are used as inputs in many other sectors, and/or whose products are also used by sectors that are themselves central. The USA, however, has higher network density, average degree of the network, weighted outdegree, average clustering, and average clustering ratios than Oman, revealing the complexity of the production network in the USA where sectors are more central and more interconnected with each other. This implies that in the economy of the USA there are a larger number of more centralized sectors supplying to many other sectors,[116] whereas in Oman there are fewer centralized sectors and more sectors that are isolated from each other.

*Table 5. 1: Oman's and the USA's Multi-Sectoral Production Network Structures' Characteristics for the Year 2005*

| No. | | Oman | USA |
|---|---|---|---|
| 1 | Number of Sectoral Activities/nodes | 32 | 33 |
| 2 | Total edges | 1024 | 1089 |
| 3 | 1% >= Trade Cover | 86.5% | 84.9% |
| 4 | 1% >= with Edges | 120 | 329 |
| | Network Density | 11.7% | 30.2% |
| 5 | Average Degree of Network | 8.2 | 22.1 |
| | Represnet; | 25.5% | 66.9% |
| 6 | Weighted Out degree | 7.5 | 19.9 |
| | Represnet; | 23.4% | 60.4% |
| 7 | Average Clustering | 40.1% | 69.4% |
| 8 | Avergare Closness Centrality | 0.50 | 0.68 |

*Source: Measured by Author using Gephi software*

[115] The weighted outdegree of a node is like the degree. It is based on the number of edges for a node, but ponderated by the weight of each edge. This measure ranges from 0 if a sector does not supply inputs to any other sectors, to n if a single sector is the sole input supplier of every sector in the economy.

[116] This is also confirmed visually in Figure 5.2.

In Oman the average degree of network is 8.2, and the input-supplying sectors with the highest degree of network, as shown in Table (5.2), are real estate; construction; wholesale & retail trade, restaurants & hotels; manufacture of chemicals, rubber & plastic products; manufacture of basic metals; transport and storage; recreational & cultural services; manufacture of paper and paper products, publishing; and finally, manufacture of coke, refined petroleum products and nuclear fuel, with degrees of 23, 14, 13, 11, 11, 11, 11, 9 and 9, respectively.

In the USA, meanwhile, the average degree of network is 22.1, and the input supplying sectors with the highest degrees of network, as shown in Table (5.3), are wholesale and retail trade; R&D and other business activities; transport and storage; financial intermediation, pulp, paper, paper products, printing and publishing; and finally, chemicals and chemical products, with degrees of 34, 32, 31, 30, 24 and 23, respectively.

The M&Q sector in Oman has a ranking of 15, out of the 32 sectors, with a degree of 7. In the USA economy, meanwhile, the M&Q sector has a ranking of 20 out of the 33 sectors and a degree of 14. This implies that, in both the economies, the M&Q sector is not the most dominant supplier. In fact, wholesale and retail trade seems to be one of the most dominant sectors in both economies.[117]

[117] Using a 417-sector IO table for the year 2002 in the USA, Carvalho (2014) also found that wholesale and retail trade is the most dominant sector in the USA economy.

*Table 5. 2: Oman's Multi-Sectoral Average Degree and Weighted-Degree Measures for the Year 2005*

| Multi-Sectoral | No. | Average Degree | Weighted Degree |
|---|---|---|---|
| Agriculture and livestock | 1 | 5 | 7 |
| Fishing | 2 | 5 | 5 |
| Extraction of crude petroleum & natural gas | 3 | 7 | 7 |
| Service activities; incidental to oil & gas extraction | 4 | 4 | 4 |
| Other mining & quarrying | 5 | 3 | 3 |
| Manufacture of food products and beverages | 6 | 8 | 9 |
| Manufacture of textiles | 7 | 4 | 4 |
| Manufacture of wearing apparel, dressing & dyeing of furnitur | 8 | 2 | 2 |
| Manufacture of leather luggage & hand bags | 9 | 1 | 1 |
| Manufacture of wood & w. products except furniture | 10 | 6 | 7 |
| Manufacture of paper and paper products, publishing | 11 | 9 | 9 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | 9 | 9 |
| Manufacture of chemicalls, rubber & plastic products | 13 | 11 | 11 |
| Manufacture of other non-metallic mineral products | 14 | 8 | 8 |
| Manufacture of basic metals | 15 | 11 | 11 |
| Manufacture of fabricated metal products | 16 | 6 | 6 |
| Manufacture of machinery and equipment | 17 | 8 | 8 |
| Manufacture of electric machinery and apparatus | 18 | 8 | 8 |
| Manufactures nec: recycling | 19 | 8 | 8 |
| Manufacture of motor vehicles, trailers and semitrailers | 20 | 4 | 4 |
| Manufacture of other transport equipment, n.e.c. | 21 | 6 | 6 |
| Electricity and gas | 22 | 2 | 2 |
| Water works and supply | 23 | 3 | 3 |
| Construction | 24 | 14 | 15 |
| Wholesale & retail trade, restaurants & hotels | 25 | 13 | 17 |
| Transport and storage | 26 | 11 | 13 |
| Communication | 27 | 6 | 6 |
| Financial institutions | 28 | 3 | 3 |
| Insurance | 29 | 3 | 3 |
| Real estate | 30 | 23 | 25 |
| Public administration, defence, education, health | 31 | 2 | 2 |
| Recreational & cultural services | 32 | 11 | 14 |

*Source: Measured by Author using Gephi Software*

*Table 5. 3: The USA's Multi-Sectoral Average Degree and Weighted-Degree Measures for the Year 2005*

| Multi-Sectoral | No. | Average Degree | Weighted Degree |
|---|---|---|---|
| Agriculture, hunting, forestry and fishing | 1 | 13 | 14 |
| Mining and quarrying | 2 | 14 | 19 |
| Food products, beverages and tobacco | 3 | 13 | 14 |
| Textiles, textile products, leather and footwear | 4 | 12 | 12 |
| Wood and products of wood and cork | 5 | 12 | 12 |
| Pulp, paper, paper products, printing and publishing | 6 | 24 | 29 |
| Coke, refined petroleum products and nuclear fuel | 7 | 12 | 14 |
| Chemicals and chemical products | 8 | 23 | 27 |
| Rubber and plastics products | 9 | 20 | 23 |
| Other non-metallic mineral products | 10 | 15 | 15 |
| Basic metals | 11 | 15 | 18 |
| Fabricated metal products | 12 | 20 | 24 |
| Machinery and equipment, nec | 13 | 18 | 23 |
| Computer, Electronic and optical equipment | 14 | 21 | 24 |
| Electrical machinery and apparatus, nec | 15 | 16 | 18 |
| Motor vehicles, trailers and semi-trailers | 16 | 14 | 16 |
| Other transport equipment | 17 | 12 | 12 |
| Manufacturing nec; recycling | 18 | 16 | 17 |
| Electricity, gas and water supply | 19 | 20 | 22 |
| Construction | 20 | 18 | 19 |
| Wholesale and retail trade; repairs | 21 | 34 | 39 |
| Hotels and restaurants | 22 | 12 | 13 |
| Transport and storage | 23 | 31 | 38 |
| Post and telecommunications | 24 | 13 | 18 |
| Financial intermediation | 25 | 30 | 35 |
| Real estate activities | 26 | 18 | 23 |
| Renting of machinery and equipment | 27 | 9 | 10 |
| Computer and related activities | 28 | 13 | 16 |
| R&D and other business activities | 29 | 32 | 41 |
| Public administration and defence; compulsory social security | 30 | 16 | 17 |
| Education | 31 | 7 | 7 |
| Health and social work | 32 | 11 | 11 |
| Other community, social and personal services | 33 | 16 | 18 |

*Source: Measured by Author using Gephi Software*

Since our focus is on the potential of non-M&Q tradable sectors within Oman's economy, Table (5.4) shows only the tradable sectors having an average degree of 8 and above. Interestingly, all the sectors are related directly to manufacturing activities.

*Table 5. 4: Oman's Tradable Sectoral Average Degree and Weighted-Degree Measures for the Year 2005*

| Multi-Sectoral | No. | category | Average Degree | Weighted Degree |
|---|---|---|---|---|
| Manufacture of chemicalls, rubber & plastic products | 13 | Tradable | 11 | 11 |
| Manufacture of basic metals | 15 | Tradable | 11 | 11 |
| Manufacture of paper and paper products, publishing | 11 | Tradable | 9 | 9 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | Tradable | 9 | 9 |
| Manufacture of food products and beverages | 6 | Tradable | 8 | 9 |
| Manufacture of other non-metallic mineral products | 14 | Tradable | 8 | 8 |
| Manufacture of machinery and equipment | 17 | Tradable | 8 | 8 |
| Manufacture of electric machinery and apparatus | 18 | Tradable | 8 | 8 |
| Manufactures nec: recycling | 19 | Tradable | 8 | 8 |

*Source: Measured by Author using Gephi software*

### 5.3.2 Multi-Sectoral Output-Multipliers Model

#### 5.3.2.1 Methodology

We use an output-multipliers approach to identify which sectors in Oman's economy have the highest effect in increasing the economy's output (GDP) when their productivities are increased by one unit. We use equation (5.7) to measure the multi-sectoral output-multipliers.[118] We also compare Oman's multi-sectoral output-multipliers for the year 2005 with those of the USA for the same year 2005.

[118] The import-substitutions are also incorporated while measuring the technical coefficients ($a_{ij}$) of matrix (A), which is used in equation (5.7).

### 5.3.2.2 Interpretation of Findings

Table (5.5) shows that the five sectors in Oman's economy with the highest levels of output-multipliers ($\mu$) are: M&Q; manufacture of basic metals, real estate, manufacture of food products and beverages, and finally, manufacture of coke, refined petroleum products and nuclear fuel, with output-multipliers of 0.113, 0.086, 0.077, 0.063 and 0.061, respectively.[119] This means that, in the case of the M&Q sector, a one percent increase in its productivity will lead to an 11.3% increase in the economy's aggregate output (GDP). Out of thirteen sectors having output-multipliers above the average of 0.046, ten are non-M&Q tradable sectors, out of which eight are related to manufacturing activities.

As we did earlier in section 4.4.3.1, to obtain a more focused analysis and understanding of the main sectors in Oman's economy, we consolidate the 32 sectors in the year 2005 IO table for Oman into eleven sectors IO table,[120] and remeasure the output-multipliers. Figure (5.3) shows the output-multipliers of the eleven sectors of Oman's economy. On this basis, the combined manufacturing activities sector has the largest output-multiplier, such that a one percent increase in its productivity would lead to a 28.0% increase in the output of Oman's economy.[121]

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[119] The ranking of the sectors is the same as for DIFLI, which we measured in section 4.4.1.3 using a different method.

[120] In essence, we combined all the different manufacturing activities into one sector and created a revised 11 x 11 IO table for the year 2005.

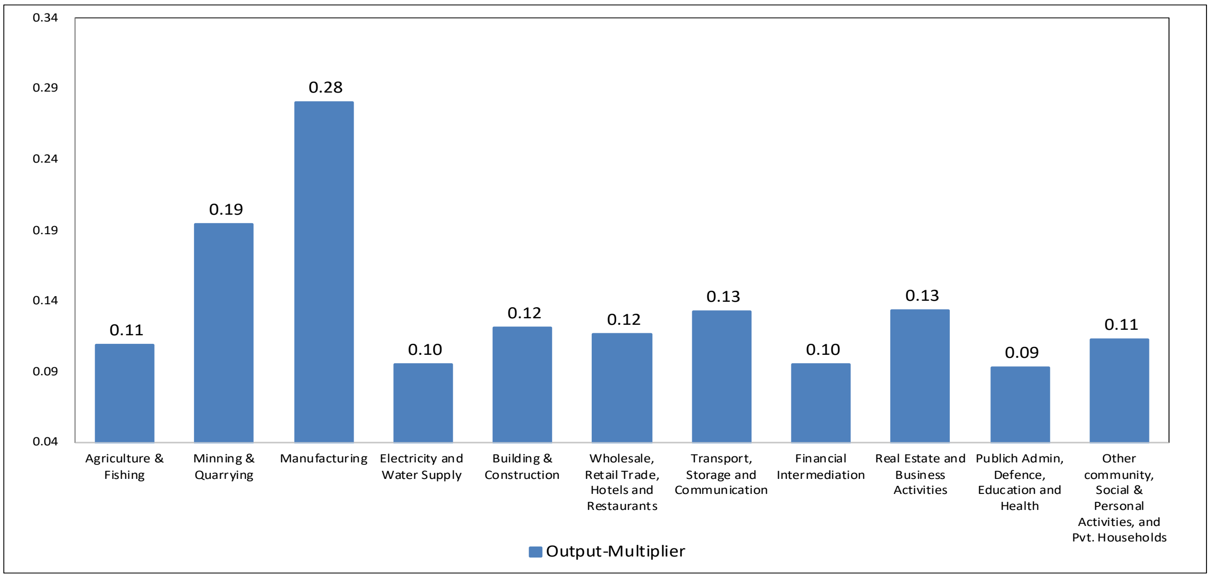
[121] It is worth mentioning here that when the full 32 sectors for the year 2005 IO table are consolidated to eleven sectors, the aggregate output-multiplier increases from 1.477 to 1.484, and when consolidated to four main sectors it changes to 1.469. This seems to be due to rounding of decimals.

*Table 5. 5: Oman's 32 Multi-Sectoral Output-Multipliers for the year 2005*

| Multi-Sectoral | No. | Output Multiplier | Ranking |
|---|---|---|---|
| Agriculture and livestock | 1 | 0.044 | 13 |
| Fishing | 2 | 0.034 | 24 |
| Extraction of crude petroleum & natural gas | 3 | 0.113 | 1 |
| Service activities; incidental to oil & gas extraction | 4 | 0.035 | 21 |
| Other mining & quarrying | 5 | 0.040 | 18 |
| Manufacture of food products and beverages | 6 | 0.063 | 4 |
| Manufacture of textiles | 7 | 0.039 | 19 |
| Manufacture of wearing apparel, dressing & dyeing of furnitur | 8 | 0.032 | 30 |
| Manufacture of leather luggage & hand bags | 9 | 0.032 | 31 |
| Manufacture of wood & w. products except furniture | 10 | 0.043 | 14 |
| Manufacture of paper and paper products, publishing | 11 | 0.057 | 6 |
| Manufacture of coke, refined petroleum products & nuclear fuel | 12 | 0.061 | 5 |
| Manufacture of chemicalls, rubber & plastic products | 13 | 0.054 | 7 |
| Manufacture of other non-metallic mineral products | 14 | 0.042 | 16 |
| Manufacture of basic metals | 15 | 0.086 | 2 |
| Manufacture of fabricated metal products | 16 | 0.050 | 9 |
| Manufacture of machinery and equipment | 17 | 0.033 | 25 |
| Manufacture of electric machinery and apparatus | 18 | 0.035 | 23 |
| Manufactures nec | 19 | 0.036 | 20 |
| Manufacture of motor vehicles, trailers and semitrailers | 20 | 0.042 | 15 |
| Manufacture of other transport equipment, n.e.c. | 21 | 0.033 | 26 |
| Electricity and gas | 22 | 0.033 | 27 |
| Water works and supply | 23 | 0.033 | 28 |
| Construction | 24 | 0.047 | 11 |
| Wholesale & retail trade, restaurants & hotels | 25 | 0.049 | 10 |
| Transport and storage | 26 | 0.051 | 8 |
| Communication | 27 | 0.041 | 17 |
| Financial institutions | 28 | 0.035 | 22 |
| Insurance | 29 | 0.032 | 32 |
| Real estate | 30 | 0.077 | 3 |
| Public administration, defence, education, health | 31 | 0.032 | 29 |
| Recreational & cultural services | 32 | 0.044 | 12 |
| | Aggregate | 1.477 | |
| | Maximum | 0.113 | |
| | Minimum | 0.032 | |
| | Arithmetic mean (Average) | 0.046 | |
| | Median | 0.041 | |
| | Variance | 0.000 | |
| | Standard Deviation | 0.018 | |

*Source: Measured by Author using Oman's Input-Output Table for the year 2005*

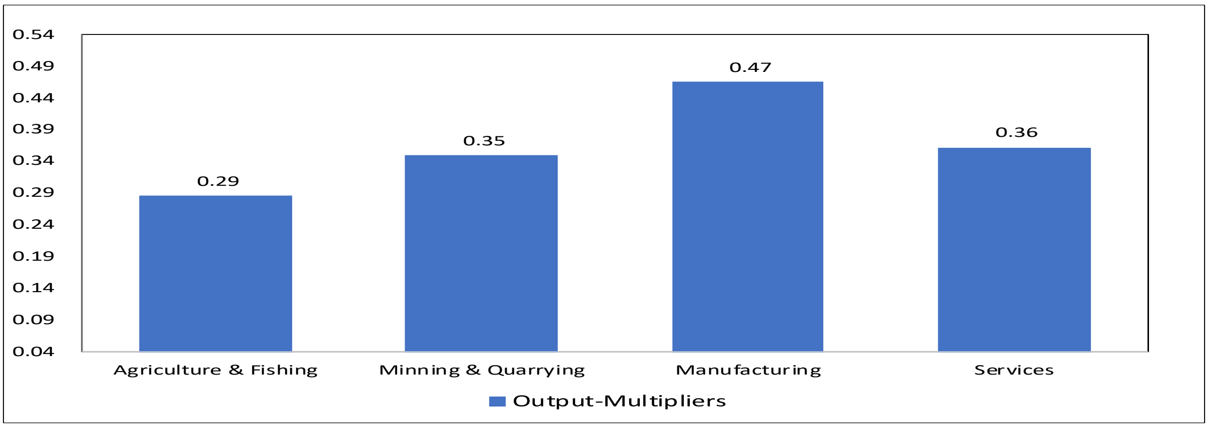
*Figure 5. 3: Oman's Eleven Multi-Sectoral Output-Multipliers for the Year 2005*




*Source: Measured by Author using Oman's Input-Output Table for the year 2005*

We further consolidated the eleven-sector IO table into a table with four main sectors.[122] Figure (5.4) shows the output-multipliers for the four main sectors, revealing that the combined manufacturing activities sector continued to have the largest output-multiplier, even larger than the consolidated services activities sector.[123]

*Figure 5. 4: Oman's Four Multi-Sectoral Output-Multipliers for the Year 2005*




*Source: Measured by Author using Oman's Input-Output Table for the year 2005*

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[122] In essence, we combined all the different services related activities into one sector and created a revised 4 x 4 IO table for the year 2005.

[123] This is in contrast to Fadinger, Ghiglino, and Teteryatnikova's (2018) findings that the services-related activities had the largest output-multipliers in all income group countries of their sample. This discrepancy could be due to Oman being a resource-based developing country, and thus having a different economic structure.

Considering the USA economy, Table (5.6) shows that the five sectors with the highest ranking of output-multipliers are wholesale and retail trade; R&D and other business activities; M&Q; financial intermediation; and finally, basic metals, with output-multipliers of 0.166, 0.146, 0.155, 0.111 and 0.088, respectively.

It is worth mentioning here that, unlike in Oman, the M&Q sector in the USA is not the sector with the largest output-multiplier, but interestingly the M&Q sector does have almost the same output-multipliers in the two countries, 0.115 and 0.113, respectively.

Comparing Oman and the USA, the following facts stand out. First, the M&Q sector's productivity performance seems to have a large impact on the output (GDP) of both economies. Second, the aggregate output-multiplier in the USA (2.064) is larger than in Oman (1.477),[124] indicating that any improvement in multi-sectoral productivity in the USA has a greater impact than in Oman on the aggregate output of the economy.

Figure (5.5) places our measured Oman's and USA's aggregate output-multipliers against the results obtained by Fadinger, Ghiglino, and Teteryatnikova (2018). This shows that the aggregate output-multiplier that we have measured for Oman (1.477) is lower than that measured for the USA (1.75). This is in line with our results, while also showing that our figure for Oman is even below the average aggregate output-multiplier in their sample (1.6). Meanwhile, the aggregate output-multiplier that we measured for the USA (2.064) was 26.7% higher than their result for the USA. The third observation is that, when the Kernel Density

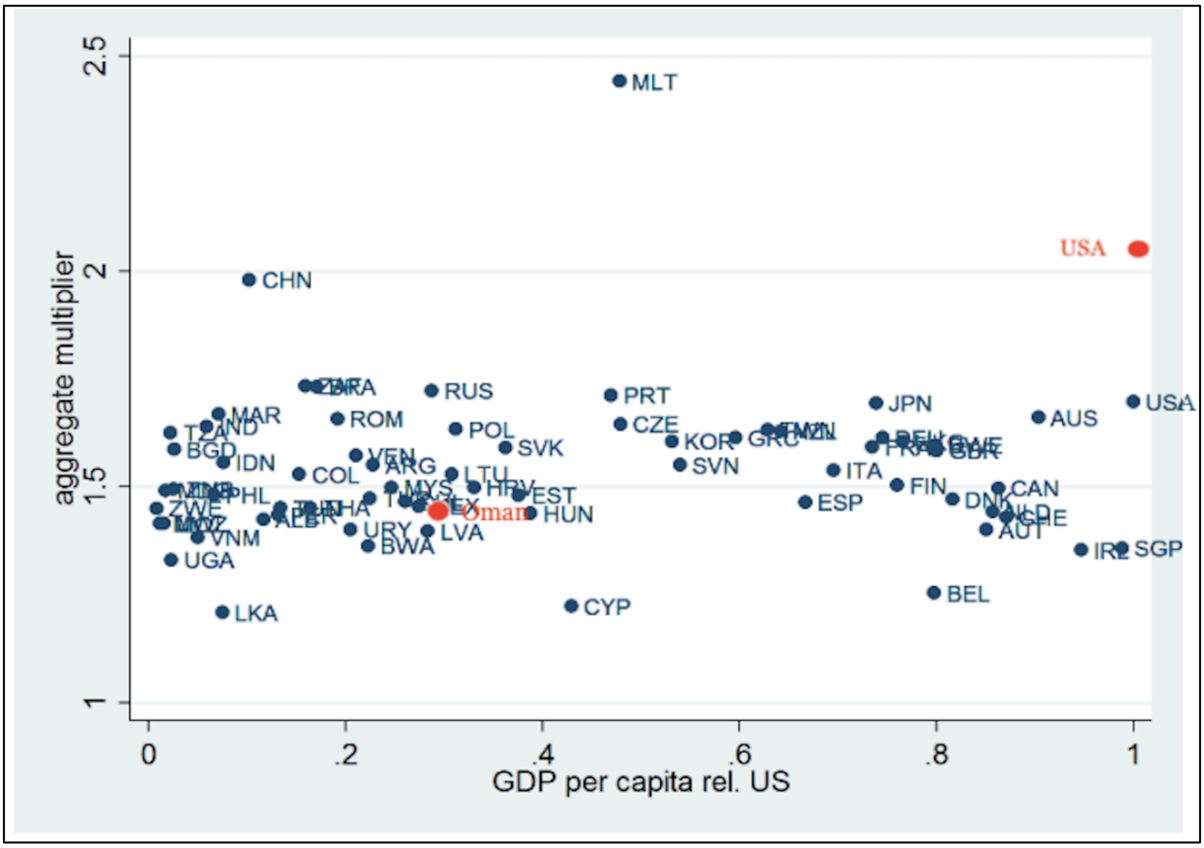
[124] Oman's aggregate output-multiplier of 1.477, leads to a share of intermediate goods of 0.323, using the formula ( $\frac{1}{1-a}$ ), whereas the actual share of intermediate goods in Oman's IO table for the year 2005 was 0.253. The USA's aggregate output-multiplier of 2.064, meanwhile, leads to a share of intermediate goods of 0.512, whereas the actual share of intermediate goods in the USA's IO table for the year 2005 was 0.459. It appears, therefore, that this simple formula provides a good approximation to the results found through computing the Leontief inverse, with a 15–20% expansion.

*Table 5. 6: The USA's 33 Multi-Sectoral Output-Multipliers for the Year 2005*

| Multi-Sectoral | No. | Output Multiplier | Ranking |
|---|---|---|---|
| Agriculture, hunting, forestry and fishing | 1 | 0.059 | 14 |
| Mining and quarrying | 2 | 0.115 | 3 |
| Food products, beverages and tobacco | 3 | 0.046 | 21 |
| Textiles, textile products, leather and footwear | 4 | 0.040 | 28 |
| Wood and products of wood and cork | 5 | 0.048 | 20 |
| Pulp, paper, paper products, printing and publishing | 6 | 0.063 | 10 |
| Coke, refined petroleum products and nuclear fuel | 7 | 0.059 | 15 |
| Chemicals and chemical products | 8 | 0.083 | 6 |
| Rubber and plastics products | 9 | 0.051 | 17 |
| Other non-metallic mineral products | 10 | 0.042 | 23 |
| Basic metals | 11 | 0.088 | 5 |
| Fabricated metal products | 12 | 0.066 | 9 |
| Machinery and equipment, nec | 13 | 0.061 | 12 |
| Computer, Electronic and optical equipment | 14 | 0.063 | 11 |
| Electrical machinery and apparatus, nec | 15 | 0.039 | 29 |
| Motor vehicles, trailers and semi-trailers | 16 | 0.059 | 13 |
| Other transport equipment | 17 | 0.037 | 31 |
| Manufacturing nec; recycling | 18 | 0.040 | 27 |
| Electricity, gas and water supply | 19 | 0.049 | 19 |
| Construction | 20 | 0.042 | 24 |
| Wholesale and retail trade; repairs | 21 | 0.166 | 1 |
| Hotels and restaurants | 22 | 0.040 | 26 |
| Transport and storage | 23 | 0.077 | 7 |
| Post and telecommunications | 24 | 0.057 | 16 |
| Financial intermediation | 25 | 0.111 | 4 |
| Real estate activities | 26 | 0.074 | 8 |
| Renting of machinery and equipment | 27 | 0.039 | 30 |
| Computer and related activities | 28 | 0.045 | 22 |
| R&D and other business activities | 29 | 0.146 | 2 |
| Public administration and defence; compulsory social security | 30 | 0.042 | 25 |
| Education | 31 | 0.037 | 32 |
| Health and social work | 32 | 0.032 | 33 |
| Other community, social and personal services | 33 | 0.049 | 18 |
| | Aggregate | 2.064 | |
| | Maximum | 0.166 | |
| | Minimum | 0.032 | |
| | Arithmetic mean (Average) | 0.063 | |
| | Median | 0.051 | |
| | Variance | 0.001 | |
| | Standard Deviation | 0.032 | |

*Source: Measured by Author using USA's Input-Output Table for the year 2005*

*Figure 5. 5: Aggregate Output-Multipliers for Oman and the USA vs GTAP Database Countries Against their GDP per Capita (Relative to USA), for the Year 2005*




*Source: Main Graph from Fadinger, Ghiglino, and Teteryatnikova (2018), and Oman & USA Aggregate Output-Multipliers (In Red), measured by Author using Oman and USA Input-Output Tables for the year 2005*

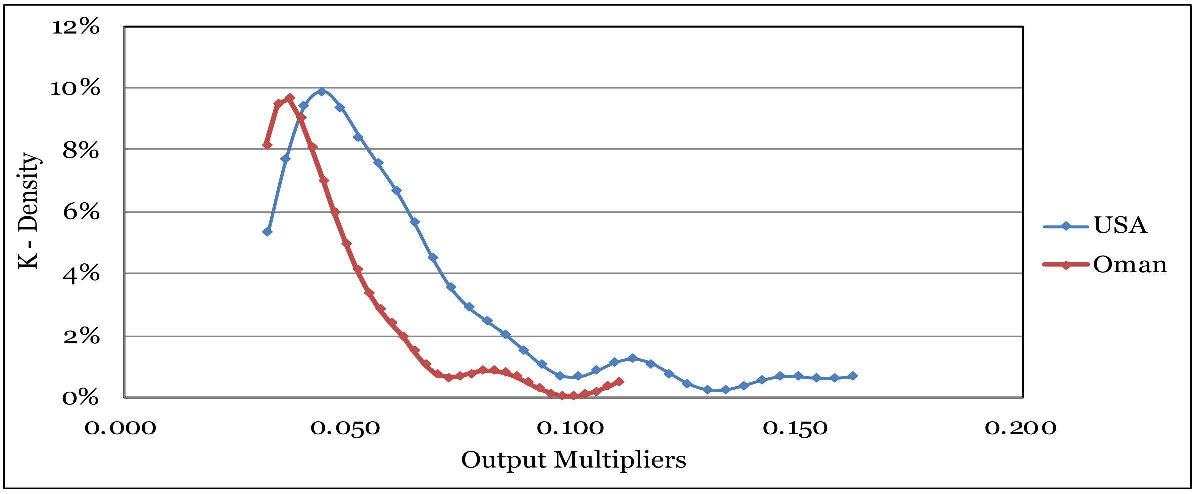
*Note: GDP per capita for Oman and USA for the year 2005 were $12,376.9 and $44,307.9, respectively, (World Bank data).*

Estimation (KDE)[125] distribution is applied to Oman's and the USA's multi-sectoral output-multipliers, it is evident both that the distributions are skewed for both economies, and that most of the sectors have low output-multipliers, with only a few sectors having output-multipliers significantly above the average (Figure 5.6). The distribution of the multi-sectoral output-multipliers in Oman's economy are more skewed towards the extremes than in the USA, and almost all sectors' output-multipliers in Oman are very low. In the USA, on the other hand, the distribution of the sectors' output-multipliers has much more mass in the centre. Our results

[125] In statistics, KDE is a non-parametric way to estimate the probability density function of a random variable.

thus confirm the findings of Fadinger, Ghiglino, and Teteryatnikova (2018) in respect to the KDE distributions of multi-sectoral output-multipliers against the income per capita between developed and the developing countries (Oman being a developing country).

*Figure 5. 6: Multi-Sectoral Density Distributions for Oman and the USA for the Year 2005*




*Source: Measured by Author using Oman's and USA's Input-Output Tables for the year 2005*

### 5.3.3 Multi-Sectoral TFP and TFP Growth Estimations Model

#### 5.3.3.1 Methodology

In this section our objectives are to estimate the productivities (TFP) and their subsequent effect on the overall aggregate productivity growth of Oman's economy and at multi-sectoral levels, during the period 1998–2016, using the theoretical framework discussed in section (5.2). We also compare the results obtained in this section with the results we estimated for the productivity growth in Chapter (3) using the aggregate growth accounting framework.

Moreover, and for comparison purposes, using the theoretical framework we estimate the USA's multi-sectoral productivities for the year 2005 and compare these with Oman's multi-sectoral productivities for the same year. We also apply the USA's multi-sectoral intermediate inputs ratios to Oman's multi-sectoral production function in order to measure the change in Oman's multi-sectoral productivities if it had the USA sectoral advantages. Finally, we use the measured the USA multi-sectoral productivities within Oman's national and multi-sectoral productions and measure the changes that take place in the national and multi-sectoral gross-outputs.

This will allow us to identify the most productive and the highest TFP growth sectors in Oman's economy, especially in respect to the non-M&Q tradable sectors. Also, comparing Oman's multi-sectoral productivity performances with a developed country's multi-sectoral productivity performances, will indicate which sectors in Oman's economy have greater potential to increase their productivities. Henceforth, if Oman managed to increase its multi-sectoral productivities to the level of a developed country, like the USA, its multi-sectoral performances, and hence its aggregate productivity, would increase, which has a direct effect on the economy's gross-output. This knowledge will support Oman's government in achieving future diversification and sustainable output growth in the economy.

In Chapter (3), we measured TFP growth at national and multi-sectoral levels for the same period, using the aggregate growth accounting framework with the Cobb-Douglas production function as the log-linear production function, in which the intermediate consumption goods were not considered as part of the productions function.[126] In this section, on the other hand, we use equation (5.3), where intermediate consumption goods are considered along with other input factors that have a direct effect on gross-output (capital stock, labour, and TFP).

Since, the production function in equation (5.3) features constant returns to scale (CRS), we can rewrite the equation as follows to measure the productivity:

$$\mathrm{TFP_i} = \mathrm{X_i} \,/\, \left[ \left(\mathrm{K_i^{\alpha_i}}\, \mathrm{L_i^{1-\alpha_i}}\right)^{1-a_\mathrm{i}} \quad \{\mathrm{z_{1i}^{a_{1i}}}\, \mathrm{z_{2i}^{a_{2i}}} \ldots \mathrm{z_{ni}^{a_{ni}}}\} \right] \tag{5.8}$$

[126] The intermediate consumption goods were not part of the production function since we were measuring the value-added (GDP) growth. In this section, on the other hand, we use the production function that measures the gross-output where the intermediates are considered.

To measure the yearly multi-sectoral TFPs using equation (5.3), and thereafter their growth during the period 1998–2016, on both national and multi-sectoral levels, we use yearly national and multi-sectoral gross-outputs,[127] capital stocks and labour and their shares, as measured and used in Chapter (3) using the NCSI data. We also require yearly multi-sectoral intermediate goods values ($\mathrm{z}$) and their intermediate input ratios ($a$) on national and multi-sectoral levels for the entire period 1998–2019 to measure the multi-sectoral productivities and thereafter their growth during the period. Since we are restricted to the IO table for Oman for the year 2005, being the only one available, we had to assume that the intermediate input ratios ($a_{\mathrm{ij}}$) between the sectors have not changed during the entire period 1998–2016, hence, we measure the intermediate consumption ratios using the 2005 multi-sectoral IO table and use them for all the years during the period.[128] We then use these measured 2005 intermediate input ratios to measure the yearly intermediate goods values ($\mathrm{z}_{\mathrm{ij}}$) for national and multi-sectoral levels for the entire period, by using equation (4.4), ($a_{\mathrm{ij}} = {}^{\mathrm{z}_{\mathrm{ij}}}/_{\mathrm{X}_{\mathrm{j}}}$), by multiplying the fixed intermediate input ratios ($a_{\mathrm{ij}}$) to each yearly actual national and multi-sectoral gross-outputs ($\mathrm{X}_{\mathrm{j}}$).

Therefore, the estimated yearly TFP and TFP growth at national and multi-sectoral levels for the period 1998–2016 using the above method are directly affected by the yearly multi-sectoral gross-outputs, yearly capital stocks and labour values and their shares, and the measured yearly intermediate goods, but not to the changes in the yearly intermediate input ratios, since these have been kept fixed for the entire period based on the year 2005. This assumption does not stand out in any economy's structure, because the intermediate consumption ratios between the sectors are dynamic and change over time. The lack of IO tables for Oman for the period,

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[127] At constant prices (also called real prices).

[128] Since the intermediate input ratios have been assumed to be fixed during the entire period and have been based on the year 2005 ratios, the shares of aggregate intermediate goods and aggregate shares of capital stock and labour on national and multi-sectoral levels would also be fixed to the output for the entire period.

however, leaves no option other than to rely on this assumption. While it should be noted that this restrictive assumption means that the results obtained in this section will be less accurate, they nonetheless remain indicative to some extent.

#### 5.3.3.2 Interpretation of Findings

Table (5.7) shows the values for all the yearly parameters that were used to estimate the TFP and TFP growth at Oman's national level for the period 1998–2016. The results show that the average TFP at the national level during the period was 3.39 per annum, with the average TFP growth being marginally positive 0.5%. With respect to the multi-sectoral level, as shown in Table (5.8), the sectors with the highest average TFP ranking during the period were mostly services, namely: public administration, defence, education and health; wholesale, retail trade, and hotels & restaurants; other community, social & personal activities and private households; and finally, building and construction, with average TFPs of 15.9, 4.7, 4.16, and 3.67, respectively. Whereas the main non-M&Q tradable sectors (manufacturing, financial intermediation, and agriculture and fisheries) had average TFP of 3.63, 3.09, and 2.33, respectively, with the manufacturing sector leading all the tradable sectors.

It is worth mentioning here that the M&Q sector, despite being a tradable sector, had the lowest average TFP of 0.92 of any sectors in Oman's economy. As shown in Chapter (3), and as will be discussed further in the next section, this is probably because it is a capital stock intensive sector.

Using the yearly multi-sectoral TFPs during the period 1998–2016, we measure their TFP growth and thereafter average TFP growth during the period. As shown in Table (5.8), the five sectors with the highest average TFP growth during the period were financial intermediation; agriculture and fisheries; transport, storage and communication; wholesale, retail trade, hotels and restaurant; and finally, building and construction, with average TFP growth of 9.0%, 3.8%,

*Table 5. 7: Oman' s Yearly and Average TFP, and TFP Growth Estimations at National Level, Using Theoretical Framework, During the Period 1998–2016*

| Year | Gross Output (X), OMR (Mn), Constant Prices | Intermediate Goods (z), OMR, (MN) | Capital Investment (I), OMR (Mn) | Capital Stock (K), OMR (Mn) | Labour (L), Mn | Aggregate Share of Intermediate Goods | Consollidated Intermediate Consumption Value | Share of Capital Stock (∝) | Share of Labour (1-∝) | Aggregate Shares of Capital & Labour | TFP | TFP Growth (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 19,855 | 5,026 | 2,231 | 43,072 | 661 | 0.25 | 5.64 | 0.71 | 0.29 | 0.75 | 3.01 | |
| 1999 | 19,937 | 5,046 | 1,912 | 42,344 | 692 | 0.25 | 5.65 | 0.71 | 0.29 | 0.75 | 3.01 | 0.2% |
| 2000 | 21,629 | 5,475 | 1,681 | 41,429 | 716 | 0.25 | 5.77 | 0.71 | 0.29 | 0.75 | 3.22 | 6.7% |
| 2001 | 22,842 | 5,782 | 1,882 | 40,771 | 763 | 0.25 | 5.85 | 0.71 | 0.29 | 0.75 | 3.33 | 3.6% |
| 2002 | 23,108 | 5,849 | 2,079 | 40,351 | 798 | 0.25 | 5.86 | 0.71 | 0.29 | 0.75 | 3.35 | 0.5% |
| 2003 | 22,807 | 5,773 | 2,517 | 40,395 | 680 | 0.25 | 5.84 | 0.71 | 0.29 | 0.75 | 3.43 | 2.5% |
| 2004 | 23,566 | 5,965 | 3,018 | 40,937 | 726 | 0.25 | 5.89 | 0.71 | 0.29 | 0.75 | 3.44 | 0.3% |
| 2005 | 25,171 | 6,371 | 3,501 | 41,928 | 755 | 0.25 | 5.99 | 0.71 | 0.29 | 0.75 | 3.54 | 2.8% |
| 2006 | 26,416 | 6,686 | 3,589 | 42,947 | 764 | 0.25 | 6.06 | 0.71 | 0.29 | 0.75 | 3.61 | 2.1% |
| 2007 | 27,774 | 7,030 | 4,727 | 45,041 | 917 | 0.25 | 6.14 | 0.71 | 0.29 | 0.75 | 3.52 | -2.7% |
| 2008 | 31,483 | 7,969 | 6,314 | 48,594 | 1,096 | 0.25 | 6.34 | 0.71 | 0.29 | 0.75 | 3.57 | 1.5% |
| 2009 | 32,717 | 8,281 | 5,956 | 51,570 | 1,193 | 0.25 | 6.40 | 0.71 | 0.29 | 0.75 | 3.49 | -2.1% |
| 2010 | 34,452 | 8,721 | 5,414 | 53,823 | 1,297 | 0.25 | 6.49 | 0.71 | 0.29 | 0.75 | 3.49 | -0.2% |
| 2011 | 36,655 | 9,278 | 5,914 | 56,438 | 1,473 | 0.25 | 6.59 | 0.71 | 0.29 | 0.75 | 3.46 | -0.6% |
| 2012 | 39,867 | 10,091 | 6,172 | 59,150 | 1,682 | 0.25 | 6.73 | 0.71 | 0.29 | 0.75 | 3.49 | 0.9% |
| 2013 | 41,799 | 10,580 | 6,935 | 62,459 | 1,864 | 0.25 | 6.81 | 0.71 | 0.29 | 0.75 | 3.44 | -1.6% |
| 2014 | 43,302 | 10,961 | 7,100 | 65,730 | 1,941 | 0.25 | 6.87 | 0.71 | 0.29 | 0.75 | 3.41 | -0.9% |
| 2015 | 45,078 | 11,410 | 7,181 | 68,882 | 2,075 | 0.25 | 6.94 | 0.71 | 0.29 | 0.75 | 3.38 | -0.9% |
| 2016 | 46,045 | 11,655 | 7,127 | 71,786 | 2,256 | 0.25 | 6.98 | 0.71 | 0.29 | 0.75 | 3.30 | -2.4% |
| Averages | | | | | | *0.25* | *6.25* | *0.71* | *0.29* | *0.75* | *3.39* | *0.5%* |

*Source: Measured by Author*

*Table 5. 8: Oman' s Average TFP and TFP Growth at National and Multi-Sectoral Levels, Using Theoretical Framework, During the period 1998–2016*

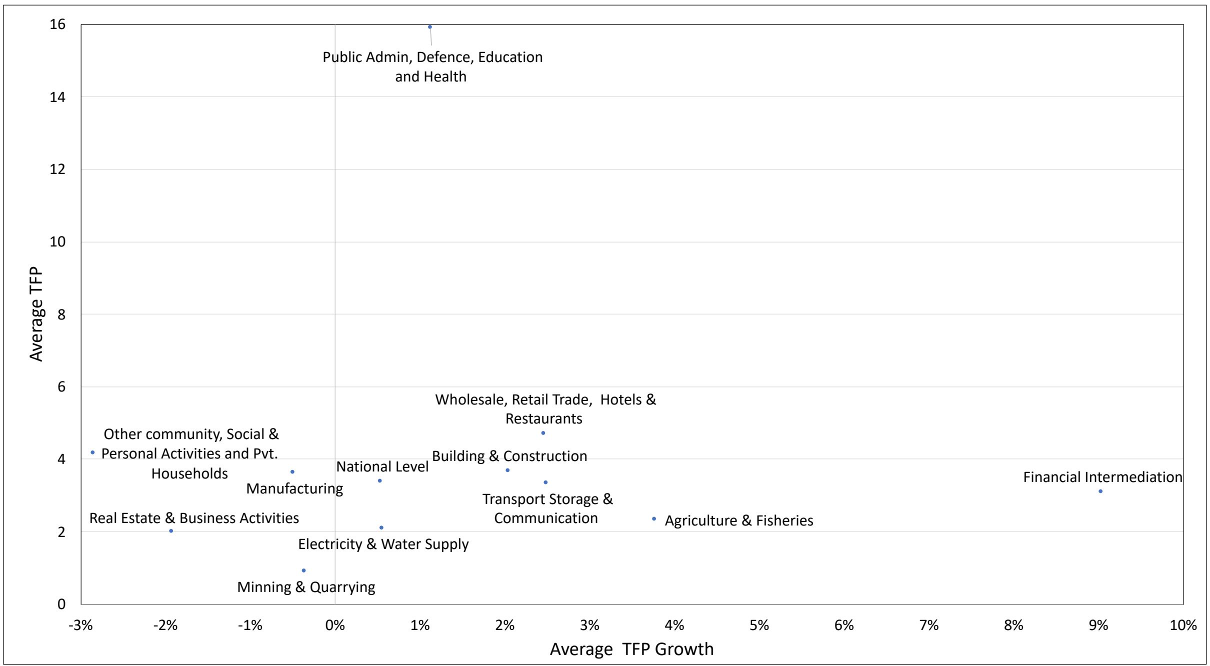
| No. | Sectoral Activities | Aggregate Share of Intermediate Goods | Consollidated Intermediate Consumption Value | Share of Capital Stock (∝) | Share of Labour (1-∝) | Aggregate Shares of Capital & Labour | TFP (2005) | Average TFP | Ranking | Average TFP Growth | Ranking |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | National Level | 0.25 | 6.25 | 0.71 | 0.29 | 0.75 | 3.54 | 3.39 | | 0.5% | |
| 1 | Agriculture & Fisheries | 0.41 | 5.00 | 0.65 | 0.35 | 0.59 | 2.15 | 2.33 | 8 | 3.8% | 2 |
| 2 | Minning & Quarrying | 0.02 | 1.09 | 0.95 | 0.05 | 0.98 | 0.92 | 0.92 | 11 | -0.4% | 8 |
| 3 | Manufacturing | 0.45 | 21.18 | 0.84 | 0.16 | 0.55 | 4.16 | 3.63 | 5 | -0.5% | 9 |
| 4 | Electricity & Water Supply | 0.51 | 16.83 | 0.81 | 0.19 | 0.49 | 1.73 | 2.09 | 9 | 0.5% | 7 |
| 5 | Building & Construction | 0.69 | 81.56 | 0.51 | 0.49 | 0.31 | 3.64 | 3.67 | 4 | 2.0% | 5 |
| 6 | Wholesale, Retail Trade, Hotels & Restaurants | 0.35 | 6.26 | 0.52 | 0.48 | 0.65 | 4.80 | 4.70 | 2 | 2.5% | 4 |
| 7 | Transport Storage & Communication | 0.44 | 8.67 | 0.76 | 0.24 | 0.56 | 3.36 | 3.35 | 6 | 2.5% | 3 |
| 8 | Financial Intermediation | 0.06 | 1.15 | 0.76 | 0.24 | 0.94 | 2.15 | 3.09 | 7 | 9.0% | 1 |
| 9 | Real Estate & Business Activities | 0.12 | 1.43 | 0.69 | 0.31 | 0.88 | 2.31 | 2.00 | 10 | -1.9% | 10 |
| 10 | Public Admin, Defence, Education and Health | 0.09 | 1.48 | 0.11 | 0.89 | 0.91 | 15.87 | 15.90 | 1 | 1.1% | 6 |
| 11 | Other community, Social & Personal Activities and Pvt. Households | 0.39 | 3.75 | 0.24 | 0.76 | 0.61 | 4.63 | 4.16 | 3 | -2.9% | 11 |

*Source: Measured by Author*

2.5%, 2.5%, and 2.0%, respectively. Moreover, the M&Q and manufacturing sectors had negative TFP growth of 0.4% and 0.5%, respectively, during the same period.

Our focus is on non-M&Q sectors that had positive TFP growth during the period, leaving aside the sectors that are related to government activities and those that are non-tradable.[129] Figure (5.7) shows that the only non-M&Q tradable sectors that had positive TFP growth during the period were the financial intermediation and agriculture and fisheries sectors.

*Figure 5. 7: Oman's Average TFP Growth vs Average TFP at National and Multi-Sectoral Levels, Using the Theoretical Framework, During the Period 1998–2016*




*Source: Measured by Author*

### 5.3.3.3 Comparison of Oman's Multi-sectoral TFP Growth Results

While it was expected that the M&Q sector would have negative TFP growth in the theoretical framework estimation, and this is in line with the finding in Chapter (3), it was not expected that the manufacturing sector would also have marginal negative TFP growth, since in Chapter

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[129] Electricity and water supply; building and construction; transport, storage and communication; public administration, defence, education and health; and wholesale, retail trade, hotels and restaurants.

(3) the manufacturing sector had a relatively high average TFP growth of 4.7% for the period 1998–2016. It is therefore worth comparing the multi-sectoral average TFP growth results measured in this chapter with the previous chapter's results that were obtained using the empirical accounting growth exercise. Table (5.9), therefore, shows the average estimated TFP growth results of both the models, revealing that in nine out of eleven sectors average TFP growth is similar and in the same directions (either being positive or negative). For example, the financial intermediation sector's average TFP growth is positive in both the models, with very similar values of 8.3% and 9.0%. The fact that, when comparing the results of both the models, almost 82% of our estimated results are on the same lines provides good comfort.

*Table 5. 9: Oman's Average TFP Growth Estimations Comparisons, Between the Empirical Growth Accounting Exercise and the Theoretical Framework, During the period 1998–2016*

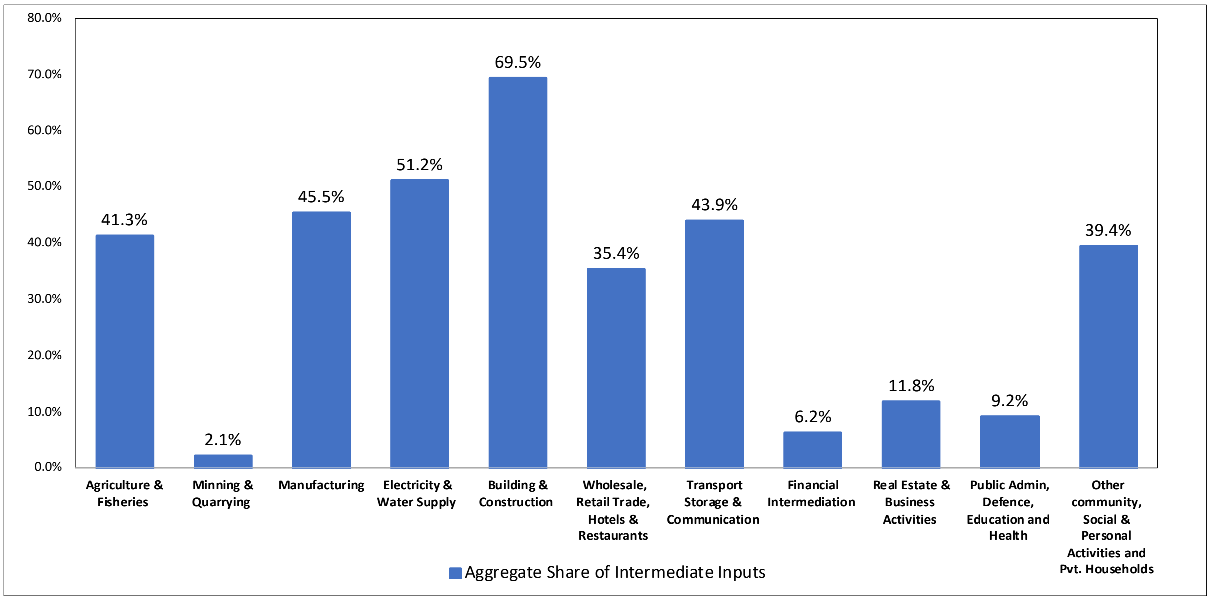
| No. | Tradable Sectoral Activities | Growth Accounting Frame-Work | IO Frame-Work |
|---|---|---|---|
| | National Level | -0.4% | 0.5% |
| 1 | Agriculture & Fisheries | 6.4% | 3.8% |
| 2 | Minning & Quarrying | -0.8% | -0.4% |
| 3 | Manufacturing | 4.7% | -0.5% |
| 4 | Electricity & Water Supply | 0.3% | 0.5% |
| 5 | Building & Construction | 7.9% | 2.0% |
| 6 | Wholesale, Retail Trade, Hotels & Restaurants | 1.8% | 2.5% |
| 7 | Transport Storage & Communication | 5.1% | 2.5% |
| 8 | Financial Intermediation | 8.3% | 9.0% |
| 9 | Real Estate & Business Activities | -3.6% | -1.9% |
| 10 | Public Admin, Defence, Education and Health | -1.4% | 1.1% |
| 11 | Other community, Social & Personal Activities and Pvt. Households | -5.1% | -2.9% |

*Source: Measured by Author*

Interestingly, despite the M&Q sector being the dominant sector in terms of its revenue streams and share of the economy's output (GDP), its average TFP growth results were negative 0.8% in the growth accounting model and negative 0.4% in the theoretical framework model. Considering the M&Q sector's TFP growth results from both the models and analysing the input factors[130] (share of intermediate inputs) that contributed to its productivity, and thus possibly to its TFP growth during the period, the following could be highlighted.

As was discussed earlier, the share of aggregate intermediate input ratio $(a)$ of a sector has a direct effect on its TFP and hence on its aggregate output (GDP).[131] As shown in Figure (5.8), the M&Q sector had the lowest value of the intermediate input shares out of all the sectors in Oman's economy (2.1%). This could therefore also be the reason why its average TFP of 0.92.

*Figure 5. 8: Oman's Multi-Sectoral Aggregate Intermediate Inputs/Consumptions Ratios for the Year 2005, Using the Theoretical Framework*




*Source: Measured by Author*

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[130] The effects of the M&Q sector's input factors (capital stock and labour) on its negative TFP growth were previously analysed in section (3.3.4), for the same period 1998–2016. This showed that the TFP growth of the sector was negative because of inefficient allocation of these input factors.

[131] The effect of a sector's TFP improvement on aggregate output becomes extremely large when intermediate inputs increase ($a \rightarrow 100\%$, 1) and get close to one when ($a \rightarrow 0\%$, 0).

From both the models a clear fact comes out: five out of the six sectors that have the highest positive rankings of average TFP growth during the period 1998–2016, as shown in Table (5.9), are related to services activities;[132] financial intermediation; building and construction; transport, storage and communication; wholesale, retail trade, hotels and restaurants; and finally, electricity and water supply. The main two non-M&Q tradable sectors with the highest rankings in both the models, meanwhile, are the financial intermediation and agriculture and fisheries sectors.

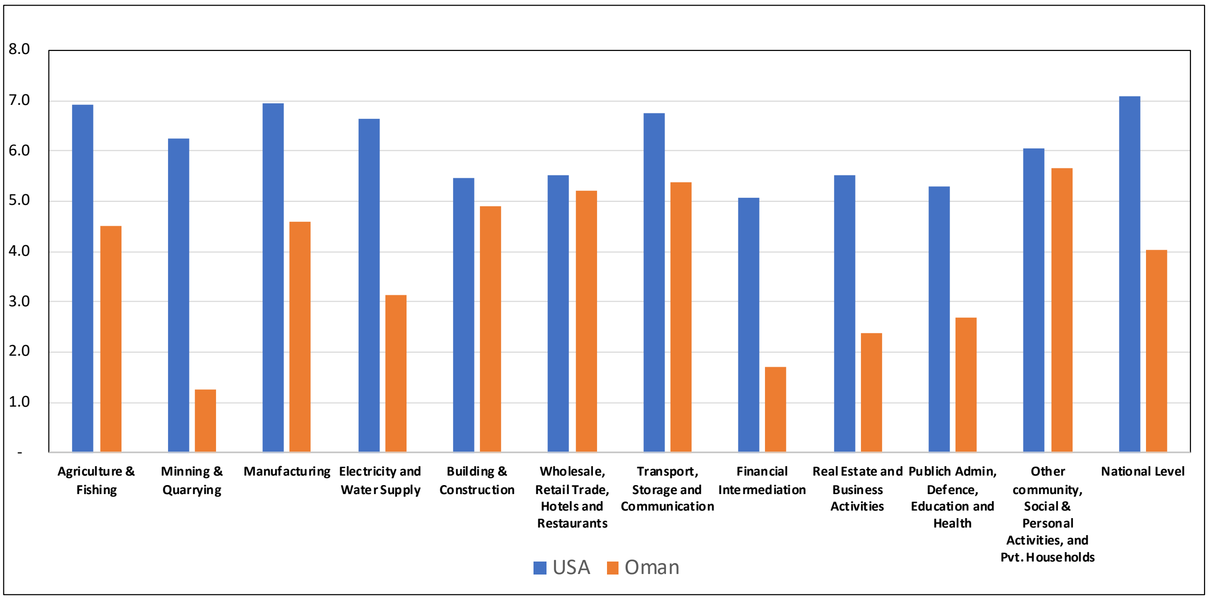
#### 5.3.3.4 Oman and USA Multi-sectoral TFP Performances

In this section we will compare Oman's national and multi-sectoral productivity performances with those of the USA, using the 2005 multi-sectoral IO table for both economies. We also measure the changes in Oman's national and multi-sectoral productivity performances if the USA's national and multi-sectoral intermediate input ratios are used in Oman's national and multi-sectoral production. Moreover, we will measure the changes in Oman's national and multi-sectoral gross-outputs when the USA's measured productivities are used in Oman's production.

We use equation (5.8) to estimate the national and multi-sectoral productivity performances (TFP) for both economies for the year 2005. Figure (5.9) shows the TFP performances for Oman and the USA. The results are very robust and, as expected given that the USA is a more highly developed country than Oman, the aggregate productivity and all multi-sectoral productivity performances in the USA are higher than in Oman.

[132] The same results were also found by Caliendo, Parro and Tsyvinski (2017), namely that the services sector had the highest TFP growth rates during the period of their sample.

*Figure 5. 9: Estimated Productivity (TFP) Performances for Oman and the USA at National and Multi-Sectoral Levels for the Year 2005, Using the Theoretical Framework*




*Source: Measured by Author*

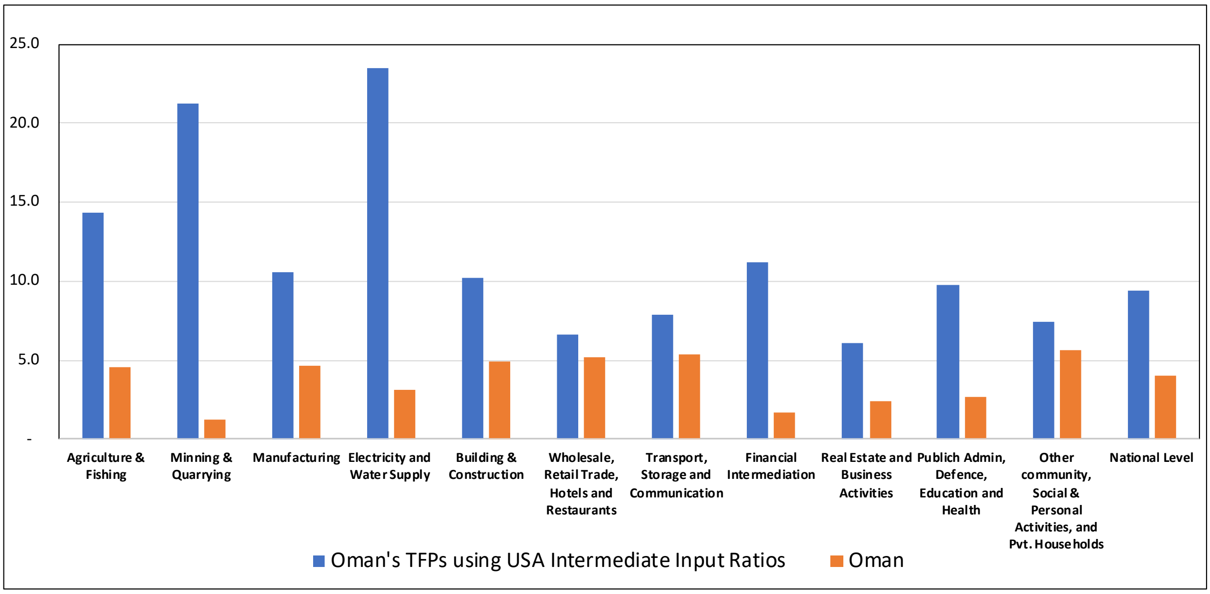
As was discussed earlier, the aggregate shares of multi-sectoral intermediate input ratios have a direct effect on multi-sectoral productivity performances. Hence, applying the USA's national and multi-sectoral intermediate input ratios instead of Oman's national and multi-sectoral input ratios in equation (5.8) to measure Oman's multi-sectoral productivities will show by how much Oman's multi-sectoral productivity performances would change if it had the USA's sectoral advantages. Moreover, the quantum of this change in Oman's multi-sectoral productivity performances will indicate which sectors in Oman's economy have a greater potential for an increase in their productivities, and thus ultimately aggregate output.

The equation (5.8) can be rewritten as:

$$\mathrm{TFP_{iOman}} = \mathrm{X_{iOman}}/[\left(\mathrm{K_{iOman}^{\propto_{iOman}}}\ \mathrm{L_{iOman}^{1-\propto_{iOman}}}\right)^{1-a_{\mathrm{iUSA}}} \{\mathrm{z_{1iOman}^{a_{1iUSA}}}\ \mathrm{z_{2iOman}^{a_{2iUSA}}} \dots \mathrm{z_{niOman}^{a_{niUSA}}}\}\ ] \qquad (5.9)$$

Figure (5.10) shows the results. As expected, the aggregate TFP and all the multi-sectoral productivity performances increased in Oman's economy.

*Figure 5. 10: Oman's Estimated Productivity (TFP) Performances at National and Multi-Sectoral Levels Before and After Incorporating the USA's Intermediate Input Ratios in Oman's Production in the Year 2005, Using the Theoretical Framework*




*Source: Measured by Author*

Knowing Oman's initial national and multi-sectoral productivity performances, we can measure the extent of the changes in Oman's productivities when the intermediate input ratios of the USA were used. For this, we apply the following equation:

$$\Delta TFP_{iOman} = TFP_{iOman\ using\ USA\ Inetrmediate\ Input\ Ratios} - TFP_{iInitial\ Oman} \quad (5.10)$$

As shown in Table (5.10), Oman's national productivity performance could increase by 133% if Oman were to increase its inter-sectoral linkages to the level of the USA's economy. The five sectors in Oman that have the highest potential to increase their productivities if their multi-sectoral linkages increased to the levels of the USA are M&Q; electricity and water supply; financial intermediation; public administration, defence, education and health; and finally, agriculture & fisheries.

Again, since our focus is on non-M&Q productive tradable sectors, financial intermediation, agriculture & fisheries, and manufacturing are the main sectors of interest. These have the potential to increase their productivities by of 559%, 218%, and 129%, respectively.

*Table 5. 10: Extent of Changes in Oman's Estimated Productivity (TFP) Performances at National and Multi-Sectoral levels after Incorporating the USA's Intermediate Input Ratios in Oman's Production in the Year 2005, Using the Theoretical Framework*

| Sectors | Sr. NO. | Oman Initial TFP | Oman TFP after using USA Intermediate Input RatiosPercentages | (ΔTFP) | Ranking |
|---|---|---|---|---|---|
| Agriculture & Fishing | 1 | 4.52 | 14.35 | 218% | 5 |
| Minning & Quarrying | 2 | 1.27 | 21.20 | 1576% | 1 |
| Manufacturing | 3 | 4.61 | 10.56 | 129% | 7 |
| Electricity and Water Supply | 4 | 3.14 | 23.51 | 649% | 2 |
| Building & Construction | 5 | 4.90 | 10.19 | 108% | 8 |
| Wholesale, Retail Trade, Hotels and Restaurants | 6 | 5.22 | 6.65 | 27% | 11 |
| Transport, Storage and Communication | 7 | 5.37 | 7.89 | 47% | 9 |
| Financial Intermediation | 8 | 1.70 | 11.20 | 559% | 3 |
| Real Estate and Business Activities | 9 | 2.39 | 6.06 | 153% | 6 |
| Publich Admin, Defence, Education and Health | 10 | 2.68 | 9.77 | 265% | 4 |
| Other community, Social & Personal Activities, and Pvt. Households | 11 | 5.65 | 7.39 | 31% | 10 |
| National Level | | 4.04 | 9.40 | 133% | |

*Source: Measured by Author*

Now, we use equation (5.3) to measure national and multi-sectoral gross-outputs in Oman's economy, when the USA's national and multi-sectoral productivities are used. Equation (5.3) can be rewritten as follows:

$$X_{iOman} = TFP_{iUSA} \left[ \left(K_{iOman}^{\propto_{iOman}} L_{iOman}^{1-\propto_{iOman}}\right)^{1-a_{i\,Oman}} \{z_{1iOman}^{a_{1iOman}} z_{2iOman}^{a_{2iOman}} \dots z_{niOman}^{a_{niOman}}\} \right] \quad (5.11)$$

Knowing Oman's initial national and multi-sectoral gross-outputs, we can measure the extent of the changes in Oman's gross-outputs when the USA's productivities were used. For this, we applied the following equation:

$$\Delta X_{iOman} = X_{iOman\ using\ USA\ TFP} - X_{i\ initial\ Oman} \quad (5.12)$$

As shown in Table (5.11), Oman's national aggregate gross-output could increase by 75% if Oman were to increase its multi-sectoral productivity performances, and hence its aggregate productivity, to the level of the USA's economy. The five sectors in Oman that have the highest potential to increase their gross-outputs if their productivity performances increased to the

USA's levels are: M&Q; financial intermediation; real estate and business activities; electricity and water supply; and finally, public administration, defence, education and health. Again, since our focus is on non-M&Q productive tradable sectors, it is the financial intermediation, agriculture & fisheries, and manufacturing sectors that are of interest in Oman's economy. These have the potential to increase their gross-outputs by 199%, 53%, and 51%, respectively.

*Table 5. 11: Extent of Changes in Oman's Gross-Outputs at National and Multi-Sectoral levels after Incorporating the USA's National and Multi-Sectoral Productivities (TFP) in Oman's Production in the Year 2005, Using the Theoretical Framework*

| Sectors | Sr. NO. | Oman Initial Gross-Output | Oman Gross-output after using USA TFP | (ΔX) | Ranking |
|---|---|---|---|---|---|
| Agriculture & Fishing | 1 | 192,460 | 294,888 | 53% | 6 |
| Minning & Quarrying | 2 | 6,371,453 | 31,484,479 | 394% | 1 |
| Manufacturing | 3 | 3,064,907 | 4,625,948 | 51% | 7 |
| Electricity and Water Supply | 4 | 616,385 | 1,304,998 | 112% | 4 |
| Building & Construction | 5 | 1,683,454 | 1,876,681 | 11% | 9 |
| Wholesale, Retail Trade, Hotels and Restaurants | 6 | 1,090,588 | 1,153,550 | 6% | 11 |
| Transport, Storage and Communication | 7 | 1,235,272 | 1,552,043 | 26% | 8 |
| Financial Intermediation | 8 | 436,343 | 1,304,332 | 199% | 2 |
| Real Estate and Business Activities | 9 | 723,738 | 1,672,784 | 131% | 3 |
| Publich Admin, Defence, Education and Health | 10 | 1,773,048 | 3,508,949 | 98% | 5 |
| Other community, Social & Personal Activities, and Pvt. Households | 11 | 360,171 | 386,576 | 7% | 10 |
| National Level | | 17,547,819 | 30,771,351 | 75% | |

*Source: Measured by Author*

## 5.4 Conclusion

The main objectives of this chapter were to identify the non-M&Q tradable sectors in Oman's economy that have dominant positions within Oman's multi-sectoral network structure, as well as the ones with large output-multipliers, and large positive TFP, in the year 2005. Also, to identify the main non-M&Q tradable sectors in Oman's economy that had high TFP performances and TFP growth during the period 1998–2016. This was achieved using three different models.

1) The outcome of the analysis of Oman's multi-sectoral production network structure for the year 2005 showed that, although the network structure in Oman was not as complex as that of the USA, there were still a few dominant intermediate sectors which played a major role in the production of economy's output. The manufacturing sector was revealed to be the most dominant non-M&Q tradable sector in Oman's economy, supplied and received the most intermediate goods from other sectors. Moreover, in the economies of both Oman and the USA, the M&Q sector did not have the characteristics of a dominant sector, which confirms earlier findings that this sector exists in isolation from other sectors.
2) The output-multipliers analysis for the year 2005 also showed that there were only a few dominant sectors whose productivities had large and direct effects on the overall output of Oman's economy, since most of the sectors had low output-multipliers. The results showed that the most dominant non-M&Q tradable sector in Oman's economy was the manufacturing sector. Moreover, the model results showed that many more sectors in the USA's economy, than in Oman's, had large output-multipliers, hence having a larger effect on the economy's output if their productivities increased by one unit.
3) The multi-sectoral productivity performances and their growth estimation using the theoretical model, showed that Oman's average productivity growth during the period 1998–2016 was 0.5%. Whereas the average growth in capital stock, labour, and intermediate inputs were 2.9%, 7.3% and 4.8%, respectively, during the same period. The average productivity growth of 0.5% during the period is quite marginal if compared with the growth in the other input factors, which indicates that the aggregate gross-output growth in Oman's economy of 4.8%[133] during the period was mainly driven by capital investments and labour accumulations, rather than productivity. The results showed that out of all the

[133] Measured using the data in Table (5.7).

non-M&Q tradable sectors, the manufacturing sector showed the largest average TFP during the period, while the two non-M&Q sectors that showed the highest average TFP growth during the period were financial intermediation and agriculture and fisheries.

4) The analysis of multi-sectoral productivity performances of Oman's in the year 2005 with those of the USA in the same year showed that all the sectors in the USA have larger productivity performances. When the USA's multi-sectoral intermediate input ratios were incorporated in the multi-sectoral production function of Oman all the sectors' productivity performances increased in Oman's economy. The largest gain was in the M&Q sector, with an increase of 1,576%, if its multi-sectoral intermediate inputs and interlinkages between other sectors of Oman's economy reached the levels seen in the USA. The main non-M&Q sectors that showed the highest potential for an increase in their productivity performances if the USA's level of interlinkages were to be achieved were the financial intermediations, agriculture and fisheries, and manufacturing sectors, with potential increases in productivity of 559%, 218%, 129%, respectively. The results of incorporating the USA's multi-sectoral productivity performances in the multi-sectoral production function of Oman showed an aggregate gross-output gain of 75% in Oman's economy. The largest gain was in the M&Q sector, with an increase of 394% if its productivity were to reach the level of the USA. The main non-M&Q sectors that showed the highest potential for an increase in their gross-outputs if the USA's levels of productivities were to be achieved were the financial intermediations, agriculture and fisheries, and manufacturing sectors, respectively.

The models showed that the three non-M&Q tradable sectors (manufacturing, financial intermediation and agriculture and fisheries) are the ones that have the most effect on the aggregate output in Oman's economy. To some extent, this could be considered as encouraging news for Oman's government, since it implies that output expansion and economic growth can be attained in future if policies are introduced to promote only these three crucial sectors. This contrasts with the USA, for example, where, as shown in Graphs (5.2) and (5.6), there are many more dominant sectors, a denser production network, and many sectors with large output-multipliers. That means that the government of the USA has to promote many more sectors than Oman if it is to achieve sustained economic growth.

# Chapter 6: Effect of Putative Multi-Sectoral Taxes and Subsidies in Oman

In previous chapters we used various economic models to identify the main non-Mining and Quarrying (M&Q) tradable sectors in Oman's economy whose output was significantly influenced by Total Factor Productivity (TFP), and the ones that had positive TFP growth during the period 1998–2016. We also managed to identify which non-M&Q tradable sectors had the greatest effect on the economy's production through their inter-sectoral linkages.

The main objective of identifying these non-M&Q tradable sectors was to enable the government of Oman to further allocate resources to these sectors that would have the most impact on future economic output growth, and diversification away from the M&Q sector.

For the government to allocate further resources to these promising productive tradable sectors would require it either to reallocate resources between economy's sectors or provide extra resources. Hence, in this chapter we will be focusing on the effect on the economy's aggregate gross-output of reallocation of resources between sectors by applying taxes on a particular sector and forwarding these proceeds into another sector (i.e., a policy of subsidizing one sector from proceeds raised from another). Moreover, we apply a fixed resource support by the government to each sector in the economy to measure the effects on the economy's aggregates value-added (GDP) and gross-output.

The following counter-factual exercises will be performed within Input-Output (IO) framework:

1) We will apply different tax rates to what we have found to be the non-productive M&Q sector and use the proceeds to subsidize what we have found to be the more productive manufacturing sector, and then measure the changes that take place in input factors (intermediate inputs, capital and labour), imports, and aggregates value-added and

gross-output in Oman's economy, using the Cobb-Douglas production function and Ghosh models.

2) We will apply a fixed resource support by the government to each sector in Oman's economy, to measure the change in each sector's value-added and gross-output, and hence the aggregates value-added and gross-output, using the Ghosh closed model.

## 6.1 Effects of Taxes and Subsidies Using the Cobb-Douglas Production Function Model

In this section, using Oman's multi-sectoral 2005 IO table, we apply different tax rates to the non-productive M&Q sector and use the proceeds to subsidize the productive manufacturing sector, and then measure the effects on Oman's economy's outputs. Such exercise will support Oman's government in identifying which sectors to tax and by how much, and which sectors to allocate these tax proceeds to as a subsidy to support diversification away from the M&Q sector and hence future economic growth.[134]

### 6.1.1 Methodology

The model assumes a non-market economy, where the decisions on the allocation of taxes and resources are taken by a central planner (government), and one of those missions is to increase the economy's overall output. We assume that the government applies taxes on one sector's input factors (intermediate inputs, and value-added (capital and labour)) and forwards the same proceeds to another sector's input factors. Besides the changes that take place in the production-related capital and labour used by these two sectors as a result of the reallocations of resources, the multi-sectoral IO structure also changes since the intermediate inputs used by these two

[134] Although we will be performing this counter-factual exercise on only two sectors in Oman's economy, in future the same exercise could be performed as a multi-sectoral level simulation.

sectors are now different. This reallocation of resources between sectors affects each sector's imports, value-added and gross-output, and since the measure of an economy's aggregates value-added and gross-output are results of multi-sectoral outputs, the aggregate values are also affected.[135]

Referring to the theoretical framework that we discussed in section (5.2.1). In the equation (5.3), let's consider applying an equal rate of tax (τ) on all input factors of sector (1), and forwarding the tax proceeds (TP) to the input factors of sector (2), pro-rata to their shares in the sector's gross-output,[136] while keeping the other sectors' (*i*-2) input factors unchanged. We fix the multi-sectoral TFPs at the values[137] measured in Chapter (5) and listed in Table (5.10). While varying the values of the sectors' intermediate inputs might result in price changes, we assume that these will be compensated by the change in aggregate imports. We also assume that sectors that have been taxed and subsidized are not optimizing their profits, since these taxes and subsidization policies have been imposed on them by the central planner.

We apply these amendments to equation (5.3) in order to estimate the new aggregate gross-output ( $\mathrm{X}'$ ), and thereafter the changes that take place at the aggregate levels with respect to intermediate inputs, capital stocks and labour, imports, and finally, value-added (GDP). When taxes and subsidies are applied to sectors (1) and (2), equation (5.3) can be rewritten as follows:

$$\mathrm{X}' = \sum_{i=1}^{n} \mathrm{X}_i' = \sum_{i=1}^{n} \mathrm{TFP_i}\ [\ (\mathrm{K}_i^{\propto_i}\ \mathrm{L}_i^{1-\propto_i})^{1-a_i}\quad \{\mathrm{z}_{1i}^{a_{1i}}\ \mathrm{z}_{2i}^{a_{2i}}\ \mathrm{z}_{3i}^{a_{3i}} \ldots \mathrm{z}_{ni}^{a_{ni}}\}\ ] \qquad (6.1)$$

Where, $\mathrm{X}_i'$ is the new gross-output and $\mathrm{TFP_i}$ is the exogenous total factor productivity of sector (i). The parameters $\propto_i$ and $1-\propto_i$ are shares of the capital stock and labour in the inputs,

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[135] As was discussed in Chapters (4) and (5), the multi-sectoral IO structure has direct effect on an economy's outputs.

[136] The pro-rata distribution keeps the ratios of the technical coefficients ($a_{ji}$) unchanged.

[137] By keeping each sector's productivity fixed we assume that the reallocation of resources between sectors does affect the sectoral productivities.

respectively. The associated values of the parameters in this production function satisfy, $a_i = \sum_{j=1}^{n} a_{ji}$, and $0 < \propto_i < 1$, so the production function features constant returns to scale.

In equation (6.1), while measuring the gross-outputs specifically for sectors (1) and (2), after applying taxes ($\tau$) to sector (1) and subsidizing (TP) to sector (2), the input factors for these two sectors to be incorporated as follows:

- $K'_1$ and $K'_2$ are the new capital stocks:

  $(1 - \tau)\ K_1$, and $\left(1 + (TP * \left(\frac{K_2}{X_2}\right))\right) K_2$, respectively.

- $L'_1$ and $L'_2$ are the new labour:

  $(1 - \tau)\ L_2$, and $\left(1 + (TP * \left(\frac{L_2}{X_2}\right))\right) L_2$, respectively.

- $z'_{i1}$ and $z'_{i2}$ are the new intermediate inputs:

  $(1 - \tau)\ z_{i1}$, and $\left(1 + (TP * \left(\frac{z_{i2}}{X_2}\right))\right) z_{i2}$, respectively.

Knowing the initial aggregate gross-output for the year 2005 from the IO table, we can measure the change in the aggregate gross-output when different tax rates are applied on the M&Q sector and the proceeds are used to subsidize the manufacturing sector.

### 6.1.2 Interpretation of Findings

Table (6.1) shows the results of the multi-sectoral gross-output and the aggregate gross-output. When different taxes rates were applied on the M&Q sector and these tax proceeds were forwarded to the manufacturing sector, only those two sectors' gross-outputs changed, whereas all the other sectors' gross-outputs remained unchanged. This indicates that the model captured only the direct affects that took place on these two sectors, leaving aside the indirect inter-sectoral IO effects that should have occurred in the production of the other sectors due to these resource reallocations.

Moreover, increasing the tax rates on the M&Q sector's input factors increased the subsidization of the manufacturing sector's input factors but reduced the economy's aggregate gross-output.

The results also showed that the overall decrease in the M&Q sector's gross-output was always larger than the increase in the manufacturing sector's gross-output, hence reducing the aggregate gross-output.

*Table 6. 1: Oman's Multi-Sectoral Gross-outputs and Aggregate Gross-outputs Estimations OMR (Bn), when Different Tax Rates are Applied on the M&Q Sector and Proceeds Subsidized to the Manufacturing Sector, in the Year 2005, Using the Theoretical Model,*

| Tax on M&Q | Agriculture & Fishing | Minning & Quarrying | Manufacturing | Electricity and Water Supply | Building & Construction | Wholesale & Retail Trade + Hotels & Restaurants | Transport Storage & Communication | Financial Intermediation | Real Estate & Business Activities | Publich Admin & Defence +Education + Health | Other community, Social & Personal Activities + Pvt. Households | Agrregate Gross output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0.19 | 6.37 | 3.06 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 17.5 |
| 10% | 0.19 | 5.75 | 3.40 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 17.3 |
| 15% | 0.19 | 5.43 | 3.55 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 17.1 |
| 20% | 0.19 | 5.12 | 3.70 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 16.9 |
| 25% | 0.19 | 4.81 | 3.85 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 16.8 |

*Source: Measured by Author*

Besides the overall decrease in Oman's aggregate gross-output, the following were observed, as shown in Table (6.2):

1) The aggregate intermediate inputs increased as the tax rates increased. This seems to be due to the fact that the manufacturing sector makes much more extensive use of intermediate inputs for its production than the M&Q sector: 45.5% of its gross-output as compared to 2.1%.
2) Because the intermediate inputs used by the manufacturing sector are higher than those used by the M&Q sector (as discussed in point 1), total imports increased.

3) The aggregate labour also increased, again because the manufacturing sector uses more labour as a percentage of its gross-output than the M&Q sector: 15.4% as compared to 2.1%

4) In addition, the aggregate capital stock decreased, because the manufacturing sector uses a lot less capital than the M&Q sector: 39.1% of its gross-output as compared to 95.7%.

5) Since the aggregate gross-output decreased, and the total imports increased, aggregate value-added (GDP) had to decrease in order to accommodate the increase in aggregate intermediate inputs.[138]

*Table 6. 2: Extent of Changes in Oman's Aggregate-Outputs, OMR (Bn), when Different Tax Rates are Applied on the M&Q Sector and the Proceeds Subsidized to the Manufacturing Sector, in the Year 2005, Using the Theoretical Model*

| Tax on M&Q | Agrregate Gross-output | Aggregate Gross-output Change (%) | M&Q Contribution to output | Manufacturing Contribution to output | Aggregate Intermediate Inputs | Aggregate Labour | Aggregate Capital | Total Imports | VA (GDP) |
|---|---|---|---|---|---|---|---|---|---|
| 0% | 17.5 | 0.0% | 36.3% | 17.5% | 4.4 | 3.0 | 10.1 | 0.9 | 13.1 |
| 10% | 17.3 | -1.7% | 33.3% | 19.7% | 4.7 | 3.1 | 9.7 | 1.2 | 12.8 |
| 15% | 17.1 | -2.6% | 31.8% | 20.8% | 4.9 | 3.1 | 9.6 | 1.3 | 12.7 |
| 20% | 16.9 | -3.5% | 30.2% | 21.9% | 5.0 | 3.2 | 9.4 | 1.5 | 12.6 |
| 25% | 16.8 | -4.4% | 28.7% | 23.0% | 5.1 | 3.2 | 9.2 | 1.6 | 12.4 |

*Source: Measured by Author*

## 6.2 Effects of Taxes and Subsidies Using the Ghosh Model

The results obtained in section (6.1) clearly showed that the Cobb-Douglas production function model used could not capture the indirect inter-sectoral IO effects that should have occurred in

[138] It is worth mentioning here that the sum of aggregate input factors (intermediate inputs, capital and labour) always remained the same (OMR 17.5 Bn), while the decrease in value-added was always equal to the increase in total imports.

the production in the economy's other sectors as a result of the reallocation of resources between the M&Q and the manufacturing sectors. To capture the direct and indirect inter-sectoral effects of the reallocation of resources between sectors we therefore use the Ghosh model (Ghosh, 1958).

### 6.2.1 Theoretical Structure of the Ghosh Model

The Ghosh model is in a way similar to Leontief's model, except that, as discussed in Chapter (4), section (4.1.5), the Leontief model is a demand-driven model, whereas the Ghosh model is a supply-driven model:

$$X_j = \sum_{i=1}^{n} z_{ij} + V_j \tag{6.2}$$

Where, $X_j$ and $V_j$ are the gross-output and value-added of sector (j), respectively, and $(z_{ij})$ are the intermediate inputs into the sector (j), which are again a function of total output $(X_i)$:

$$z_{ij} = f_{ij}\,(X_i) \tag{6.3}$$

but now $(X_i)$ refers to the sum of rows in the IO table. In other words, the intermediate input flow from sectors (i) to (j) depend entirely on the total output of sector (i), which results in ratios called allocations or supply coefficients[139] (Guerra and Sancho, 2010):

$$a_{ij}^{*} = {}^{z_{ij}}/_{X_i} \tag{6.4}$$

As in the case of the Leontief model, the supply coefficients are assumed to be fixed, hence, any increase in the production of sector (i) will be allocated in a fixed proportion to all the recipient sectors. In Leontief's model, these supply coefficients do not remain fixed when there is an exogenous change in final demand, while the technical coefficients remain fixed. In the Ghoshian approach, however, it is the opposite: when there is an exogenous change in value-

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[139] In Leontief's model they are called technical or IO or direct input coefficients.

added, the technical coefficients do not remain fixed while the supply coefficients do remain fixed.

Using the supply coefficient relationship in equation (6.4), we can see that in the Ghosh model this becomes:

$$X_i = {}^{z_{i1}}/_{a^*_{i1}} = {}^{z_{i2}}/_{a^*_{i2}} = \cdots = {}^{z_{in}}/_{a^*_{in}} \tag{6.5}$$

As discussed earlier in Chapter (4), the main problem with the above simple formulation is that, when a particular input (i) is not used in the production of (j) (i.e., $a_{ij} = 0$), the output becomes infinitely large. Therefore, a more appropriate production function is embodied in the model[140]:

$$X_i = \min\left({}^{z_{i1}}/_{a^*_{i1}}, {}^{z_{i2}}/_{a^*_{i2}}, \ldots, {}^{z_{in}}/_{a^*_{i3}}\right) \tag{6.6}$$

Substituting equation (6.4) into equation (6.2), we can rewrite the multi-sectoral supply and demand questions as:

$$X_1 = a^*_{11} X_1 + a^*_{21} X_2 + a^*_{31} X_3 + \cdots + a^*_{n1} X_n + V_1 = \sum_{j=1}^{n} a^*_{j1} X_j + V_1$$

$$X_2 = a^*_{12} X_1 + a^*_{22} X_2 + a^*_{32} X_3 + \cdots + a^*_{n2} X_n + V_2 = \sum_{j=1}^{n} a^*_{j2} X_j + V_2$$

$$. \quad . \quad . \quad . \quad . \quad . \tag{6.7}$$

$$X_n = a^*_{1n} X_1 + a^*_{2n} X_2 + a^*_{3n} X_3 + \cdots + a^*_{nn} X_n + V_n = \sum_{j=1}^{n} a^*_{jn} X_j + V_n$$

And, if generalized, the Ghosh supply and demand balanced equation (6.7) can be rewritten as:

$$X_j = \sum_{i=1}^{n} a^*_{ij} X_i + V_j \tag{6.8}$$

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[140] For more details on the model, refer to section (4.1.5).

Using the simple matrix format of equation (6.8), this can be written as:

$$\begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} a^*_{11} & \cdots & a^*_{1n} \\ \vdots & \ddots & \vdots \\ a^*_{n1} & \cdots & a^*_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} + \begin{bmatrix} V_1 \\ \vdots \\ V_n \end{bmatrix} \tag{6.9}$$

Where, A* is called the allocation or supply coefficients matrix = $\begin{bmatrix} a^*_{11} & \cdots & a^*_{1n} \\ \vdots & \ddots & \vdots \\ a^*_{n1} & \cdots & a^*_{nn} \end{bmatrix}$,

In simple notation, equation (6.9) can be presented as V= $[1 - A^*]$ X. Assuming the inverse of $[I - A^*]$ exists, we get $X = [I - A^*]^{-1}$ V, where $[1 - A^*]^{-1}$ is defined as the Ghosh inverse matrix.

### 6.2.2 Methodology

We use the same methodology that was discussed in section (6.1.1), but instead of the Cobb-Douglas production function model, we use the Ghosh model. When an equal rate of tax (τ) is applied on all input factors of sector (1), and the tax proceeds (TP) are forwarded to the input factors of sector (2) pro-rata to their shares in the sector's gross-output, while keeping the other sectors' (*i*-2) input factors unchanged, the equation (6.9) can be rewritten as:

$$\begin{bmatrix} X'_1 \\ X'_2 \\ X'_3 \\ \vdots \\ X'_n \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \cdots 0 \\ 0 & 1 & 0 \cdots 0 \\ 0 & 0 & 1 \cdots 0 \\ \vdots & \vdots & \vdots \cdots \vdots \\ 0 & 0 & 0 \cdots 1 \end{bmatrix} - \begin{bmatrix} a^*_{11} & a^*_{12} & a^*_{13} \ldots a^*_{1n} \\ a^*_{21} & a^*_{22} & a^*_{23} \ldots a^*_{2n} \\ a^*_{31} & a^*_{32} & a^*_{33} \ldots a^*_{3n} \\ \vdots & \vdots & \vdots \cdots \vdots \\ a^*_{n1} & a^*_{n2} & a^*_{n3} \cdots a^*_{n} \end{bmatrix}^{-1} \cdot \begin{bmatrix} V'_1 \\ V'_2 \\ V_3 \\ \vdots \\ V_n \end{bmatrix} \tag{6.10}$$

Where, X′ are multi-sectoral new gross-outputs and $a^*_{ij}$ are the newly measured allocation coefficient ratios,[141] and $V'_1$ and $V'_2$ are sectors' (1) and (2) value-added after taxes are applied to sector (1) and the proceeds forwarded to sector (2):

[141] In the previous model, the technical coefficient ratios did not change when the input factors of sectors (1) and (2) were reallocated between the two sectors. In the Ghosh model the case is different, however, in that the reallocation of input factors have a direct effect on the supply coefficient ratios.

$(1-\tau)\ V_1$, and $\left(1+\left(TP*\left(\frac{V_2}{X_2}\right)\right)\right)V_2$, respectively.

We use the matrix format in equation (6.10) to measure the new multi-sectoral gross-outputs, and hence the new aggregate gross-output, when different tax rates are applied to the M&Q sector and the proceeds are used to subsidize the manufacturing sector. Knowing the initial multi-sectoral gross-outputs and aggregate gross-output from the year 2005 multi-sectoral IO table, we can measure the changes that take place in the outputs. We also measure the changes that take place at the aggregate levels with respect to intermediate inputs, imports and finally, value-added (GDP).

### 6.2.3 Interpretation of Findings

Table (6.3) shows the results for multi-sectoral gross-outputs and aggregate gross-outputs. Unlike the previous model, where only the M&Q and the manufacturing sectors reacted to the reallocation of resources that took place between them, in this model all the remaining sectors in Oman's economy also reacted due to this reallocation of resources. In other words, besides the changes that took place in the gross-outputs of the M&Q and the manufacturing sectors due to the reallocation of resources between them, all the other sectors' gross-outputs also changed. This indicates that this model captured both the direct and the indirect inter-sectoral IO effects when reallocation of resources took place between the M&Q and the manufacturing sectors.

*Table 6. 3: Oman's Multi-Sectoral Gross-outputs and Aggregate Gross-outputs Estimations in OMR (Bn) when Different Tax Rates are Applied on the M&Q Sector and the Proceeds Subsidized to the Manufacturing Sector, in the Year 2005, Using the Ghosh Model*

| Tax on M&Q | Agriculture & Fishing | Minning & Quarrying | Manufacturing | Electricity and Water Supply | Building & Construction | Wholesale & Retail Trade + Hotels & Restaurants | Transport Storage & Communication | Financial Intermediation | Real Estate & Business Activities | Publich Admin & Defence +Education + Health | Other community, Social & Personal Activities + Pvt. Households | Agrregate Gross-output |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0% | 0.19 | 6.37 | 3.06 | 0.62 | 1.68 | 1.09 | 1.24 | 0.44 | 0.72 | 1.77 | 0.36 | 17.5 |
| 10% | 0.20 | 5.74 | 3.79 | 0.58 | 1.82 | 1.12 | 1.28 | 0.44 | 0.73 | 1.79 | 0.37 | 17.8 |
| 15% | 0.20 | 5.43 | 4.16 | 0.57 | 1.88 | 1.13 | 1.30 | 0.44 | 0.73 | 1.80 | 0.37 | 18.0 |
| 20% | 0.20 | 5.11 | 4.54 | 0.55 | 1.94 | 1.15 | 1.32 | 0.44 | 0.73 | 1.80 | 0.37 | 18.2 |
| 25% | 0.21 | 4.80 | 4.92 | 0.54 | 2.00 | 1.16 | 1.34 | 0.44 | 0.73 | 1.81 | 0.38 | 18.3 |

*Source: Measured by Author*

Moreover, as the tax rates were increased by the government on the M&Q sector's input factors, thus increasing the subsidization of the manufacturing sector's input factors, the economy's aggregate gross-output increased.

In addition, as shown in Table (6.4), the results also revealed:

1) As the rate of tax applied by the government on the M&Q sector was increased, the contribution of the M&Q sector to aggregate gross-output decreased, whereas that of the manufacturing sector increased.
2) The aggregate intermediate inputs increased as the tax rates increased. This seems to be due to the fact that the manufacturing sector makes much more extensive use of intermediate inputs for its production than the M&Q sector: 45.5% of its gross-output as compared to 2.1%.
3) Because the intermediate inputs used by the manufacturing sector are higher than the M&Q sector (as discussed in point 2), total imports increased.
4) The aggregate labour also increased, again because the manufacturing sector uses more labour as a percentage of its gross-output than the M&Q sector: 15.4% as compared to 2.1%

5) The aggregate capital stock decreased, because the manufacturing sector uses a lot less capital than the M&Q sector: 39.1% of its gross-output as compared to 95.7%.
6) Since the aggregate gross-output decreased, and the total imports increased, aggregate value-added (GDP) had to decrease in order to accommodate the increase in aggregate intermediate inputs.

*Table 6. 4: Extent of Changes in Oman's Multi-sectoral Contributions, Intermediate Inputs, Imports, and Value-added in OMR (Bn), when Different Tax Rates are Applied on the M&Q Sector and the Proceeds Subsidized to the Manufacturing Sector, in the Year 2005, Using the Ghosh Model*

| Tax on M&Q | Agrregate Gross-output | Aggregate Gross-output Change (%) | M&Q Contribution to output | Manufacturing Contribution to output | Aggregate Intermediate Inputs | Total Imports | VA (GDP) |
|---|---|---|---|---|---|---|---|
| 0% | 17.5 | 0.0% | 36.3% | 17.5% | 4.4 | 0.9 | 13.1 |
| 10% | 17.8 | 1.7% | 32.7% | 21.1% | 4.7 | 1.2 | 12.8 |
| 15% | 18.0 | 2.6% | 30.9% | 22.9% | 4.9 | 1.3 | 12.7 |
| 20% | 18.2 | 3.5% | 29.0% | 24.7% | 5.0 | 1.5 | 12.6 |
| 25% | 18.3 | 4.4% | 27.2% | 26.5% | 5.1 | 1.6 | 12.4 |

*Source: Measured by Author*

## 6.3 Effects of Multi-Sectoral Extra Resources Using the Ghosh Closed Model

In this section, using Oman's multi-sectoral 2005 IO table, we will apply a fixed resource to each sector in Oman's economy in order to measure the changes that take place in each sector's gross-output and value-added (GDP), and the overall changes in the economy's aggregates gross-output and value-added. This will support Oman's government in identifying which non-M&Q tradable sectors should receive additional resources for its future diversification away from the M&Q sector, and hence achieve future economic growth.

### 6.3.1 Methodology

Guerra and Sancho (2010) were the first to propose a closed version of the Ghosh model by incorporating value-added as an endogenous variable. They suggested that the final consumption for each good should be a positive fraction of the corresponding sectoral output, making the consumption coefficients fully coherent with the output allocation coefficients, while sectoral value-added depends on aggregate consumption. In their version of the Ghosh closed model, the only exogenous variable is what we may call a public input, and therefore production is driven from this supply side variable of the economy (Manresa and Sancho, 2012). The Ghosh closed model assumes a non-market economy where decisions on output allocation are taken by a government whose objective, here, is to enhance the collective good and guarantee a viable distribution of goods. This economy comprises productive units, a private agent and government. The private agent provides capital and labour services to all sectors and in exchange receives income (value-added) that is used to finance his consumption needs and his contribution to the sustainment of the collective. From this contribution, the government provides infrastructure services that are used in the allocation process. These services also provide value to the collective to facilitate goods to society in the form of public goods. The aggregate level of these public goods is of course constrained by the overall contributions to the collective. Assuming that the government decides to allocate additional resources to a particular sector, for example sector (1), these additional exogenous resources may, for example, materialize as new equipment to be used in sector (1) that serves to increases its production levels (pure impact). This impact additionally boosts output levels due to the inter-sectoral multiplicative effects generated by this supply shock in the remaining sectors (indirect impact), according to the IO structure of the economy. In other words, if additional intermediate demand is allocated to the remaining sectors, there would be endogenous supply effects coming from these sectors that further affect the output values in sector (1), increasing the overall value-added in the system.

Following Guerra and Sancho (2010), we use Leontief's demand-driven equation (4.2) and Ghosh's supply-driven equation (6.2), and incorporate government collective consumption ($G$)

and contribution to the collective (C) in these equations, respectively. Thus, we can rewrite the equations as:

$X_i = \sum_{j=1}^{n} z_{ij} + Y_i + G_i$ (demand driven equation), $i = 1{:}\,n$ (6.11)

$X_j = \sum_{i=1}^{n} z_{ij} + V_j + C_j$ (supply driven equation), $j = 1{:}\,n$ (6.12)

In equations (6.11) and (6.12), ($z_{ij}$) are the value of intermediate inputs used between sectors (i) and (j), ($Y_i$) is the consumption of goods (i) by the private agent, ($G_i$) is the collective consumption of goods (i), ($V_j$) is the income (value-added) accruing to the private agent in sector (j), whereas ($C_j$) is the materialization of the contribution to the collective.

Equation (6.11) represents the 'output' distribution for each of the goods, whereas equation (6.12) represents the 'input' repercussions of the said output allocations that are budget feasible. The 'Walras-law'[142] aggregate feasibility constraint in both equations then implies:

$$\sum_{i=1}^{n} G_i + \sum_{i=1}^{n} Y_i = \sum_{j=1}^{n} C_j + \sum_{j=1}^{n} V_j \quad (6.13)$$

The left-hand side of equation (6.13) can be interpreted as national output, as calculated from the expenditure side. The right-hand side, in turn, is national output as obtained from the income side. Alternatively, if the private and public agents behave so as to satisfy some sort of disciplined budget constraint, such as:

$$\sum_{i=1}^{n} G_i = \sum_{j=1}^{n} C_j \text{ and } \sum_{i=1}^{n} Y_i = \sum_{j=1}^{n} V_j \quad (6.14)$$

then the national output accounting in equation (6.13) follows from the aggregation of the budget constraints in (6.14).

[142] The Walras Law states that the existence of excess supply in one market must be matched by excess demand in another market so that both factors are balanced out. It asserts that an examined market must be in equilibrium if all other markets are in equilibrium, (Wikipedia).

Using the matrix forms of equation (6.11) and (6.12), we can arrive at the following equations:[143]

$$\Delta X' = \Delta C' \ (I - A^{*} - d.\lambda')^{-1} \tag{6.15}$$

$$V' = X'.d.\lambda' \tag{6.16}$$

Equation (6.15) is used to measure the change in each sector's gross-output ($\Delta X'$), hence the aggregate gross-output when the extra contribution to the collective ($\Delta C$) is provided to a particular sector (where $(I - A^{*} - d.\lambda')^{-1}$ is the extended Ghosh inverse matrix). Equation (6.16), meanwhile, is used to measure the value-added ($V'$). The same equation could be used to measure the change in each sector's value-added ($\Delta V'$), hence, the change in aggregate value-added:

$$\Delta V' = (X' + \Delta X').d.\lambda' - V' = \Delta X'.d.\lambda' \tag{6.17}$$

Where, $X'$ is the sector's initial gross-output, ($\Delta X'$) is the change in the sector's gross-output, measured using equation (6.15), ($d.\lambda'$) reflects the allocation coefficients for private consumption in terms of value-added, and $V'$is the sector's initial value-added.

### 6.3.2 Interpretation of Findings

We use equations (6.15) and (6.17) to measure the changes in each sector's gross-output ($\Delta X$) and value-added ($\Delta V$), hence the change in Oman's aggregates gross-output and value-added, when Oman's government decides to allocate additional resources ($\Delta C$) to a particular sector. So that, the results can be compared, we apply the same ($\Delta C$) to each sector at a time and measure the changes.

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[143] Refer to Appendix (2) and Guerra and Sancho (2010) for further details on the Ghosh closed model.

Table (6.5) shows Oman's multi-sectoral IO table for the year 2005 before any additional resources are placed by the government in any sector. Table (6.6), meanwhile, as an example, shows the results when OMR 50 million of extra resources have been allocated by the government to the manufacturing sector. In this case, the extra resources generated an overall increase in aggregate gross-output of OMR 1,033,310[144] (from OMR 17,547,821 to OMR 18,581,131), which represent a 5.9% increase in economy's gross-output. This overall production increase is the result of the initial direct increase in the manufacturing sector to satisfy its extra resources support, and the production increase of the latter and all other sectors due to the inter-sectoral linkages effects. The direct production increase in the manufacturing sector (in own production effect) generated OMR 227,118 (from OMR 3,064,908 to OMR 3,292,025), which includes the initial stimulus to satisfy the initial support of OMR 50 million, and OMR 177,118 as a second-round effect, which represents 22.0%. The linkages effects to other sectors, meanwhile, generatd a production increase of OMR 806,192, which represents a 78.0% increase. [145]

Given our focus on non-M&Q tradable sectors, and their value addition to Oman's economy, we highlight that financial intermediation, agriculture & fisheries and finally, manufacturing sectors showed increases in aggregate value-added of 6.3%, 6.1% and 5.7%, respectively; and increases in aggregate gross-output of 6.2%, 6.2%, and 5.9%, respectively, as shown in Table (6.7).

If the Oman's government decided to maximize the economy's output through non-M&Q tradable sectors, therefore, the initial contribution to the collective should be placed in the financial intermediation sector. This is because the implied effects of resources allocation to

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[144] All OMR thereafter are in (000').

[145] This confirms our earlier results of manufacturing sector having strong intersectoral linkages with other sectors in Oman's economy.

this sector, in terms of aggregates value-added and gross-output, are higher than for the other two non-M&Q tradable sectors.

Table 6. 5: Oman' s Multi-Sectoral IO Table for the year 2005, before the Government Sectoral Support, in the IO Framework, OMR (000' )

| | Sr. NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Sum of Inputs | Private Agent | Collective ( G ) | Aggregate Gross Output (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture & Fishing | 1 | 20,277 | 0 | 38,922 | 0 | 148 | 26,276 | 580 | 0 | 105 | 209 | 102 | 86,619 | 104,308 | 1,532 | 192,460 |
| Minning & Quarrying | 2 | 0 | 35,807 | 523,981 | 290,279 | 128,593 | 169 | 147 | 0 | 0 | 31 | 0 | 979,007 | 5,391,014 | 1,433 | 6,371,453 |
| Manufacturing | 3 | 34,168 | 74,796 | 720,544 | 0 | 667,954 | 163,192 | 179,321 | 2,598 | 11,436 | 81,138 | 32,336 | 1,967,483 | 902,300 | 195,125 | 3,064,908 |
| Electricity and Water Supply | 4 | 3,412 | 4,951 | 5,398 | 2,026 | 943 | 5,391 | 410 | 159 | 1,665 | 2,213 | 1,552 | 28,120 | 588,265 | 0 | 616,385 |
| Building & Construction | 5 | 64 | 2,565 | 10,140 | 314 | 326,903 | 5,449 | 8,044 | 2,387 | 14,296 | 10,800 | 1,635 | 382,596 | 1,297,594 | 3,264 | 1,683,454 |
| Wholesale & Retail Trade + Hotels & Restaurants | 6 | 21,272 | 2,088 | 16,840 | 1,454 | 2,811 | 24,759 | 46,049 | 3,055 | 7,435 | 2,312 | 6,178 | 134,254 | 880,237 | 76,097 | 1,090,588 |
| Transport Storage & Communication | 7 | 380 | 5,146 | 12,460 | 16,844 | 7,485 | 23,376 | 226,943 | 1,365 | 3,866 | 3,674 | 27,720 | 329,259 | 874,566 | 31,447 | 1,235,273 |
| Financial Intermediation | 8 | 3 | 72 | 1,024 | 0 | 1,260 | 2,583 | 25,408 | 2,570 | 1,683 | 969 | 784 | 36,356 | 396,368 | 3,619 | 436,343 |
| Real Estate & Business Activities | 9 | 0 | 8,374 | 56,419 | 729 | 12,849 | 115,273 | 12,813 | 11,188 | 23,740 | 34,309 | 44,583 | 320,277 | 374,065 | 29,397 | 723,738 |
| Publich Admin & Defence +Education + Health | 10 | 4 | 2,386 | 676 | 889 | 232 | 429 | 198 | 336 | 699 | 17,177 | 2,920 | 25,947 | 1,262,506 | 484,594 | 1,773,048 |
| Other community, Social & Personal Activities + Pvt. Households | 11 | 0 | 436 | 7,888 | 3,016 | 20,277 | 19,113 | 42,389 | 3,602 | 20,827 | 9,984 | 24,261 | 151,792 | 196,363 | 12,016 | 360,171 |
| | | | | | | | | | | | | | 4,441,709 | 12,267,587 | 838,525 | 17,547,821 |
| Sum of Inputs | | 79,579 | 136,622 | 1,394,291 | 315,549 | 1,169,455 | 386,010 | 542,301 | 27,260 | 85,752 | 162,816 | 142,072 | 4,441,709 | | | |
| Value Added (VA) | | 103,684 | 5,930,371 | 1,524,160 | 271,382 | 433,554 | 652,465 | 633,943 | 388,232 | 603,403 | 1,525,506 | 200,888 | 12,267,587 | | | |
| Collective ( C ) | | 9,197 | 304,461 | 146,457 | 29,454 | 80,444 | 52,114 | 59,028 | 20,851 | 34,584 | 84,725 | 17,211 | 838,524 | | | |
| Aggregate Gross Output (X) | | 192,460 | 6,371,453 | 3,064,908 | 616,385 | 1,683,454 | 1,090,588 | 1,235,273 | 436,343 | 723,738 | 1,773,048 | 360,171 | 17,547,821 | | | |

Source: Measured by Author

*Table 6. 6: Oman' s Multi-Sectoral IO Table for the year 2005 with Government Support of OMR 50 Mn in the Manufacturing Sector, OMR (000' )*

| | Sr. NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Sum of Inputs | Private Agent | Collective ( G ) | Aggregate Gross Output (X) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture & Fishing | 1 | 21,436 | 0 | 41,147 | 0 | 156 | 27,779 | 613 | 0 | 111 | 221 | 108 | 91,572 | 110,273 | 1,620 | 203,465 |
| Minning & Quarrying | 2 | 0 | 37,756 | 552,495 | 306,075 | 135,591 | 179 | 155 | 0 | 0 | 32 | 0 | 1,032,284 | 5,684,386 | 1,510 | 6,718,180 |
| Manufacturing | 3 | 36,699 | 80,339 | 773,938 | 0 | 717,452 | 175,285 | 192,609 | 2,790 | 12,283 | 87,151 | 34,733 | 2,113,278 | 969,163 | 209,585 | 3,292,025 |
| Electricity and Water Supply | 4 | 3,593 | 5,213 | 5,684 | 2,133 | 993 | 5,676 | 432 | 168 | 1,753 | 2,330 | 1,634 | 29,610 | 619,445 | 0 | 649,056 |
| Building & Construction | 5 | 68 | 2,724 | 10,766 | 333 | 347,081 | 5,785 | 8,540 | 2,534 | 15,178 | 11,466 | 1,736 | 406,211 | 1,377,687 | 3,465 | 1,787,364 |
| Wholesale & Retail Trade + Hotels & Restaurants | 6 | 22,474 | 2,206 | 17,792 | 1,537 | 2,969 | 26,158 | 48,650 | 3,228 | 7,855 | 2,442 | 6,527 | 141,838 | 929,962 | 80,396 | 1,152,196 |
| Transport Storage & Communication | 7 | 402 | 5,437 | 13,164 | 17,796 | 7,908 | 24,697 | 239,769 | 1,442 | 4,084 | 3,882 | 29,287 | 347,868 | 923,995 | 33,225 | 1,305,088 |
| Financial Intermediation | 8 | 3 | 76 | 1,080 | 0 | 1,329 | 2,723 | 26,787 | 2,710 | 1,774 | 1,022 | 827 | 38,329 | 417,876 | 3,815 | 460,021 |
| Real Estate & Business Activities | 9 | 0 | 8,830 | 59,491 | 768 | 13,549 | 121,550 | 13,510 | 11,797 | 25,033 | 36,177 | 47,011 | 337,715 | 394,432 | 30,997 | 763,144 |
| Publich Admin & Defence +Education + Health | 10 | 4 | 2,517 | 713 | 938 | 244 | 452 | 209 | 355 | 738 | 18,122 | 3,081 | 27,373 | 1,331,901 | 511,231 | 1,870,505 |
| Other community, Social & Personal Activities + Pvt. Households | 11 | 0 | 460 | 8,324 | 3,182 | 21,398 | 20,170 | 44,732 | 3,801 | 21,978 | 10,536 | 25,602 | 160,185 | 207,221 | 12,680 | 380,086 |
| | | | | | | | | | | | | | 4,726,264 | 12,966,342 | 888,525 | 18,581,131 |
| Sum of Inputs | | 84,678 | 145,558 | 1,484,594 | 332,762 | 1,248,670 | 410,454 | 576,008 | 28,825 | 90,788 | 173,382 | 150,545 | 4,726,264 | | | |
| Value Added (VA) | | 109,590 | 6,268,161 | 1,610,975 | 286,839 | 458,249 | 689,629 | 670,053 | 410,346 | 637,772 | 1,612,398 | 212,330 | 12,966,342 | | | |
| Collective ( C ) | | 9,197 | 304,461 | 196,457 | 29,454 | 80,444 | 52,114 | 59,028 | 20,851 | 34,584 | 84,725 | 17,211 | 888,524 | | | |
| Aggregate Gross Output (X) | | 203,465 | 6,718,180 | 3,292,025 | 649,056 | 1,787,364 | 1,152,196 | 1,305,088 | 460,021 | 763,144 | 1,870,505 | 380,086 | 18,581,131 | | | |

*Source: Measured by Author*

*Table 6. 7: Oman' s Multi-Sectoral with the Government Support of OMR 50 Mn in each sector at a time, OMR (000' )*

| | | Endogenous Changes in Key variables | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sectors** | **Exogenous Shock of** | Δ VA | ΔX1 | ΔX2 | ΔX3 | ΔX4 | ΔX5 | ΔX6 | ΔX7 | ΔX8 | ΔX9 | ΔX10 | ΔX11 | Aggregate ΔX |
| Agriculture & Fishing | Δ C (1) | 6.1% | 34.8% | 5.8% | 6.1% | 5.6% | 5.7% | 6.4% | 5.7% | 5.8% | 5.8% | 5.8% | 5.7% | 6.2% |
| Minning & Quarrying | Δ C (2) | 6.3% | 5.9% | 6.8% | 6.0% | 6.2% | 5.8% | 5.9% | 5.8% | 6.0% | 6.0% | 6.0% | 5.9% | 6.2% |
| Manufacturing | Δ C (3) | 5.7% | 5.7% | 5.4% | 7.4% | 5.3% | 6.2% | 5.6% | 5.7% | 5.4% | 5.4% | 5.5% | 5.5% | 5.9% |
| Electricity and Water Supply | Δ C (4) | 6.3% | 6.0% | 6.0% | 5.9% | 14.0% | 5.7% | 5.9% | 5.8% | 6.0% | 6.0% | 6.0% | 5.9% | 6.2% |
| Building & Construction | Δ C (5) | 6.3% | 5.8% | 6.0% | 5.8% | 5.9% | 9.4% | 5.9% | 5.8% | 6.0% | 6.0% | 6.0% | 5.9% | 6.3% |
| Wholesale & Retail Trade + Hotels & Restaurants | Δ C (6) | 5.9% | 6.0% | 5.6% | 5.5% | 5.5% | 5.3% | 10.2% | 5.6% | 5.6% | 5.6% | 5.6% | 5.5% | 5.8% |
| Transport Storage & Communication | Δ C (7) | 6.1% | 5.7% | 5.8% | 5.7% | 5.8% | 5.5% | 5.8% | 10.6% | 5.8% | 5.8% | 5.8% | 6.1% | 6.1% |
| Financial Intermediation | Δ C (8) | 6.3% | 5.8% | 6.0% | 5.8% | 5.8% | 5.6% | 5.9% | 6.1% | 17.5% | 6.0% | 6.0% | 5.9% | 6.2% |
| Real Estate & Business Activities | Δ C (9) | 5.8% | 5.5% | 5.6% | 5.6% | 5.4% | 5.4% | 6.3% | 5.6% | 5.7% | 12.7% | 5.7% | 6.4% | 5.9% |
| Publich Admin & Defence +Education + Health | Δ C (10) | 4.6% | 4.2% | 4.4% | 4.2% | 4.3% | 4.1% | 4.3% | 4.2% | 4.4% | 4.4% | 7.2% | 4.3% | 4.6% |
| Other community, Social & Personal Activities + Pvt. Households | Δ C (11) | 6.0% | 5.6% | 5.7% | 5.6% | 5.6% | 5.6% | 5.9% | 6.2% | 5.8% | 6.1% | 5.8% | 20.5% | 6.0% |

*Source: Measured by Author*

## 6.4 Conclusion

The main objective of this chapter was to measure the changes that take place in Oman's economy with respect to its input factors, total imports, and value-added and gross-output, when the government reallocates resources between the sectors of the economy. The chapter also sought to identify the non-M&Q tradable sectors in Oman's economy that have the highest potential for future output growth if they were to receive support from Oman's government.

1) The outcome of the counter-factual analysis when using the Cobb-Douglas production function model, applying taxes on the M&Q sector's input factors and directing the proceeds of those taxes to the manufacturing sector's input factors, showed that, as the tax rates were increased by the government on the input factors of the M&Q sector, the economy's aggregate gross-outputs decreased. In addition, only the M&Q and the manufacturing sectors reacted to these taxes and subsidies, the gross-outputs of the remaining sectors remained unchanged. Hence, this model could not be used to measure effects of multi-sectoral taxes and subsidies on Oman's economy.
2) The outcome of the counter-factual analysis when using the Ghosh model, showed that, as the tax rates were increased on the M&Q sector's input factors, the economy's gross-output, intermediate inputs, and imports all increased, while the value-added decreased. In an economy, an increase in its gross-output is considered to be favourable, but a decrease in its value-added is considered to restrain economic growth. As mentioned earlier, we have performed this exercise of allocation of resources between only two sectors of Oman's economy. If a similar counter-factual exercise were to be performed using a simulation, the results could be more useful in providing policy guidance for Oman's government as to which non-tradable sectors in its economy to tax and at what rate, and which non-M&Q tradable sectors those tax proceeds should be allocated to.

3) The outcome of the Ghosh closed model-based analysis of the counter-factual exercise of the government supporting specific sectors with extra resources showed that, although the M&Q sector is the dominant sector in Oman's economy, with aggregates GDP and gross-output shares of 47.6% and 36.3%, respectively, in the year 2005, supporting that the sector does not lead to the biggest increase in the economy's value-added nor in aggregate gross-output. Rather, the non-M&Q tradable sectors of financial intermediation, manufacturing, and agriculture and fisheries, all showed bigger increase in aggregates value-added and gross-outputs when supported, with financial intermediation being the highest. The government of Oman should therefore prioritize the allocation of its current or any future extra resources towards the non-M&Q tradable sectors of the economy, and especially the financial intermediation sector.

# Chapter 7: Conclusion and Future Policy Recommendations

This final chapter summarizes the findings of the thesis and reflects on the implications of those findings in terms of policies to encourage greater economic diversification in Oman, and ultimately more sustainable output growth. The chapter is organized in the following manner. Section (7.1) provides a synthesis of this study's findings. Section (7.2) summarizes the work performed in Chapters (2) to (6) and provides policy recommendations based on those findings. Finally, section (7.3) discusses the limitations of this study and recommendations for future work.

## 7.1 Synthesis of Findings

Oman was chosen for this research since it has experienced a rapid economic development over the last five decades, but this has been dependent mainly on the vast income generated through its Mining and Quarrying (M&Q) sector resources. With those waning, the ability to expand the capacity of its non-M&Q sectors is increasingly important if the country's economic growth is to be sustained in the future.

In this context, the overall objective of this thesis was to review the structural transformation and the development that has taken place in Oman's economy since M&Q products started to be produced and exported in the country. The thesis has focused on identifying the most productive and dominant non-M&Q tradable sectors in Oman's economy. Identification of those sectors allows the government to prioritize the allocation of resources to support their expansion, thus encouraging overall future economic diversification and sustainable growth. This was achieved through five interrelated themes: (i) estimating multi-sectoral input factors, (ii) measuring and analysing multi-sectoral direct and indirect backward and forward linkages, (iii) measuring and analysing multi-sectoral relationships with respect to their demand, supply and prices, (iv) measuring and analysing multi-sectoral network structure, output-multipliers and productivity performances, (v) measuring and analysing multi-sectoral direct and indirect impacts arising from their demand shocks, taxes and subsidies, and their hypothetical extraction from the economy.

Time-series data on Oman was used to measure the multi-sectoral productivities and their growth performances from 1998–2016. Data from the only Input-Output (IO) table available for Oman (for the year 2005) was used for the analysis of the multi-sectoral linkages, network production structure, and the effects of demand shocks, taxes and subsidies, and the hypothetical extraction of those sectors from the economy.

This research is, to the author's knowledge, distinct from most earlier works. There has been no previous attempt to use a selection of economic models to measure and analyse such a range of multi-sectoral input factors contributions, and their growth in Oman's economy over such a long period. Nor has there been any work using the IO framework to measure and analyse such a range of multi-sectoral direct and indirect backward and forward linkages, their demand, supply and prices relationships, their output-multiplier effects, their production network structures, and the effects on an economy's output of sectoral demand shocks, taxes and subsidies, and the hypothetical extraction of those sectors from the economy.

The findings of this study could have important policy implications, not only for Oman, but also for other countries that rely mainly on mineral resources as their main source of revenues. The study can support the public policy makers in these countries in identifying and highlighting the main non-M&Q tradable sectors in their economies that could be prioritized for support to underpin future economic sustainability and growth. Further, since these sectors are mainly driven by private sector activity, the research also supports policies to increase the role of the private sector in an economy.

The preceding chapters of this study showed that the discovery of M&Q sector products, and their extraction, export, and associated revenues, have played a significant role in structuring Oman's economy and in driving economic growth in the country; and, indeed, that Oman's Gross Domestic Product (GDP) growth rates are intimately linked to the contribution of the M&Q sector. Moreover, the dominant sector is shown to have, directly and indirectly, affected the development and growth of other sectors in the economy during the period of our study; in particular the services sector but also, to a lesser extent, the agriculture and fisheries, and manufacturing sectors. Moreover, the study showed that Oman's output growth was mainly driven by capital accumulation and labour contributions rather than productivity contribution. Nonetheless, there are a few productive, dominant, tradable sectors within the economy, and these could be supported to expand further in the interests of economic diversification and sustainable output growth.

## 7.2 Summary of Main Findings and Policy Recommendations

### 7.2.1 Oman's Economy as a Whole

The overall analysis of Oman's economic structural composition and development experience showed that the discovery of M&Q sector products, their extraction, export, and associated export revenues have played a significant role in structuring Oman's economy and in driving economic growth in the country. The data analysis for the period of our research (1998–2016) showed that GDP growth rates have depended mainly on the contribution of the M&Q sector, which has an average share of 51.1% and an average export share of 74.4% during the period. Moreover, this dominant sector affected the development and growth of other sectors in the economy, both directly and indirectly. The services sector was the most affected; its GDP share increased rapidly during the period from 30.6% in 1998 to 49.5% in 2016, with an average share of 39.4% during the period, dwarfing the marginal growth in the share of GDP held by the manufacturing sector, and by the agriculture and fisheries sector.

The overall analysis concluded that, given the risks associated with the M&Q sector, and since the services sector is a non-tradable sector, it is crucial for Oman's long-term economic growth that the country decouple itself from dependency on the M&Q sector, and from the services sector that has grown alongside the M&Q sector. Hence, it needs to adopt a dynamic policy of reallocation and further deployment of its M&Q resources towards the other non-M&Q tradable sectors in its economy.

Based on the main findings summarized above, sections (7.2.2) to (7.2.5) summarize the work performed using different economic models to identify the main non-M&Q tradable sectors that had positive productivity performances, and strong multi-sectoral interplay and structural (direct and indirect) linkages to other sectors in Oman's economy.

### 7.2.2 Oman's Multi-Sectoral Input Factors

The estimation of the input factors contributing to output growth at national and multi-sectoral levels was achieved using an empirical growth accounting exercise that decomposes the growth rate of aggregate output (GDP) into contributions of capital stock, labour, and Total Factor Productivity (TFP). This was considered important for the following reasons. First, to understand the contribution of input factors to output growth and how they have changed through the course of the period. Second, to show the contribution of TFP, as well as whether the growth was simply an accumulation of capital and labour, or whether it was also due to TFP. Third, to show how efficiently input factors have been used in the overall economy and in each sector. Fourth, estimation of TFP contribution of the consolidated sectors, excluding the M&Q sector, would suggest if those sectors can sustain output growth in Oman's economy in the absence of the M&Q sector.

The analysis of the data showed that the output growth in Oman's economy was mainly driven by capital accumulation, of 54.4%, and labour contribution, of 55.8%, rather than productivity, negative of 10.2%, during the tested period. The analysis also showed that the M&Q sector has been significantly driven by the contribution of capital stock rather than technology, with declining capital efficiency, labour productivity, and the possibility of misallocation in its input factors. The consolidated sectors' productivity contribution to output growth was positive during the same period, however; implying that those sectors have the ability to play a significant role in increasing the economy's overall output growth and diversifying the economy away from the M&Q sector. Moreover, the multi-sectoral data analysis showed that, during the tested period, the productive non-M&Q tradable sectors in Oman's economy were agriculture and fisheries, financial intermediation, and manufacturing, respectively. This suggests that, to achieve greater economic diversification and more sustainable growth, the government should promote those sectors and allocate additional resources to support their expansion.

### 7.2.3 Oman's Multi-Sectoral Interlinkages

A number of empirical models within the IO framework were used to measure the multi-sectoral interlinkages in Oman's economy for the year 2005, with respect to their direct and indirect forward and backward linkages, their final demand and total output, final demand and total supply, value-added ratios and prices, and impacts arising from demand shocks in those sectors, or from their hypothetical extractions from the economy. This served to identify the most dominant non-M&Q tradable sectors in Oman's economy.

The forward and backward linkages data analysis showed that, although the M&Q sector in Oman had a leading role (forward linkages) in promoting other sectors and hence the economy, its backward linkages with other sectors were very weak. This indicates that the M&Q sector was working in relative isolation from other sectors in the economy during the study period.

On the other hand, the non-M&Q tradable sectors were the sectors with the strongest linkages in Oman's economy, with manufacturing being the most dominant of those. The data analysis also showed that although any increase in the economy's final demand had a significant impact on the M&Q sector's output and supply, this increase had a relatively low impact on the economy's gross-output. Moreover, any increase in the M&Q sector's value-added showed a large positive effect on the economy's prices, while any increase in the demand from non-M&Q tradable sectors had a significant impact on both the output of those sectors and the economy's gross-output as a whole, especially of the manufacturing sector. Moreover, any increase in multi-sectoral value-added (GDP) led to significant price increases in the non-M&Q tradable sectors. The analysis also showed that any increase in non-tradable sector demand had a significant impact on the economy's gross-output, as well as on those sectors' supply.

The data analysis of multi-sectoral demand shocks confirmed the same findings, i.e. that the non-tradable sectors overall had a greater impact on the economy's gross-output when their demand was increased. The non-M&Q tradable sector that had the largest effect on the economy's gross-output when its demand was increased was the manufacturing sector (as the sector intensively uses intermediate inputs for its gross-output production, as high as 45.5%). The same result was showed using the extraction model: i.e. the manufacturing sector had the greatest impact on the economy's gross-output when it was extracted from Oman's economy.

The study also compared Oman's multi-sectoral linkages to those evident in a more developed economy—the USA—for the same year. The synopsis of the multi-sectoral interlinkages structure in Oman's economy showed that, compared to the USA, only a few sectors have interlinkages with each other.

The overall analysis concluded that, for Oman's economy to grow in a sustainable way in the long term, consideration should be given to utilizing the M&Q sector's resources to further increase its backward linkages with other sectors of the economy. As discussed earlier, a sector's backward linkages increase if it uses more intermediate inputs for its production from other sectors of the economy. In this case, the M&Q sector's backward linkages could be increased by establishing domestic M&Q sector-related equipment manufacturing and/or logistics and/or chemical industries, that could be used by the M&Q sector as intermediate inputs for its production.

Moreover, while developing such domestic industries, policy steps to be considered to avoid a drastic change in the economy's value-added ratios so as to prevent a large increase in prices within the non-M&Q tradable sectors. It would be especially important to pay attention to the non-tradable services sector value-added ratio, since this would be likely to increase due to further demand for services generated by these new domestic industries. One way this could be achieved would be by introducing additional taxes on the services sector in order to reduce its overall demand. Furthermore, the proceeds of those taxes could be redeployed to support the further development of the domestic industries.

### 7.2.4 Oman's Multi-Sectorial Network Structures, Output-Multipliers and Productivity Performances

The multi-sectoral interlinkages in Oman's economy for the year 2005 were measured with respect to their production network structure and output-multipliers, and TFP performances. This was done in order to identify the most dominant non-M&Q tradable sectors in Oman's economy. The analysis was achieved using Gephi software and by applying different empirical models within the IO framework. The study also compared Oman's multi-sectoral linkages and TFP performances with those of the US economy for the same year.

The analysis of Oman's and the USA's multi-sectoral production network structures showed that, although the network structure in Oman was not as complex as that of the USA, there were still a few dominant intermediate sectors that played a major role in the production of the economy's output. The manufacturing sector was revealed to be the most dominant non-M&Q

tradable sector in Oman's economy, supplying and receiving the most intermediate goods from other sectors. Moreover, in both economies, the M&Q sector was not exhibited to be a dominant sector, which confirms the earlier findings that the sector worked almost in isolation from other sectors of both the economies.

Moreover, the data analysis of the output-multiplier results showed that most of the sectors in Oman's economy had low output-multipliers. This means that there were only a few dominant sectors whose productivities had large and direct effects on the economy's output. In the US economy, however, there were many more dominant sectors with large output-multipliers. The results showed that the most dominant non-M&Q tradable sector in Oman's economy was again the manufacturing sector.

The comparison of Oman's multi-sectoral productivity performances in the year 2005 with those of the USA showed that all the sectors in the USA economy had larger productivity (TFP) performances than the parallel sectors in Oman. Furthermore, if the USA's multi-sectoral productivity performances were incorporated in the multi-sectoral production function of Oman, it would lead to an aggregate gross-output gain of 75% in Oman's economy. The largest gain was in the M&Q sector, with an increase of 394%, if its productivity attained that of the USA's M&Q sector. The non-M&Q tradable sectors that showed the highest potential for growth in their gross-outputs if their productivity levels reached the level of the parallel sectors in the USA were the financial intermediations, agriculture and fisheries, and manufacturing sectors, respectively.

The study also estimated TFP and TFP growth in Oman at national and multi-sectoral levels during the period 1998–2016, using a theoretical framework with a Cobb-Douglas production function, instead of using the aggregate growth accounting framework that was used in Chapter (3). The study also made a comparison between the results obtained from both these frameworks.

The data analysis showed that, at the national level, the average productivity growth during the period was 0.5% per annum, while the average growth in capital stock and labour were 2.9% and 7.3% per annum, respectively, during the same period. The fact that the average productivity growth was quite marginal compared to the average growth in the other input factors, indicated that Oman's economy's average gross-output growth of 4.8% per annum during same the period was mainly driven by capital investments accumulations and labour contributions, rather than by productivity. These findings, then, were similar to the ones obtained using the aggregate growth accounting framework. The results at the multi-sectoral level showed that, out of all the non-M&Q tradable sectors, the manufacturing sector showed the largest average TFP during the period. The two non-M&Q tradable sectors that showed the highest average growth during the period, meanwhile, were financial intermediation, and agriculture and fisheries.

The overall analysis concluded that the three non-M&Q tradable sectors (manufacturing, financial intermediation and agriculture and fisheries) were the ones that had the most effect on the aggregate output in Oman's economy. This implies that, to achieve greater economic diversification and more sustainable growth, the government should promote those sectors and allocate additional resources to support their expansion.

### 7.2.5 The Putative Effect of Multi-Sectoral Taxes and Subsidies in Oman

Based on the findings and recommendations highlighted in sections (7.2.1) to (7.2.4), the thesis demonstrates that if the government of Oman wishes to diversify the country's economy and embed sustainable output growth it needs to reduce the economy's dependency on the M&Q sector resources, and adopt a policy of reallocating the resources of that sector, and/or deploying additional resources, to support the expansion of the main productive and the dominant non-M&Q tradable sectors in the economy.

Building on these findings, the thesis also sought to measure the effects on the economy's outputs of the reallocation of resources between sectors, specifically through policies applying additional taxes on the input factors of a particular sector (in our case the non-productive M&Q sector) and forwarding these proceeds to the input factors of another sector (in our case the productive manufacturing sector), (i.e., a policy of subsidizing one sector from proceeds raised from another). This was achieved by performing counter-factual exercises using the Ghosh model, within the IO framework.

The data analysis showed that as the tax rates were increased on the M&Q sector's input factors, the economy's gross-output, intermediate inputs, and imports all increased, while the aggregate value-added decreased.

Moreover, the study also measured the effects on the economy's value-added and gross-output if a policy of the government deploying extra resources to support a particular sector were to be adopted. This was achieved using the Ghosh closed model, within the IO framework.

The data analysis showed that further support for the dominant M&Q sector would not greatly increase either the economy's value-added or gross-output. Rather, the non-M&Q tradable sectors of financial intermediation, manufacturing, and agriculture and fisheries, all showed larger increases in the economy's value-added and gross-outputs when supported, with the financial intermediation sector being the most impactful in this regard.

The overall analysis noted that when applying taxes and subsidies to an economy's sectors careful consideration needs to be given to the fact that while an increase in aggregate gross-output is considered to be favourable, a decrease in aggregate value-added serves to restrain economic growth. Besides, the government of Oman should prioritize the allocation of its current or any future extra resources mainly towards the non-M&Q tradable sectors of the economy, and in this case the priority should be given to the financial intermediation sector.

### 7.2.6 Further Policy Recommendations

When examining the multi-sectoral linkages in Chapter (4), the study also examined the possible impact of the Dutch disease on Oman's economy during the period 1998–2016, due to the windfall gains from the M&Q sector. The overall analysis of all the tested parameters (exchange rates, multi-sectoral growth and labour movement between the sectors) showed that, the economy did not exhibit the characteristics of the Dutch disease.

Although, under the conventional model of the Dutch disease, one would expect to see the movement of input factors from the non-M&Q sectors in Oman's economy to the booming M&Q sector, especially labour movement, the data analysis showed that this did not in fact take place. This may have been due to the M&Q sector being a capital-intensive sector, thus requiring more capital than labour. Moreover, the enormous increase in the services sector during the period, which arose due to the high demand for services, both from the M&Q sector and the government, and due to the limited role of the manufacturing and agriculture and fisheries sectors in the economy, meant that the services sector attracted most of the labour during the period (83.3% of total workforce in the year 2016).

The overall data analysis showed that the tradable sectors, such as manufacturing and agriculture and fisheries, did not gain as much benefit from the M&Q sector's boom as the non-tradable services sector. Hence, it is crucial for Oman's government to direct further resources to support the expansion of those productive non-M&Q tradable sectors.

### 7.2.7 Summary of Recommendations

Countries that derive their major revenue from a single natural resource are vulnerable to uncertainties such as how long such revenue would continue, resource price volatility, and changes in demand, or even substitution. To ensure their future economic sustainability and growth, therefore, they need to identify new revenue streams.

In the case of Oman, this thesis has shown that it is crucial for the government to decouple its economy from the M&Q sector revenue through prioritizing the allocation of M&Q income to the most productive and dominant non-M&Q tradable sectors in the economy. Such a policy should encourage the expansion of those non-M&Q tradable sectors, and thus embed overall economic diversification and sustainable output growth. Moreover, the adoption of this policy would help to increase productivity by gradually transforming the economy from an investment and labour-driven economy to a productivity-driven one.

## 7.3 Limitations and Future Work

### 7.3.1 Limitations

As with all pieces of research, this study is affected by a number of limitations. These are surveyed here.

A key initial limitation was that the literature on multi-sectoral input factors contributions to output growth, and on sectoral interlinkages within the IO framework is very limited in respect to Oman, and in many cases not available at all. This limited the extent of historical analysis and comparison that it was possible to conduct in this study.

In addition, clearly, a study of this kind is utterly dependent on access to accurate, timely and reliable statistics. In that regard, with respect to the measure of multi-sectoral input factor contributions to output growth, data was only available for the period between 1998 and 2016. This presents a limitation in the sense that a longer timeline of data would have been preferable in order to have a better understanding of trend shifts, especially since the M&Q sector was already well-established as the main contributor to Oman's GDP by 1998. Moreover, the initial capital stocks in the various sectors in the year 1998 were not available and thus had to be measured using different models, which could have introduced some unreliability into the obtained results.

Another limitation of this study was that all the multi-sectoral interlinkages models were based on just one IO table, since there is only one IO table available for Oman (for the year 2005). This limited the scope of work that it was possible to perform within this thesis, as is discussed in section 7.3.2 below. Moreover, to measure the multi-sectoral productivities and their growth during the period 1998–2016 the multi-sectoral intermediate input ratios for years other than 2005 had to be calculated based on the ratios from the 2005 IO table. This inevitably introduced a weakness into the analysis. Furthermore, basing the entire analysis period on one year of IO table data was also a limitation in the sense that the data is now almost 16 years old, and it is entirely plausible that Oman's economy has already changed since then.

Moreover, the overall IO models that have been used in this research are comparative statistical models, which have their own limitation as was discussed in section (4.1.6), hence, the reported findings of this research should be considered with caution.

### 7.3.2 Future Work

This study covered nineteen years (1998–2016) with respect to measuring and analysing multi-sectoral input factors contributions to output growth, and one year only (2005) with respect to multi-sectoral interlinkages within the IO framework. Future studies are therefore needed when new data becomes available so results can be assessed periodically, and policies improved accordingly.

A vital area of future work, therefore, is the development of additional IO tables for Oman for years other than 2005. Additional IO tables could be used to measure the multi-sectoral interlinkages, using the same models in this thesis, so as to compare the dynamics of the changes that have taken place in Oman's economy across different periods. Moreover, if more than one IO table were available, multi-sectoral productivity (TFP) performances and intermediate inputs changes and their dynamics could also be measured using IO models.

An area in which the work in this thesis could be extended in order to give a fuller picture of the impacts of reallocating resources across sectors is in respect to understanding the effects of such changes on the labour market. For example, in section (4.4.4), a multi-sectoral extraction model was used to measure the direct and indirect effects on Oman economy's gross-output, when a particular sector is extracted from the economy. The same model could be used to measure the direct and indirect effects on the labour workforce when a particular sector is extracted from Oman's economy.

In addition, in section (6.2), counter-factual exercises were performed to measure the effects on the economy's outputs at national and multi-sectoral levels when taxes and subsidies were enforced by the government on two sectors only. The same model could be used to measure and analyse the effects on the economy's output when taxes and subsidies are applied to more than two sectors. This could be achieved using simulation softwares.

Finally, this work has focused on Oman. Most other countries in the Gulf Cooperation Council (GCC), however, are experiencing similar challenges to Oman in terms of adjusting their economies to a post-oil and gas future. Despite the fact that this is considered a high priority by the governments in the region, as in Oman, their remains a lack of suitable and up to date studies adopting the range of methodologies applied in this thesis to understand the IO framework and multisectoral interlinkages in those economies. This means that, again as in Oman, policy interventions are currently not informed by a robust model of these countries' economies. Given the increasing urgency of the need to diversify the economies in the region, the kind of research undertaken in this study also needs to be conducted for the other GCC economies, including the background development of robust datasets if necessary.

# Appendix (1)

To confirm that technical coefficients ($a_{ji}$) actually correspond to the entries of the IO matrix (A). We redefine the coefficients as ($\tilde{a}_{ji}$).

Considering a profit maximization of an intermediate producer:

$$\mathrm{MAX}_{z_{ji}}(\pi_i) = P_i X_i - \sum_{j=1}^{n} P_j z_{ji} - r\,k_i - w\,l_i \tag{1}$$

Where $P_i$, $P_j$, r, and w are prices of goods i and j, interest rate and labour wages, respectively.

Substituting $X_i$ from equation (5.3):

$$\mathrm{MAX}_{z_{ji}}(\pi_i) = P_i\, A_i\, (K_i^{\alpha_i}\, L_i^{1-\alpha_i})^{1-\tilde{a}_i} \{z_{1i}^{\tilde{a}_{1i}}\, z_{2i}^{\tilde{a}_{2i}} \ldots z_{ni}^{\tilde{a}_{ni}}\} - \sum_{j=1}^{n} P_j\, z_{ji} - r\,k_i - w\,l_i \tag{2}$$

Where, $\tilde{a}_i = \sum_{j=1}^{n} \tilde{a}_{ji} \in (0,1)$.

Then, the first-order condition with respect to $z_{ji}$:

$$\tilde{a}_{ji} = \frac{P_j z_{ji}}{P_i X_i} = \frac{\text{Value of good j used in producing of good i}}{\text{Total value of good i}}$$

$$= \frac{\text{Share of good j used in producing of good i}}{\text{Total share of good i}} \tag{3}$$

Hence, $\tilde{a}_{ji} = a_{ji}$.

This completes the Proof.

# Appendix (2)

The Leontief demand-driven equation, and the Ghosh's supply-driven equation, discussed in section 6.3.1, can be represented in matrix terms, respectively, as follows:

$$Z\,.\,e + Y + G = X \tag{1}$$

$$e'.Z + V' + C' = X' \tag{2}$$

Where $e$ is a summation vector, Z is the intermediate inputs matrix, Y is the consumption of good by the private agent, G is the collective consumption of a good, X is gross-output, V is income (value-added) accruing to the private agent, and $C$ is the materialization of the contribution to the collective.

We now need to define the matrix A* of allocation coefficients:

$$\text{where, } [A^*]_{ij} = \left[\widehat{X}^{-1}.\ Z\right]_{ij} = a^*{}_{ij} = {}^{z_{ij}}\!/_{X_i} \tag{3}$$

The $\widehat{X}$ stands for the diagonalized version of X, while $\widehat{X}^{-1}$ is the inverse matrix of $\widehat{X}$. Solving for Z in (3) and substituting in identity (2), we obtain an equation in X:

$$e'.Z + V' + C' = e'.\widehat{X}\,.\,A^* + V' + C' = X'\,.\,A^* + V' + C' = X' \tag{4}$$

Now, assuming a possible closure for value-added, we define coefficient $\lambda_i$ as value-added per unit of aggregate private consumption, and $d_j$ as the allocation coefficient for private consumption:

$$\lambda_i = {}^{V_i}\!\Big/_{\sum_{j=1}^{n} Y_j} \tag{5}$$

$$d_j = {}^{Y_j}\!\Big/_{X_j} \tag{6}$$

From (5) and (6) we find:

$$V_i = \lambda_i \, . \, \sum_{j=1}^{n} d_j \, . \, X_j \tag{7}$$

Equation (7) in matrix terms becomes:

$$V = \begin{bmatrix} V_1 \\ \vdots \\ V_n \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \vdots \\ \lambda_n \end{bmatrix} . \begin{bmatrix} d_1 & \dots & d_1 \end{bmatrix} \, . \begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} = \lambda \, . \, d' . \, X \tag{8}$$

Where, the matrix $\lambda \, . \, d'$ reflects the allocation coefficients for private consumption in terms of value-added. Under this possible closed version of the Ghoshian approach, this matrix allows endogenizing changes in value-added V generated and accumulated by the private agent when there is an exogenous change in that part of the production value contributed to the collective, i.e., ΔC.

Rearranging equation (8), and then incorporating it into equation (4), we achieve:

$$V' = X' . \, d \, . \, \lambda' \tag{9}$$

$$X' = X' \, . \, A^* + V' + C' = X' \, . \, A^* + X' \, . \, d \, . \, \lambda' + C' \tag{10}$$

Solving again for $X'$, we achieve:

$$X' = C' \; (I - A^* - d \, . \, \lambda')^{-1} \tag{11}$$

Hence,

$$\Delta X' = \Delta C' \; (I - A^* - d \, . \, \lambda')^{-1} \tag{12}$$

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