Estimating the Rate of Technical Change in the Oil and Gas Industry using Data from Private and National Companies

by

Tochukwu C. Akobi

BEng. Metallurgical and Materials Engineering
Ahmadu Bello University, 2006

SUBMITTED TO THE SYSTEM DESIGN AND MANAGEMENT PROGRAM
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2016

Signature of Author____
Tochukwu C. Akobi
System Design and Management Program
May 20, 2016

Certified by____
Dr. Sergey Paltsev
Senior Research Scientist, Joint Program on the Science and Policy of Global Change
Thesis Supervisor

Accepted by____
Patrick Hale
Executive Director, System Design and Management Program

Estimating the Rate of Technical Change in the Oil and Gas Industry using Data from Private and National Companies

by

Tochukwu C. Akobi

Submitted to the System Design and Management Program on
May 20, 2016 in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Engineering and Management

ABSTRACT

Modelling the long term prices for crude oil and natural gas has been a critical undertaking of many governments, companies, and analysts. The most important goal of this exercise is to effectively project the price of crude oil and natural gas to inform and shape today's decisions. Most long-run energy models in use today are unable to quantify properly a factor for supply growth due to technical change – a component that has played a significant role in the provision of access to newer streams of crude oil and natural gas - because the measurement of productivity and technical change at the oil and gas industry aggregate level are limited to a small set of studies for few countries.

This thesis attempts to measure the rate of change in technical change for the oil and gas industry using data from private and national major companies. Publicly available financial data are aggregated from eight major producers over a time period of at least fifteen years for the national oil companies and forty five years for the private oil companies. The time period chosen effectively covers three distinct periods of different crude oil price behavior.

Three productivity measurement methods are applied - the growth accounting, index number theory, and regression method – to measure for the rate of change in productivity and technical change for the private and national oil companies, and for the aggregate that allows to infer the rates for the entire industry. The thesis concludes that the rate of technical change for the industry can be assessed and it proposes a reasonably estimated range (1.4-1.7 per cent per year) that can be incorporated into long-run energy models. The thesis also presents insights to the drivers that influence the rate of growth. Finally, the thesis provides a dataset containing the information about output and labor and capital inputs for major oil and gas companies that can be used by researchers to enhance studies on the rate of technical change in the oil and gas industry.

Thesis Supervisor: Sergey Paltsev

Title: Senior Research Scientist, Joint Program on the Science and Policy of Global Change

ACKNOWLEDGEMENTS

My advisor Sergey Paltsev who influenced the content and thoughts reflected in this piece of work. His guidance and thoughtfulness helped provide me the right direction and a path to successfully completing this research. For that, I will always be grateful.

My time in MIT has been a memory I will not forget – the spirit of collaboration and the desire to learn and apply. I will never let go of these. The professors and advisors who I had the opportunity to interact with and through this process I was able to challenge myself and aspire to be more. I would like to thank Christopher Knittel, Andrew Lo, Bill Aulet, Scott Stern, Michael Cusumano, and many others who helped create and shape my MIT experience.

Over the last 21 months, I have had the opportunity to interact and learn from a multitude of talented System Design and Management Program Fellows. Most of all, I would like to mention my SDM'15 cohorts, I won't forget the barbeques, get-togethers, and of course, the core classes and OSs. Each of you have influenced my life and made this experience worth it!

The MIT expert librarians: Nicholas Albaugh, Christine Sherratt, and Katherine McNeil. I am grateful for the immense support you all provided me and how it enabled me locate data to build the data set I needed for this research work. Thank you!

My time in MIT won't be complete without a mention of my work as a research assistant with Professor Michael Golay, and later as a BP Fellow with MIT Energy Initiative seconded to the Joint Program on the Science and Policy of Global Change. I am grateful for these opportunities to work on academic projects of interest.

DEDICATION

Every joy in my life comes from one source, my family. My wife, Chinaza, and son, Naeto. You both will continue to be the foundation for every success I have experienced throughout my career, school experience, and life. Thank you for your support and understanding; I love you both.

I would like to dedicate this thesis to my father and mother. You taught me how to work hard and to always maintain a positive attitude. I am who I am because of your love, the opportunities that you provided me, and your constant support throughout my life. Thank you for everything you have ever done for me; I love you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. PROBLEM AND MOTIVATION

"'Peak oil' is proving a misleading idea. The foreseeable problem is not finite resources but the rate at which these very large resources can be converted into reserves for potential production. Reserves of oil and gas have each more than doubled since 1980 – faster than the increase in production. Technologies are developing which are creating new reserves of 'unconventional' oil, as they already have for gas." (Mitchell, Mitchell, & Marcel, 2012)

1.1. INTRODUCTION AND RESEARCH QUESTION

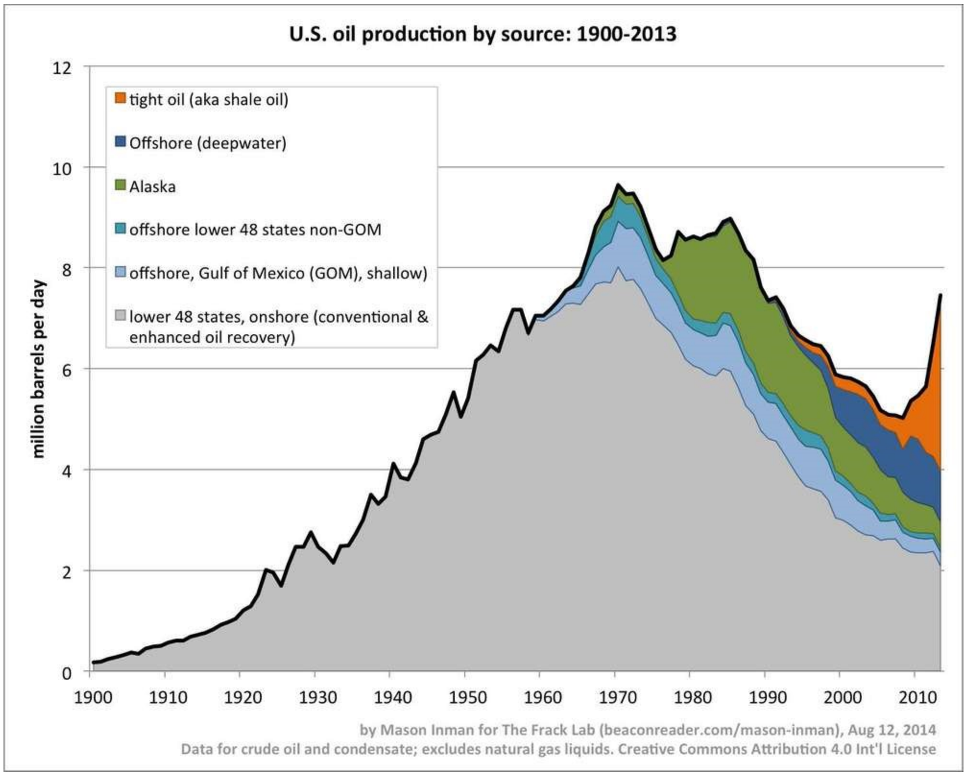
"Essentially, all models are wrong, but some are useful"

George E. P. Box, English statistician

Modelling the long term prices for crude oil and natural gas has been a critical undertaking of majority of governments, researchers, companies, and analysts. The most important goal of this exercise is to effectively predict the price of crude oil and natural gas and inform and shape today's decisions. These decisions span across a wide spectrum affecting multiple stakeholders in different ways. From influencing the future amounts of income available to governments to shaping the macroeconomic climates that directly or indirectly affect global industries all the way to local businesses to influencing the overall standards of living of individuals in the economy. It is no surprise how critical crude oil and natural gas are to the stability of the world and its economy and, as a result, the level of importance placed on understanding and attempting to estimate future long term prices.

Supply and demand relationships that connect prices and quantities, elasticity of supply, income and price elasticities of demand, and macroeconomic factors such as macroeconomic consumption and real gross domestic product (GDP) are areas that have been given tremendous focus when modelling long term crude oil and natural gas prices. The other area with enormous research interest that has had significant influence on future prices of crude oil, but at the same time embodies higher levels of uncertainty, is the focus on the non-market forces and the geopolitics that results from the activities of nations especially the major global crude oil and natural gas producers like the Organization of the Petroleum Exporting Countries (OPEC), Russia, and most recently, North America. Recent events worth noting are the actions (or reaction) by conventional oil producers to protect their market share by maintaining or increasing their oil production volumes. These actions are attempts to prevent North America's increased production from new oil resources like tight oil[1] from tight oil reservoirs in the US and crude bitumen from the tar sands of Canada (see Figure 1 for the U.S oil production from different sources). The entrants of these unconventional sources, and their strengthening position as "newer sources of crude oil" (Mitchell et al., 2012) has led to these reaction from OPEC resulting in a steep decline in the prices of crude oil and contemporaneously, the flooding of the global market with crude oil. This event has been explained to some degree by new research corroborating OPEC's tendency to tolerate ordinary substitutes to its oil but deter high-potential ones like the unconventionals from North America. (Andrade de Sá & Daubanes, 2014).

[1] Tight oil is conventional oil found within reservoirs with very low permeability. The oil contained in these reservoirs will typically not flow to the wellbores at economic rates without assistance from technologically advanced drilling and completion processes. (Resources, 2012)



Source: (Inman, 2014)

Figure 1 – US Oil Production by Source: 1900 - 2013

At the center of the declining crude oil prices and the oversupply of crude oil in the global markets is the confluence of two significant observations. The first is the proliferation of newer crude oil sources and the second, the robust ability of producing countries to deal effectively with lower and lower crude oil prices countering the common knowledge that these countries needed crude oil prices to be above a specific price point to cover their range of respective marginal costs needed to maintain higher production levels. Putting these observations in context, the overall objective of this thesis is focused on addressing the rate of technological progress in oil and natural gas companies, the role technological improvement has played in improving the extraction of oil and gas from technically recoverable resources, increasing long term supply of crude oil and natural gas, and conversely effecting some influence on the long term price of oil.

The thesis will focus on a set of questions in the light of meeting the overall objective of this research work. These research questions are listed below and are based on the above discussion:

1. Can productivity and technical change[2] *at the global industry level be estimated?*

2. Can this assessment of productivity and technical change be useful in quantifying the changes in the supply and price of crude oil and natural gas?

3. What are the underlying drivers influencing the changes in productivity and technical change?

1.2. STRUCTURE OF THESIS

The thesis will comprise of five chapters. The first two chapters will introduce my research work, review the applicable literature available and expand on how my research adds to the current available body of literature. I will introduce and define concepts fundamental to understanding my research work. I will then build on these concepts and link currently established theories and assumptions to shape the methodology I will be adopting. The methodology and the follow-up analysis will be presented in the third and fourth chapters where I will mainly be presenting and analyzing my data to reveal relevant findings. My findings will be presented in a way that aligns directly with the objectives of my research while answering the critical research questions. The final chapter will summarize these findings, provide insights to what they could mean, and shed some light on future directions for follow-up research.

[2] The concept of productivity and technical change will be addressed in later sections of this chapter.

The next sections introduces and defines concepts fundamental to understanding this body of research.

1.3. An Overview of the Global Oil and Gas Exploration and Production Industry

"Prospecting for oil is a dynamic art... The greatest single element in all prospecting, past, present and future, is the man willing to take a chance"

Everett DeGolyer, American geophysicist.

Oil and gas industry is concerned with the exploration, development, and operation of oil and gas fields. Its primary activities include oil and gas exploration, crude oil extraction, natural gas extraction, liquefied natural gas (LNG) production, liquefied petroleum gas (LPG) production, and oil shale extraction.

The oil and gas exploration and production industry is a subset of the petroleum value chain represented by the red boundary in Figure 2. This area covers the prospecting for the exploration for oil and/or gas, then the appraisal, development of new reserves, and finally the production of oil and gas from developed projects. All together, these activities are commonly referred to as exploration and production (E&P) or simply as "upstream" oil and gas (Tordo & Arfaa, 2011). The upstream oil and gas industry subset will be the primary focus of this thesis. For future reference and source of data, the international designation for the oil and gas industry is NAICS 211[3] and ISIC 06[4].

---

[3] North American Industry Classification System (NAICS, pronounced "nakes") is used by business and government to classify business establishments according to type of economic activity (process of production) in Canada, Mexico, and the United States of America. This designation follows the 2012 NAICS definition. (US Census Bureau Special Projects Staff, 2012)

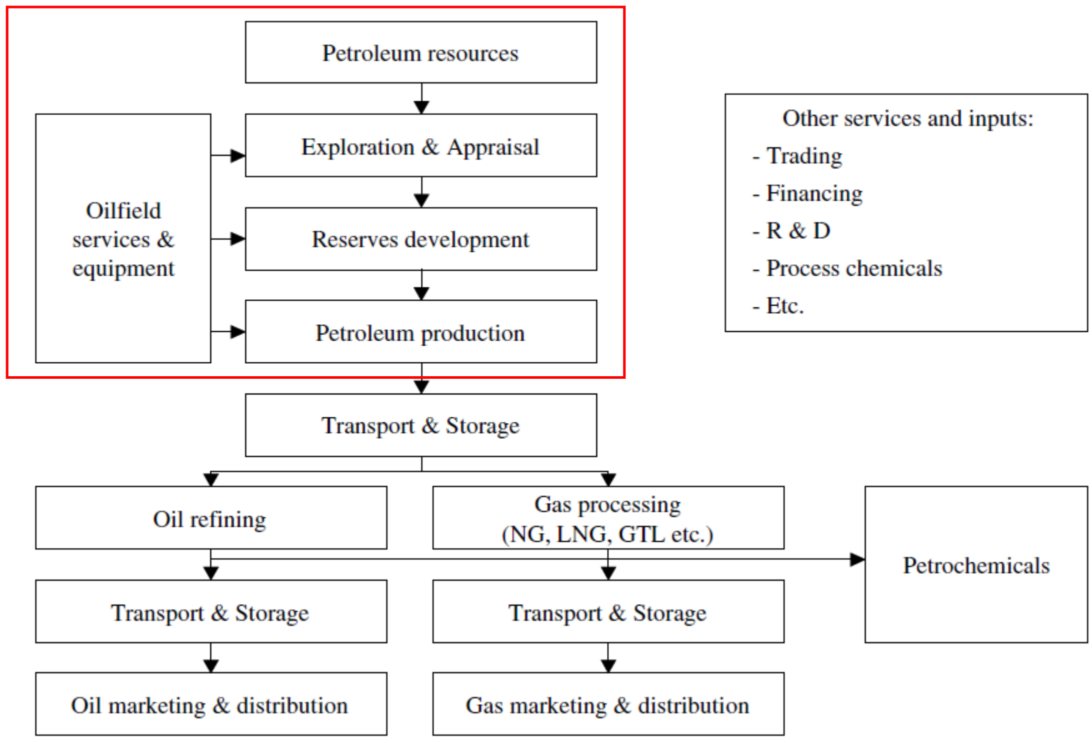
[4] The ISIC code represents the International Standard Industrial Classification of all economic activities. A classification created in 1948 by the Department of Economic and Social Affairs of the United Nations and adopted

Within this subset there are a variety of players: fully integrated companies, national oil companies, independent oil and gas producers, oilfield services companies, etc. These players differ by many factors, such as: core business capabilities, type and size of operations, geography, customers, etc. This thesis will focus on understanding and analyzing the activities of two major types of players within this industry - the fully-integrated Private[5] Oil Companies abbreviated to POC, and their national counterparts, the National[6] Oil Companies, similarly abbreviated to NOC. Selecting companies from these two major buckets, as will be seen in Chapter 3, was critical in creating a subset of data considered to be representative of the global oil and gas supply production.

by majority of countries as their national activity classification or have developed national classifications based of the ISIC (Department of Economic and Social Affairs, 2008)

[5] Large private sector firms are usually referred to as "International Oil Companies" (IOCs), however, there is recognition that some NOCs also operations outside their home country, and some oil and gas companies are neither state-owned nor international hence "POC" is suggested as a more appropriate designation.

[6] A national oil company (NOC) is one fully or majority owned by a national government.



Source: *(Wolf, 2009)*

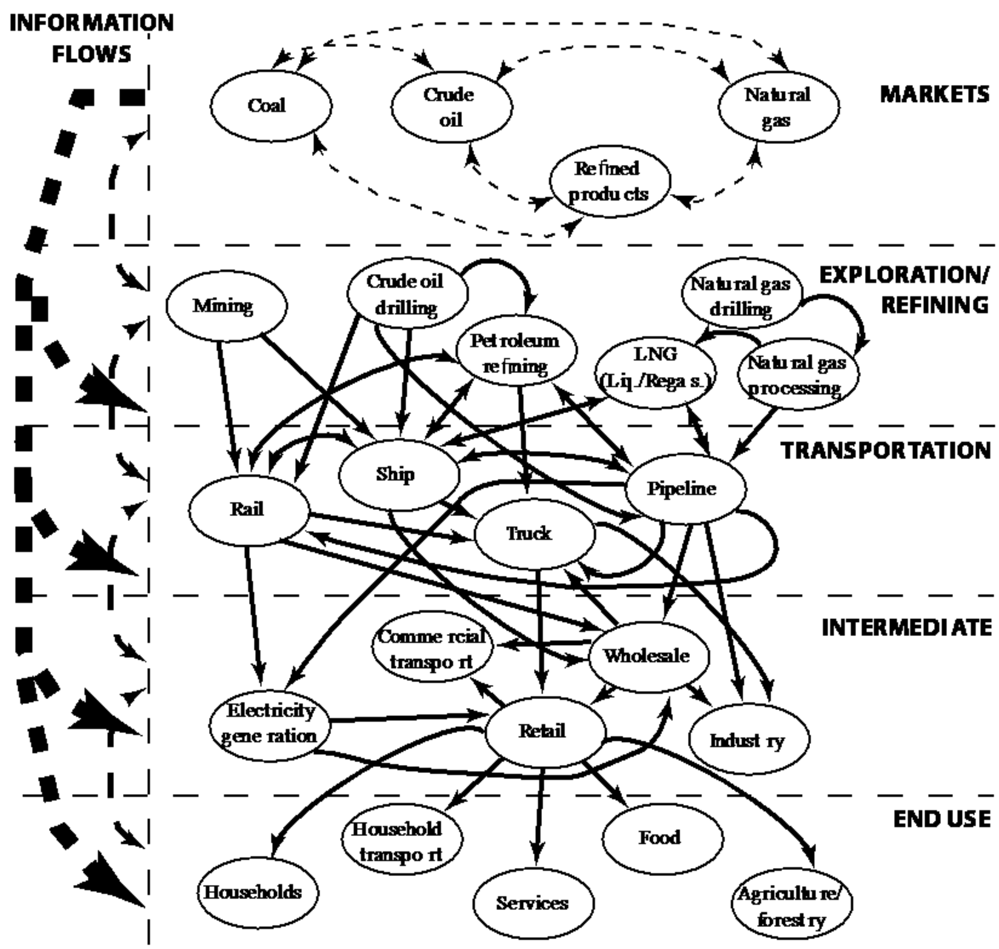
Figure 2 – Petroleum Value Chain[7]

Oil and gas extraction industry dates back to the 19th century. During this time there existed a number of small scale "uncouth" exploratory and production activities going on. The first significant production of crude oil is documented to have happened in the beginning of the 20th century with the discovery of the Spindletop oilfield in Texas - the consequential growth in the oil industry is credited to this event (Wooster & Moor Sanders, 1952). Since then, the production of oil has proliferated tremendously and so has the world demand for oil. The growing use of crude oil and gas and its entrenchment in the world's economy –transportation, power generation, manufacturing industries, etc. – has unsurprisingly led to the creation of a complex system of stakeholders whose interactions cut across various levels of abstractions. To provide an illustration of the complex system within which the oil and gas plays a key role, a CLIOS (Complex Large-

[7] Based primarily practices common to conventional oil.

scale Interconnected Open Sociotechnical) representation is used (see Figure 3). This diagram provides a static view of the "Fossil Fuels Complex" – the nodes of activity, hierarchy, physical/value flows of product, and flows of information. (Dodder, McConnell, Mostashari, & Sgouridis, 2007; Ramberg & Webster, 2015).

At the top of this sociotechnical structure are the markets, within which, the system interactions play out and establish the prices of the various fossil fuels and their substitutes. The fossils fuels compete aggressively against one another (and also against their non-fossil fuel substitutes, e.g., renewables) for a share in the energy sources mix. Figure 3 emphasizes the degree to which crude oil and natural gas remain at the center of the world economy.



Source: *(Ramberg & Webster, 2015)*

Figure 3 – Fossil Fuels Complex – Simplified

1.4. Common Industry Trends: Crude Oil Prices and World Oil Supply

"Trends, like horses, are easier to ride in the direction they are going."

John Naisbitt, American Author

Be it changes in supply or demand of crude oil and natural gas, or global resource volume levels or "reserves to production" ratios, these are all important trends that continue to be observed and researched in the oil and gas industry. The myriad of energy outlook documents published each year from various organizations across the globe, suggesting short to long term outlooks for various plausible energy scenarios is testament to the level of importance placed on understanding, interpreting, and preparing for the changes in these industry trends. With the numerous resources and efforts placed on understanding these trends, their changes and in some cases, sudden shocks, the one most important factor that influences them is the price of crude oil and natural gas. Over time these trends have kept changing due to a host of reasons – geopolitics, national security issues and instability, changes in demand-supply fundamentals, etc. This in itself is indicative of the variability and unpredictability present in the industry – some also attribute it to the complex dynamics of the energy system and the interrelationships that exists within this sociotechnical geopolitical system.

This is not to say that all trends in this industry are implicitly unpredictable and naïve in behavior or rationale. There are a number of trends that are relatively easier to predict, they have their causal factors well understood with minimal variabilities. An example of more robust projections is a short-term change in the demand for oil. Over time, the industry has been able to come up with fairly accurate, detailed and robust projections of world demand for fossil fuels by estimating variables like global population, improvement in the standard of living (and the growth of the middle class), overall economic growth, improvement in energy efficiency for fossil fuel consuming processes, and changes in the world's energy mix. The oil supply projections can be improved by better understanding drivers such as technological change and its ability to provide breakthrough access to resources initially considered technically infeasible to reach. The following section will focus on two specific trends most relevant to this thesis. These are crude oil prices and world oil supply.

1.4.1. Crude Oil Prices

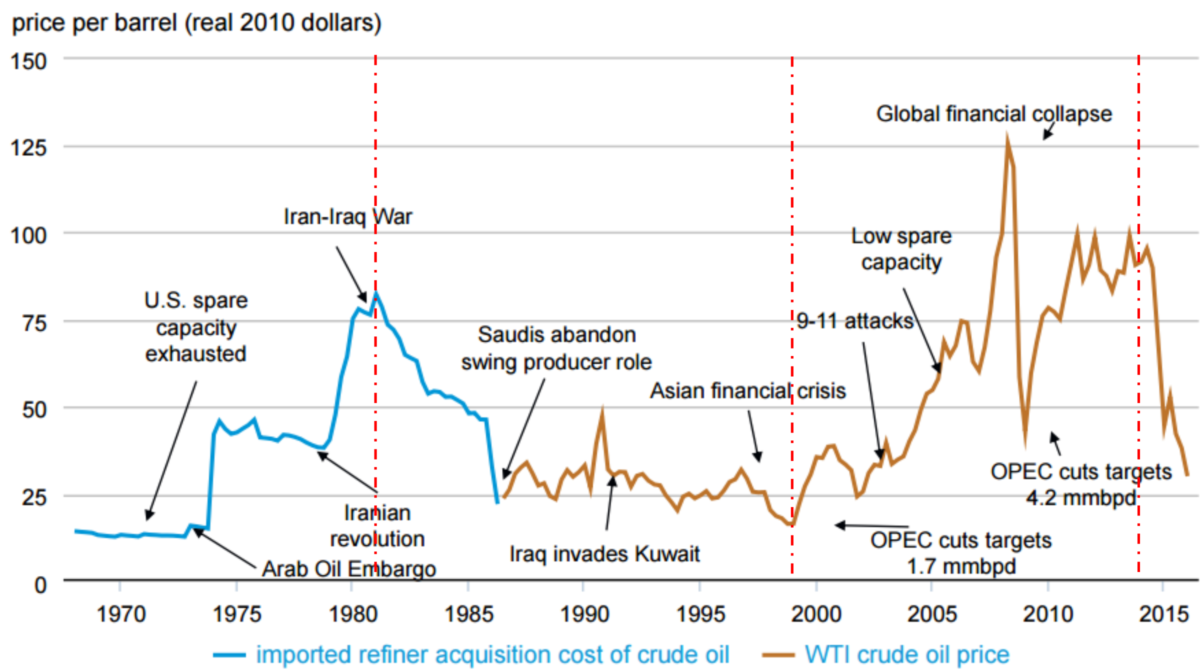
Oil price usually refers to the spot price of a barrel of benchmark crude oil. This is the current price that crude oil consumers need to pay to purchase a given quantity of a benchmark crude oil. A major benchmark widely used is called Brent Crude, this is a grade of light sweet oil from North Sea, and currently it is used to price two thirds of the world's crude oil supplies that are internationally traded (Fattouh & Stern, 2011). Brent crude oil is traded on the Intercontinental Exchange (ICE) for delivery at Slalom Voe in Scotland. In North America, the benchmark is the spot price of West Texas Intermediate (WTI) that is a grade of light sweet oil from Texas. WTI/light crude is traded on the New York Mercantile Exchange (NYMEX) for delivery at Cushing, Oklahoma (Fattouh & Stern, 2011). For simplicity, I will be using the Brent prices as the reference price for this thesis.

The price of oil or gas remains one of the most germane topics within the industry – what factors influence crude oil prices? Is there some consistent and repeatable way to directly extrapolate energy system dynamics today to estimate prices for tomorrow? How can these factors be measured to determine their causality with price, etc. A lot of work has been done in modelling the prices of oil using various types of models that seek to explain the price volatility based on world oil supply and demand (Li, 2015). Most of these models have been considered too simplistic and unable to capture all the complex intricate relationships present in the industry. Again, a lot of these models are quantitative in nature and unsurprisingly, unable to find a common ground or realistic means to quantify qualitative and speculative behaviors within the fossil fuel complex system.

Over time, history has shown that the price of crude oil has changed significantly and that most of these changes have been in reaction to variety of geopolitical and economic events (Figure

4). The trend reveal three distinct periods: 1970 – 1981, a period of increasing prices mainly as a result of Arab oil embargo and unrests in Iran and Iraq. The second period of interest, is the consecutive period 1981 to 1999, this represents a period in which prices declined mainly due to a breakdown within OPEC and Saudi's decision to abandon its swing producer role. Most recently is the last period of interest, 1999 – 2014, a period with a relative increase in crude oil prices relative to its original price in 1999. These increases were driven by the terrorist attacks in the U.S. in 2001 and the Iraq war and OPEC cuts in 2010. During this period a sharp decline was witnessed in 2008 and 2009 consistent with the global recession. The interesting question is what might happen after 2015 and how would this possible future behavior shape activities within the industry.

Seeking to understand how the industry thrived during these three distinct periods might be indicative and informative to what could potentially happen as we go into another distinctive period. Following on this premise, this thesis will build most of its analysis over a time series consistent with these three distinct periods.



Source: U.S. Energy Information Administration, Thomson Reuters

Figure 4 – Crude oil prices 1970 – 2015

	Fraction of Production (%)	
	2000	2014
OPEC (*Including Saudi)*	53%	47%
USA	15%	18%
Canada	5%	6%
Russia	11%	14%
Production from these countries as % of global production	76%	83%

Data adapted from U.S. Energy Information Administration (Energy Information Administration, 2014)

Table 1 – Total Oil Supply Change

1.4.2. World Oil Supply

The world crude oil production has increased steadily over the decades with the biggest producers being Russia, US, and the Middle East. This steady increase has been driven mainly by a slow but steady growth in energy demand in developed countries and a rapid economic growth (and industrialization) of emerging economies mostly led by China. To put it in perspective, from 1980 to 2014, total oil supply has increased by about 57%. In this period (and after that), OPEC oil supply has grown slower compared with that of the US, Canada, and Russia respectively. It is also worth noting that during this period, the US, Russia, and Canada have all increased their market share at the expense of OPEC (Table 1).

Overall, as shown in Figure 5, the total world crude oil supply has increased steadily, so far disproving the Hubbert's 1956 suggestion of reaching peak oil soon (a concept that will be addressed in detail in Chapter 2). The steadily increasing oil production raises the questions about how countries (and producers) are able to substantially increase their oil supply by chasing more difficult to reach oil reserves – examples being tight oil in the US, bitumen crude from tar sands in Canada, and oil and condensate from ultra-Deepwater in Brazil and the Russian Artic. The short and simple answer to this question is that the technological advancement in the oil and gas industry in tandem with improving crude oil prices has justified an entry into these more difficult oil reserves. This simplistic suggestion creates the hypothetical premise for this thesis. The objective of the research is to provide a justification to either confirm or counter this hypothesis. My study seeks to contribute to a better understanding of the role improvements in technology has played over the past few decades in influencing production volumes and consequentially crude oil prices in the oil and gas industry.

Source: (Gold, 2014)

Figure 5 – World Oil production 1950 – 2010

1.5. GENERAL CONCEPTS AND DEFINITIONS

It is important to differentiate between the concepts of productivity and technical change. Although these two concepts are linked together, they are quite different and relate to different aspects of the production function. The next section will provide definitions to productivity, technical change, and the production function. Even though sometimes the words "productivity" and "technical change" will be used interchangeably, the main goal of this thesis is to assess the rate of technical change as defined below.

1.5.1. Productivity

Productivity is usually referred to a ratio of a measure of output to a measure of input. It can be considered as the average measure of the efficiency of the production process – ability to produce more output with same (or less) amounts of input. It is the measure of output relative to production input factors. Overall, productivity incorporates everything about the production process – process efficiency, technical change (embodied and disembodied), economies of scale, organizational capabilities, etc. A good proxy for productivity is Labor productivity. This refers to the total output produced per worker. Usually productivity measurement can be decomposed so as to identify the drivers of the production process. Productivity can be decomposed into the portion contributed by the input factors, e.g., labor productivity, capital productivity, and capital intensity and the residual, referred to as technical change.

1.5.2. Technical Change

Technical change is often referred to as the currently known ways of converting resources into outputs (Griliches, 1987). It measures the additional output not attributed to changes in quantities of the input factors. It is also referred to as "costless" output because it is not tied to input factors – usually measured as the residual of output after discounting for the input factors used up by the production process (Comin, 2006). A lot of uncertainties remain attributed to this concept and how best to measure and interpret it because technical change as a residual to productivity embodies within it a host of other direct and indirect influences surrounding the production process such as economies of scale, organizational structure of the firm, overall system efficiency gains, etc. Disentangling these influences from technical change in order to directly quantify technological progress continues to remain a debate.

Nonetheless, technical change is defined as the multifactor productivity (or total factor productivity) and represents shifts in the aggregate production function as against movements along the production function (Figure 6)

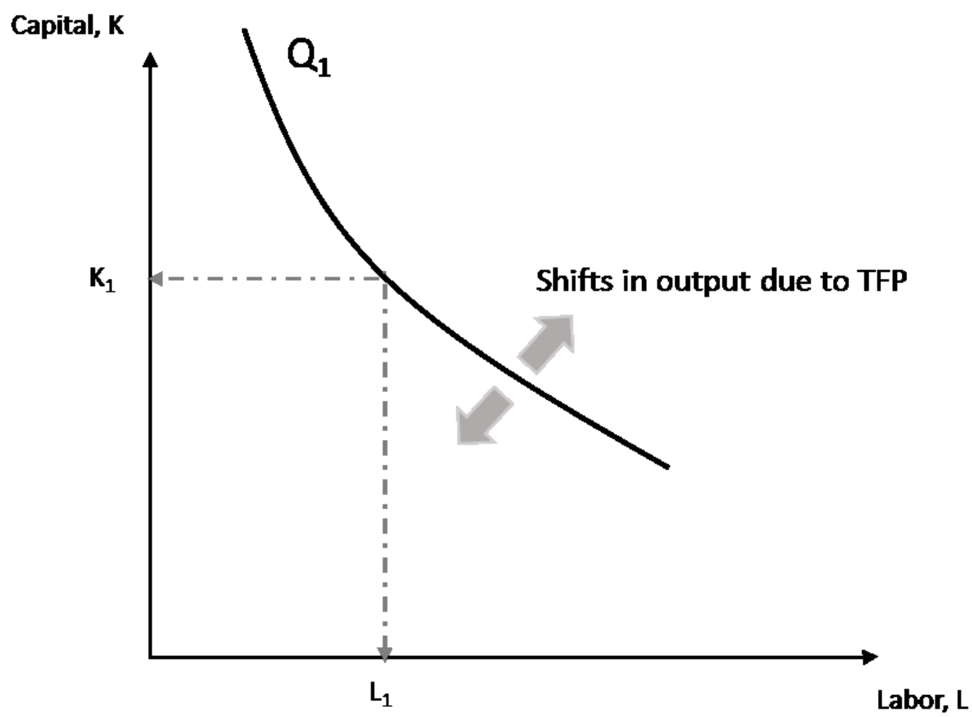


Figure 6 – Production Function Isoquant

1.5.3. The Production Function

Production function is a relationship that defines the production process – the conversion of inputs to outputs. It is a key concept of neoclassical economic theory. The primary objective of production function is to address allocative efficiency in the use of factor inputs in production and the resulting distribution of income to those factors. It can be expressed as a functional form linking output directly to some function that combines input factors by some mixing formula. There are a number of variation of the production function like the Cobb-Douglas function, Translog function, Leontief function, etc. This thesis will be focused predominantly on the two input factor Cobbs-Douglas function.

2. LITERATURE REVIEW

This chapter presents an overview of the published research relevant to this thesis, in particular, a presentation of a number of methodologies commonly used in measuring productivity and various applications of these methodologies. The chapter starts with an introduction of the relevant economic theories and their perspectives on the use of exhaustible natural resources. This chapter then focuses on the production function concept and overviews the research methods that will be used in this study.

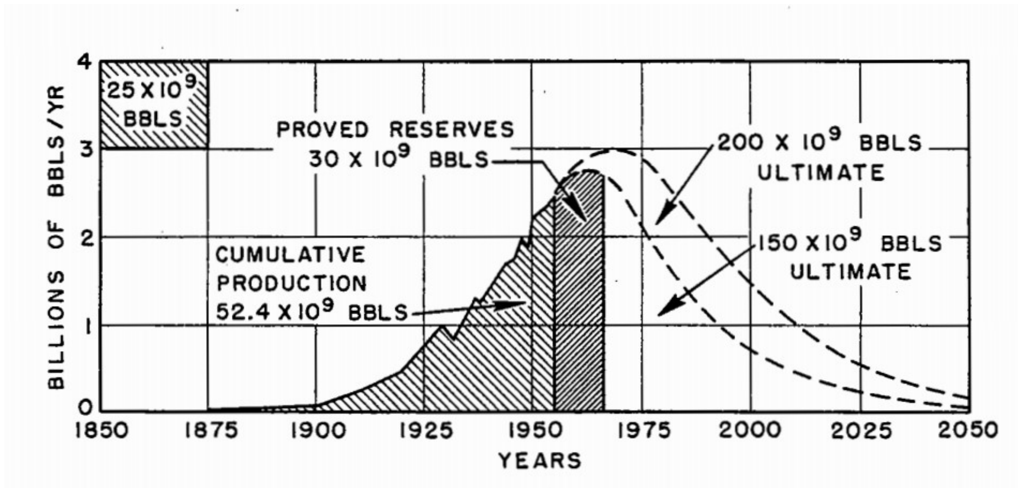
2.1. PEAK OIL – HUBBERT'S PEAK

"All good things must come to an end."

Geoffrey Chaucer, English poet

In 1956, King Hubbert, an American geophysicist predicted that the U.S. oil production from the lower 48 states would eventually peak at some point in time – within the time range from 1968 to1972. His prediction was based on calculating the rate of production at the time relative to the ultimate recovery of oil. This calculation was drawn out on a bell shaped curve based on the rates of discovery and production of oil. The bell shape suggests that oil discoveries grow exponentially at first, and then decline over time. This proposition could also be supported by the stepwise marginal cost curve (distinguished by the relative ease of disparate discoveries) for new oil finds. However, as more of these easy-to-find reservoirs are discovered, further reservoirs become harder to find and less economical and the rate of discovery slows. Production also follows a similar bell shaped curve. As oil is first discovered and produced, volumes steadily increase because oil is easy and cheap to reach up to a peak point, a point at which the maximum amount of oil is being produced. However, as more of the oil in a reservoir is extracted, the conditions necessary to sustain its continued production become dire and challenging, it then becomes more time consuming and expensive to extract. Thus, production increases as first, reaches a peak, and then declines. (Fusco, 2004). Ultimately, the rate of production will peak and Hubbert concluded that this would happen when half of the reserves available had been reached (Figure 7). The short bump of oil exploitation on the geologic time line became known as “Hubbert’s peak.”

There are numerous supporters of Hubbert’s work (Deffeyes & Silverman, 2004; Heinberg, 2003), but there are also others on the skeptical side. Some skeptics of the Hubbert peak theory make arguments that the peak can be pushed further in time as constraints on newer oil finds e.g., geological and economic factors are relaxed (Adeleman, 2004; Blackhurst, 2006; Lynch, 2005). Others believe that the production could have multiple peaks - periods where produced volumes are low then followed by increased periods of production. Another group of analysts postulate a production plateau (Lynch, 2005) – a period when the oil production not only peaks but stays flat for some time before a decline. These varying, although in some fundamental way similar, schools of thought all converge to the idea that the rate of discovery of new oil can be influenced and shaped by each or a combination of the following: technological progress which enables deeper drilling, speeded-up exploration timelines, and newer drilling locations; and improved marginal prices which incentivizes the deployment of more capital intensive investments (Blackhurst, 2006; Deffeyes, 2005). Over time, oil has witnessed all of these factors to contribute in significant ways in reshaping both the production and the proved reserve curves. These discussions continue to underpin the importance of understanding how technological advancement has evolved over time and how being able to estimate this progress can provide valuable information on what to expect as to the shape of these curves.



Source: (Hubbert, 1956)

Figure 7 – Hubbert's Original 1956 Graph Showing Peak Oil.

2.2. HOTELLING THEORY

"Live within your means, never be in debt…"

Andrew Jackson, 7th U.S president

Harold Hotelling proposed a theory to tackle the intriguing problems of the economics of exhaustible assets – the quest to maintain a balance between over production (waste) and under-production (hoarding and monopolization) (Hotelling, 1931). In simplified terms, Hotelling stated that to achieve an asset market equilibrium condition, owners of nonrenewable resources will only produce that resource if it will yield more value than other financial instruments available on the market, such as interest bearing securities and bonds. Stated otherwise, the most socially and economically profitable extraction path of a non-renewable resource is one along which the price of the resource, determined by the marginal net revenue from the sale of the resource, increases at the rate of interest. This theory describes the time path of natural resource extraction which maximizes the value of the resource stock (Gaudet, 2007). This theory was created to deal with the inadequacy of the static-equilibrium type of economic theory in relation to an industry in which the indefinite maintenance of a steady rate of production was physically impossible, and was bound to decline. Mathematically, the marginal value of a resource in the ground can be written as

$$\pi(t) = p(t) - c(t),$$

Where $p(t)$ is the marginal revenue (price of oil) the resource can fetch on the market at time t (once extracted), $c(t)$ is the marginal cost of extracting at date t (extraction cost), and $\pi(t)$ is the marginal value of oil in the ground and this represents the assets price of the resource.

Furthermore, if the rate of interest is denoted by r, then the Hotelling rule requiring asset market equilibrium requires that

$$\frac{\dot{\pi}(t)}{\pi(t)} = r.$$

In simple form, the Hotelling rule states that for a non-renewable, exhaustible resource with completely known stock, no discoveries possible, no alternatives, no recycling, private ownership and constant costs of extraction, the price of the resource will increase at the interest rate over time.

The next question is how is Hotelling theory related to measuring technological progress? Gaudet in his 2007 paper titled "Natural resource economics under the rule of Hotelling" applied this rule to seven non-renewable minerals and three non-renewable fossil fuels using U.S price data across multiple decades. His findings revealed that the entire 10 cases had no mean rate of change of price significantly different from zero – the mean rate of price change was centered at zero implying that there was no actual price level trend in these resources, in contrast to a positive trend as suggested by Hotelling. Gaudet went on to suggest and expand the application of the Hotelling rule. He stated that asides the effect of the rate of interest on the net price of the natural resources, other variables such as technological progress and its effect on the marginal costs, uncertainty, market structure, and durability also affected the rate of change of price (Gaudet, 2007). Another perspective presented by conventional resource economics is the identification of two key determinants to the cost of extraction: depletion and technological progress. Depletion is understood to lead to rising marginal cost of supply, and technological progress is expected to counteract these scarcity concerns (Wellenius, Ellerman, Marks, & Sussman, 1996). The suggestion is that technological progress in itself plays a significant role in shifting the marginal cost curve.

Putting these two important theories together, it is evident that to some degree they failed to account for the effects of technological progress and the profound effects it could have on improving access to newer reserves, increasing production efficiency of today's conventional production processes, and bringing down the overall marginal cost of a produced barrel. Understanding these effects begins by being able to estimate the rate of growth of technological progress at the company or industry level and then use this information to assess the activities of the industry.

2.3. WHY MEASURE PRODUCTIVITY?

"If you can't measure it, you can't manage it."

W. Edwards Deming, American statistician

Introducing the general thought processes behind why productivity measurements were carried out in the first place could be helpful in providing a broader picture to the importance of this exercise. Consistent with the opportunities presented by Douglas (Cobb & Douglas, 1928), there remains similar importance today to why measuring and calibrating levels and growth rates in productivity is relevant and important. The five objectives of productivity measurements include (OECD, 2001):

- **Trace and measure technical change**: An ability to trace and measure the level of technical change involved in the production process – the conversion of resources into output. This technical change could appear in a disembodied form (such as new business methods, organizational techniques) or embodied (improved quality of capital goods). While productivity measures can be linked in some way to technical change, it is worth noting that the link is not straightforward and these measures could embody many other direct and indirect influences. Total factor productivity (TFP) has the potential to capture numerous effects in the production process, not only those related to technological progress. These effects could include economies of scales, capacity utilization, measurement errors, etc. (Sharpe & Waslander, 2014). Thus, care must be taken when interpreting and communicating measured growth values in TFP as a common mistake could be to assign changes in TFP entirely to technological progress.
- **Identify & improve efficiency**: In a production process, the "engineer" believes full efficiency occurs when output is maximized to the highest level physically possible using the least fixed amounts of input at the current level of technology. As stated in OECD (2011:11), "Technical efficiency gains are thus a movement towards "best practice", or the elimination of technical and organizational inefficiencies." However, the economist might think differently. They are more likely to give credence to allocative efficiency than technical efficiency. The OECD (2001:11) notes that: "[…] when productivity measurement concerns the industry level, efficiency gains can either be due to improved efficiency in individual establishments that make up the industry or to a shift of production towards more efficient establishments."

- **Identify & measure real cost savings**: Theoretically, technical change and different types of efficiency changes can be identified and isolated. Knowing these can be informative for opportunities for cost savings across the production process. It is fair to mention that, in practice, achieving this objective is an arduous task especially relating to the earlier point of technical change embodying a potential list of direct and indirect explanatory variables.
- **Measuring improvements in living standard**: In the context of this thesis, living standard will apply to the financial performance (from a return on capital employed basis) for the firm. A rational firm will want to maximize its profits (income) through increased productivity in order to positively impact the bottom line for its shareholders. Labor productivity helps to better understand the link to increased output per worker and long-term trend in total factor productivity an important indicator of the growth possibilities of economy's potential output.
- **Benchmarking production processes**: Measuring productivity levels provide a common base to compare performance across or within firms.

2.4. MEASURING TECHNICAL CHANGE (TOTAL FACTOR PRODUCTIVITY)

The change in total factor productivity is the effect of advances in applied technology managerial efficiency, and industrial organization (Jorgenson & Griliches, 1967). A host of methodological differences continues to persist when it comes to measuring the Total Factor Productivity (TFP). At the same time, there seems to be some consensus that the Denison-Kendrick-Jorgenson-Griliches-Solow framework is appropriate and effective (Hulten, 1986). This framework enables growth rate of the real output to be decomposed into growth rates of the factor inputs and a residual component identified to incorporate changes in the efficiency of the production (or total factor productivity). With reference to the Capital (K) – Labor (L) graph (Figure 6), the input effects are associated with movements along the aggregate production function isoquant line, and the TFP (the residual) shows shifts of the aggregate production function (Solow, 1957).

In simple terms, the economic theory of production is represented by an output side and an input side. On the output side the quantities correspond to the real product output, while on the input side quantities correspond to real factor input. All prices are identified with the implicit deflators and applied for the conversion of the value of total output and total input into real terms. The standard framework for estimating total factor productivity (technical change) is adapted from the economic theory of production. For simplicity and convenience, consider the generalization of a one output-two input neo-classical production function:

$$Q(t) = A(t)F(K(t), L(t)) \quad (1)$$

$Q(t)$ denotes output at time t, $K(t)$ denotes the flow of capital services used at time t, $L(t)$) is the flow of labor inputs, and $A(t)$ is total factor productivity which appears in a Hick's neutral[8] way and measures the shifts in the production function over time.

From decomposing equation (1), Solow in his 1957 paper was able to show that the total factor productivity can be measured as the residual after discounting the growth rate in capital intensity (K/L) from the output per unit worker (Q/L). Equation (1) can be re-arranged as

[8] Shifts in the production function are defined as neutral if the marginal rates of substitution are unchanged but there exists increase or decrease in the output attainable from the given inputs (Solow, 1957). When this holds, it is said that the efficiency parameter $A(t)$ exibits a Hicks-neutral shift.

$$\frac{Q(t)}{L(t)} = A(t)F(\frac{K(t)}{L(t)}) \qquad (2)$$

and the growth accounting equation can be written as

$$\frac{\dot{Q}}{Q} - \frac{\dot{L}}{L} = \frac{\dot{A}}{A} + w_k \left[\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right] \qquad (3)$$

Dots over variables indicate derivatives with respect to time. For example the expression $\frac{\dot{Q}}{Q}$ represents the growth rate in the output variable.

Rearranging equation (3) for the growth rate in the residual gives

$$\frac{\dot{A}}{A} = \left[\frac{\dot{Q}}{Q} - \frac{\dot{L}}{L}\right] - w_k \left[\frac{\dot{K}}{K} - \frac{\dot{L}}{L}\right] \qquad (4)$$

Where w_k is the income shares of capital relative to output.

Equation (4) represents the fundamental equation of growth accounting in its continuous time or "Divisia index" form. In empirical practice, the continuous growth rates of (4) are replaced by the annual difference in the natural logarithms of the variable, e.g.,

$$\frac{\dot{Q}}{Q} = LnQ(t+1) - LnQ(t) \qquad (5)$$

And the share is replaced by the annual arithmetic average i.e., by

$$\frac{1}{2}[w_k(t+1) + w_k(t)] \qquad (6)$$

When (5) and (6) are used, the resulting index of the residual, $\frac{\dot{A}}{A}$ is termed the "Tornqvist" index of total factor productivity named after Leo Tornqvist (Törnqvist, 1981).

This formulation is an approximation for industries and economies in which their production functions are exhaustively represented as a two input factor of capital and labor. With such simplification, this approach has been applied to measure productivity (and conversely technical change) within such industries. In these conditions, the constant return to scale assumption holds (Hulten, 1986).

Another point to note is that this production function assumes that all capital services employed in the production process are fully utilized for the entire period under consideration. This assumption implies that changes in the actual states of capital services can be inaccurately captured in the residual, which is supposed to represent the total factor productivity. With this point in mind, it is indicative that the residual contains every state and condition embodied within the production process but disembodied from capital and labor inputs. In Solow's words, it captures "any kind of shifts in the production function. Thus slowdowns, speed-ups, improvement in education of the labor force, and all sorts of things will appear in 'technical change'". This implies that care must be taken in the interpretation of what the residual (or TFP) really is and fully means.

A general point about the Solow's residual result is in its conservativeness in estimating the real technological progress. It is mostly considered to have a downward bias when attempting to capture the total productivity efficiency improvement in the production process because improvements and technological progress are embodied in labor and capital inputs. These improvements lead to the direct contribution of changes in the input factors to the changes in the output amounts. In this thesis I will focus on estimating the residual and I will not delve into analysis of technological progress embodied in factor inputs.

2.4.1. COBB-DOUGLAS PRODUCTION FUNCTION

The Cobb-Douglas production function is one of the variations of the functional form representation of the production function[9] [10] and has been used to represent the relationship between the amount of output, technological relationship between the amounts of two or more input factors, and the amount of output that can be produced by those inputs. The Cobb-Douglas production function is especially useful for its unique mathematically convenience and its diminishing returns property. It was proposed by Knut Wicksell (1851 – 1926) and tested against statistical evidence by Charles Cobb and Paul Douglas in their popular 1928 paper titled "A Theory of Production" (Hong, 2008).

The standard Cobb-Douglas production function takes the form:

$$P(K,L)_t = Y_t \quad = A_t {K_t}^{\alpha} {L_t}^{\beta} \tag{7}$$

Observe that equation (7) is a variation of equation (1)

Where:

[9] The production function relates physical output of a production process to physical inputs or factors of production and remains one of the key concepts of neoclassical theories. It continues to be used to define marginal product and differentiates allocative efficiency with respect to the use of factor inputs in production and the resulting distribution of income to those factors. (Samuelson & Nordhaus, 2004)

[10] Factors of production could also be referred to as input or resources. These are what is used in the production process to produce finished goods and services (output). The three basic factors of production are land, labor, and capital. Factors of production may also refer to primary factor, these facilitate production but do not become part of the production (as with raw materials) nor become significantly transformed by the production process. (Samuelson & Nordhaus, 2004)

- P_t = total production (the monetary value of all goods produced in year t); also denoted as Y_t
- K_t = Capial input (the monetary worth of all machinery, equipment, and buildings)
- L_t = labor input (the total number of person-hours worked in a yea, or the monetary value of labor used in the production)
- A_t = total factor productivity level in year t
- α and β are the ouput elasticities of capital and labor respectively.

In their paper, Cobb and Douglas suggested that a production function relationship was needed to address a number of opportunities (Cobb & Douglas, 1928). Some of these opportunities are closely related to the objective of this thesis:

- Ability to estimate, within close limits, what is/are the major cause(s) for changes in production outside the varying quantities of the input factors – labor and capital – and the degree to which this/these drivers responded to changes in the quantity of the input factors.
- Ability to estimate the relative influence and effects of the individual input factors on production.
- As the proportion of the input factors changes from year to year, the ability to estimate the relative amount added to the total physical product by each unit of labor and capital and what is final units of the input factors in these respective years.

2.4.2. COBB-DOUGLAS PARAMETERS

2.4.2.1 Labor & Labor Productivity

Labor is a measure of the work done by human beings. Labor productivity could be thought of as the measure of real output produced by a worker in a fixed period of time. A growth in labor productivity is measured as the change in this ratio (Y/L) over time. Labor productivity changes reflect the joint influence of changes in capital, intermediate inputs (if any), as well as technical, organizational and efficiency change within and between firms, the influence of economies of scale, varying degrees of capacity utilization and measurement errors (OECD, 2001).

2.4.2.2 Capital & Capital Productivity

Adam Smith defined capital as “that part of a man’s stock which he expects to afford him revenue is called his capital.” (Aspromourgos, 2013). Capital is regarded as one of the factors of production by classical and neoclassical economics. It is considered a factor of production because it is not used up immediately in the production process like raw materials or intermediate goods and also, because it can be produced or increased. In the context of this thesis, capital will be considered as a stock of all tangible and intangible items, and all services purchased, together when all combined enables the production of output. It could also be referred to the annual (or some periodic) flow of capital services required for the production process.

Capital productivity is the measure of output per unit of value of capital services used up in the production process.

2.4.2.3 Labor & Capital Share

Labor and capital shares (of the total inputs) could be thought of as values that indicate the responsiveness of output to a change in level of either labor or capital used in production. With an increase in either of the input factors resulting in an increase in the output product commensurate to the respective share of that input factor – a return to scale. A sum of shares equal to one reveals a constant return to scale, while for a sum less than one, a decreasing return to scale, and a sum greater than one implies an increasing return to scale.

2.4.2.4 Productivity Level and Growth Rates

Productivity can be expressed either in growth rates or in levels. Productivity levels are captured in nominal terms, directly measuring the output generated by a unit of input while productivity growth rates, the term largely used by most economics literature, are captured in real terms and reflects the change in output per input unit over time. I can also show mathematically the difference between these terms.

By log-linearizing equation (7), I obtain an equation as follows:

$$ln\,(Y_t) = Ln(A_t) + \alpha ln(K_t) + \beta ln(L_t) \qquad (8)$$

I can estimate and then solve for TFP level, A for period t as follows:

$$Ln(A_t) = Ln\,(Y_t) - \alpha Ln(K_t) - \beta Ln(L_t) \qquad (9)$$

Similar to equation (9) and for the next period $t + 1$ I can estimate TFP level to be:

$$Ln(A_{t+1}) = Ln\,(Y_{t+1}) - \alpha Ln(K_{t+1}) - \beta Ln(L_{t+1}) \qquad (10)$$

Subtracting equation (3) from (4), gives the growth rate:

$$Ln(A_{t+1}) - Ln(A_t) = [Ln\,(Y_{t+1}) - Ln\,(Y_t)] - \alpha[Ln(K_{t+1}) - Ln(K_t)] - \beta[Ln(L_{t+1}) - Ln(L_t)] \qquad (11)$$

In Section 2.4, I provided equation (4) as the fundamental equation for growth accounting. Equation (11) can be varied to resemble equation (4)

$$Ln(A_{t+1}) - Ln(A_t) = Ln\left({Y_{t+1}}/{L_t}\right) - Ln({Y_{t+1}}/{L_t}) - \alpha\left[Ln\left({K_{t+1}}/{L_t}\right) - Ln({K_{t+1}}/{L_t})\right] \qquad (12)$$

The difference between the natural logs of these parameters gives an estimate of the growth rate across the period t to $t+1$ and the values for each parameter during each period gives the level index.

2.4.3. Applications of Production Function To Natural Resource Industry

Many publications that use the Cobb-Douglas production function (and other neoclassical economics' aggregate production functions) focus on the economic growth accounting of nations and/or industries – understanding economic growth rates, national industrial growth rates, cross-country per capital income differences, etc. These studies have analyzed productivity (such as labor productivity), total factor productivity growth rates, and input growth rates across different time series within and across countries. Examples of these studies include (Jorgenson & Griliches, 1967; Jorgenson, 1990; Smolny, 2000; Solow, 1957).

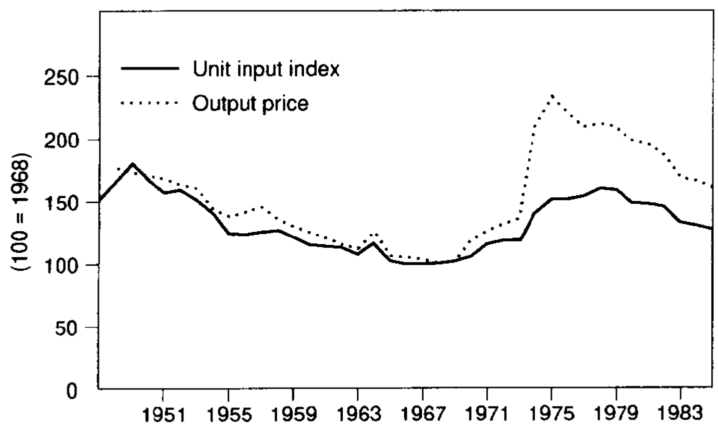
Other researchers applied concepts of productivity measurements specifically focused on exploring sectoral productivity within industries, for example the coal industry in the US (Ellerman, 1995; Ellerman, Stoker, & Berndt, 2001; Wellenius et al., 1996) or the oil and gas industry in North America (Celeste & Andrew, 2009; Sharpe & Waslander, 2014).

2.4.3.1 Application to the Coal Industry in the US

A number of Danny Ellerman's publications (Ellerman, 1995; Ellerman et al., 2001) provided improved perspectives on understanding productivity, their sources (and/or drivers), and their overall effects on commodity prices. In Ellerman (Ellerman, 1995), non-parametric methods are used to calculate for productivity across a time series and then to show how aggregate productivity statistics may not be exhaustively reflective of, and informative to, what may be going on at level of the constituent individual firms. He was able to apply this hypothesis to data for the American coal industry and show that when disaggregated across the heterogeneous individual firms present within the coal industry, the respective labor productivity trends behaved differently from the aggregate industry productivity and, in some case, one another. His work also explained the sources of productivity change and its effects on the disaggregated productivity trends (Ellerman et al., 2001).

Referring to another reverent body of work, in his 1995 paper titled "The world price of coal", built on the work of Dale Jorgenson, Ellerman was able to observe how changes in total factor productivity has been one of the primary causes of the long-term fluctuations in coal prices in the USA since the end of the Second World War. He was able to separate the notions that increasing overcapacity – a situation in which investment outruns demand with the result that excess capacity is created and prices depress in reaction – and the oil price shock hit in the 70s were responsible for the increasing US coal prices.

As stated by Ellerman "Jorgenson's data provided quality adjusted measures of price and quantity for four factors – capital, labor, energy and materials – and the appropriate gross measures of output and price for the coal industry from the late 1940s to 1985. From these data, a shared weighted index of multifactor productivity change can be created for the past 40 years, as well as the inverse, an index of unit input, which indicates the amount of each factor used in the production of one unit of output. As the inverse, declining unit input corresponds to increasing productivity which with unchanging factor prices implies failing prices; and, vice versa, for rising unit input."



Source: (A. D. Ellerman, 1995)

Figure 8 – US Coal Price and Productivity[11]

Ellerman was able to show a corresponding trend between the unit input index and the output price as shown by Figure 8. He continued "Unit input and output price decline as approximately equal rates through the 1950s and 1960s, as would be expected if factor prices remain unchanged. The 1970s are characterized by rising unit impute and rising output price, although at different rates. By the end of what appears to be a decade of technical regress, 60 per

[11] Nominal Output deflated by GDP deflator

cent more aggregate input is required to produce a unit of output, and then input costs some 40 per cent more in real terms. Then, technological progress seems to reappear and unit input and prices decline steadily again. The turning points and magnitudes of output price and productivity change are not exact' but the unit input index leaves little doubt that changing productivity is the major explanatory factor for the trend in coal prices in the USA since the end of the Second World War."

A key lesson from the work of Ellerman is the concept (and application) of aggregation production function for situations where the total output can be aggregated from individual outputs of respective firms and same for input factors – forming consistent totals from components. Adjusting for these differences and heterogeneities will be addressed in more details in later sections of this chapter.

2.4.3.2 Application to Various Industry Sectors in North America - CSLS[12]

Established in 1995 to undertake research in the area of living standards, the CSLS has been contributing to a better understanding of trends in living standards and factors determining trends through research. The CSLS provides annual research reports on productivity with specific focus on industry sectors in Canada and US.

In a number of their periodic reports, the consistent application of the Cobb-Douglas production function in growth accounting has been used in measuring productivity growths in various industries within Canada. In a recent 2014 report titled "The Impact of the Oil Boom on Canada's Labor Productivity Performance, 2000-2012", the focus was on evaluating the impact of the oil and gas industry on labor productivity growth in Canada since 2000 through exploring direct and indirect ways in which the oil and gas sector affects aggregate productivity using growth

[12] CSLS is the Centre for the Study of Living Standards. It is a Canadian based, non-profit, national, independent organization that seeks to contribute to a better understanding of trends in and determinants of productivity, living standards and economic and social well-being through research. (www.csls.ca)

accounting method to first calculate for productivity growth rates and then decompose this growth rates to the contribution of capital intensity and total factor productivity (Sharpe & Waslander, 2014).

With focus on the Canada's most important, and controversial, industries, the oil and gas extraction industry, CSLS was able to show that labor productivity growth in the sector has remained weak. Yet, paradoxically, the sector did not influence the aggregate labor productivity negatively.[13]

2.4.4. Criticisms of Cobb-Douglas Production Function

The Cobb-Douglas production function, like most popular approaches and theories, has had its share of critiques. This section mentions some of these criticisms and how the research, where necessary, has adjusted for them.

- **Dimensional analysis**: Faulted for not being dimensionally consistent, Barnett's analysis showed that the 2-input function did not have meaningful or economically reasonable units of measurements unless the elasticities of output were all equal to one, i.e., $\alpha = \beta = 1$. And in such as situation, the law of diminishing returns will be violated and there will be an unreasonably large economies of scale – a doubling of input factors will be expected to quadruple output (Barnett, 2004). In reply to this criticism, other economists have opined that other units commonly used in physics such as the log temperature or distance square could also seem unnatural. In my opinion, their argument followed the law of induction, implying that if unnatural units could be used

[13] Consistent with Ellerman's finding in the constituent firms sections relative to the aggregate US coal industry. (D. Ellerman, Stoker, & Berndt, 2001).

and accepted in physics, same should be applied in economics. My guess is we may not have seen the end to this line of discourse.

- **Lack of microfoundations & the aggregation problem:** A lot of work (Klein 1946, Solow 1956, Cass 1965, Denison 1961, 1972, Fisher 1969, Jorgenson & Griliches 1967, Jorgenson 1972), has been done that established conditions under which micro production functions can be aggregated to yield an aggregate production function especially if one wants to use sector-wide or economy-wide aggregate production function. Growth models subsequently utilized these fundamental publications to establish their legitimacy. Key to this is the fundamental assumption that the technology of an economy can be represented by an aggregate production function – otherwise stated, without the adoption of these assumptions by these growth models, the aggregate production function may not have existed. However, over time, multiple aggregation literature have shown that these conditions under which micro production functions can be aggregated so as to yield an aggregated production function are so stringent that is difficult to believe that actual economies can satisfy them. Felipe and Fisher in their 2006 paper stated that "[…] the aggregate or macro production function is a fictitious entity. […] Its importance lies in the fact that without proper aggregation we cannot interpret the properties of an aggregate production function. And without the latter, therefore, it is impossible to build a neoclassical growth model." Their conclusion was that due to the stringent conditions, considered by some economists to be near-impossible to achieve, the aggregation problem will continue to be valid and applicable to a whole host of other topics such as capital, labor, output, investment, or gross domestic product (Felipe, 2006). For simplicity, the thesis work will build its methodology off the findings and conclusion from Fisher's simulation (Fisher, 1971), stated succinctly by Felipe: “[…] as long as the share of labor happened to be roughly constant, the aggregate production function would yield good results, even though the underlying technical relationships are not consistent with the existence of any aggregate production function.” And further goes on to conclude that this argument (made by Fisher) holds and the aggregate Cobb-Douglas is a good approximate because the labor and capital shares are fairly same across the micro-aggregates.

- **Georgescu-Reogen vs. Solow/Stiglitz** (Daly, 1997): “Since the production function is often explained as a technical recipe, we might say Solow’s recipe calls for making a cake with only the cook and his kitchen. We do not need flour, eggs, sugar, etc., nor electricity or natural gas, nor even firewood. If we want a bigger cake, the cook simply stirs faster in a bigger bowl and cooks the empty bowl in a bigger oven that somehow heat itself.” Herman E. Daly, 1997. This statement is representative of the criticisms leveled against the use of the two factor Cobb-Douglas function, unto which the Solow’s residual is anchored. The argument was based on how one could produce without natural resources being factored into the production process (and the production function). Over time, a new version of the production function was formed that included a third input factor, “R”, resources. Georgescu-Roegen labelled this ‘Solow-Stiglitz variant’ and still showed that the inclusion of a third factor didn’t solve the criticism and he went on to show that substituting capital with resource, and vice versa, assuming labor and output were held constant, could lead to unreasonable outcomes. (Georgescu-Roegen, 1979, 98). A justification to this criticism is that resources could be left out of the production function because resources can be substituted by reproducible capital. Another justification was made in the influential book *Scarcity and Growth*, (Barnett and Morse, 1963) where it was suggested that

> "Advances in fundamental science have made it possible to take advantage of the uniformity of matter/energy, a uniformity that makes it feasible without preassigned limit, to escape the quantitative constraints imposed by the character of the earth's crust… Nature imposes particular scarcities, not an inescapable general scarcity." From the host of justifications made to clear this criticism, although not directly from Solow or Stiglitz, this thesis concluded that there was sufficient literature support to proceed with the two factor Cobb-Douglas production function as the basis for the research work.

2.5. THE AGGREGATE PRODUCTION FUNCTION

The aggregate production function can be defined as a function that maps aggregate inputs into aggregate outputs. Aggregation relates to forming consistent totals from components. It maps out a relationship between firm-level productivity measures and their counterparts at the macroeconomic level. In defining the aggregate production function, it is implied that a production function exists at the level of the firm. This assumption is guaranteed. Felipe and Fisher state in their 2006 paper on the topic that "if an entity assigns use of its various factors to different techniques of production so as to maximize output, then maximized output will depend only on the total amount of such factors, and that dependence can be written as a functional relationship" (Felipe, 2006).

Consistent with objectives for measuring productivity for the global oil and gas industry, this thesis will be applying most of the same work that has been done around measurement of total factor productivity but with specific application to aggregates of individual oil and gas firms (as against typical application to homogenous countries or industries within countries). In carrying out these aggregations the thesis addresses the following questions:

1. What is the aggregate technological rate of growth for international and national oil companies and the global industry level?

2. Are there rate changes for the private, national companies and the oil and gas industry between the three distinct price cycles?

3. What are the drivers behind these rate changes?

4. How do these drivers change across the three distinct price cycles?

The first step of this research will be to define some way of aggregating the data to adjust for the heterogeneity present across in the various individual firms. Some examples of these heterogeneity include their differing amounts of input factors shares, the idiosyncrasies of the individual production processes and operations of the firms, their different business locations, etc. At the same, this thesis recognizes the constraints that prevents some of these heterogeneities to be adjusted and accounted for. Some of these simplifying assumptions should help adjust for most of these differences.

The ideal scenario for the economic production function is for the aggregation to be done across homogenous producer units i.e., the units engaged in a similar principal activity[14]. There are multiple ways producer units can be classified with respect to their principal activity. Some of these ways include kind-of-activity unit (by activity), local units (by location), and establishment (by location and activity) (European_Commission_IMF_OECD_UN, 1993). This research will be aggregating firms by kind-of-activity. In the kind-of-activity unit classification, the unit is composed of producers engaged in similar principal activity. When partitioned across this classification, the resulting units can be considered to be homogenous with respect to output, cost structure and technology of production.

[14] The principal activity of a producer unit is the activity whose value added exceeds that of any other activity carried out within the same unit (European_Commission_IMF_OECD_UN, 1993)

There are numerous methods to measure productivity and technical change. First, the growth accounting method was used in which a production function was assigned to a firm (or an aggregate) and its productivity was measured deterministically and then decomposed into the contributions due to input factors and technical change (the residual). The Cobb-Douglas production function introduced in section 2.4.1 falls under the growth accounting method. Other methods have been introduced mainly to adjust for heterogeneity in the individual firms making up the aggregate production function. One of the newer methods is the regression method. This method is usually considered to be "global" because it reveals a more general functional form that can be extrapolated directly from the data (while adjusting for the heterogeneities that may exist). In the regression method, the production function relationship will assume no predetermined form and will be constructed based off from the information derived from the pool of data – measurements of output and input quantities – typically by carrying out a regression analysis. The values of the parameters will be estimated and the most likely production function relationship form revealed. This method was exercised by Solow in his 1957 paper where he tried fitting the data to five variations of a production function and tested each independently for their statistical significance. The regression method falls under the concept of econometrics (i.e., application of statistical methods to economics) and a limitation to the method is the sizeable amount of data required to run a reliable analysis. The data used for this research was limited especially for the NOC (national oil companies). Nonetheless, this approach will be carried out as part of the data analysis.

Similar to with Solow's work, and consistent with the regression technique, these five production functional form relationships will be tested on the data as part of this research

$Q = \alpha + \beta K$, a linear relationship

$Q = \alpha + \beta LnK$, a semi-logarithmic relationship

$Q = \alpha + \beta/K$, a hyperbolic relationship

$LnQ = \alpha + \beta LnK$, the Cobb-Douglas case, and finally,

$LnQ = \alpha - \beta/K$, semi-logarithmic hyperbolic hybrid relationship.

In these five cases, the econometric model will be solving for α and β, the residual and capital input factor share respectively.

The other aggregate production function method is called the Index number theory method because it employs the use of weighted indexes. Similar to the growth accounting method, this method is also a non-parametric method. It is often referred to as a "local" solution and specifically defined based on the set of quantities of each parameters – the weighted indexes (Hulten, 1986).

Following Jorgenson and Griliches (1967), the discussion below shows how total factor productivity can be defined as an aggregate of a system with multiples outputs and inputs.

First, the following notation is introduced:

Y_i – quantity of the output from the ith company

X_j – quantity of the input from the jth company

q_i – price of the ouput from the ith company

p_j – price of the ouput from the jth company

For m companies, the fundamental identity for each accounting period is that value of output equal to the value of input:

$$q_1Y_1 + q_2Y_2 + \cdots + q_mY_m = p_1X_1 + p_2X_2 + \cdots + p_mX_m \qquad (13)$$

Differentiating with respect to time and dividing both sides by the corresponding total value, I can obtain the following:

$$\sum w_i \left[\frac{\dot{q}_i}{q_i} + \frac{\dot{Y}_i}{Y_i}\right] = \sum v_j \left[\frac{\dot{p}_j}{p_j} + \frac{\dot{X}_j}{X_j}\right] \qquad (14)$$

where weights w_i and v_j are the relative shares of the value of the ith output in the value of total output and the value of jth input in the value of total input:

$$w_i = \frac{q_i Y_i}{\sum q_i Y_i}, \quad v_j = \frac{p_j X_j}{\sum p_j X_j}$$

To verify that both sides of (14) are weighted averages, I observe that:

$$w_i \geq 0, \qquad i = 1 \ldots m;$$

$$v_j \geq 0, \qquad i = 1 \ldots n;$$

$$\sum w_i = \sum v_j = 1$$

A useful index of the quantity of total output may be defined in terms of the weighted averages of the rates of growth of the individual outputs from (14); denoting this index of output by Y, the rate of growth of this index is

$$\frac{\dot{Y}}{Y} = \sum w_i \frac{\dot{Y}_i}{Y_i};$$

Replicating same for the index of the quantity of total input, say X, the rate of growth is

$$\frac{\dot{X}}{X} = \sum v_j \frac{\dot{X}_j}{X_j};$$

These quantity indexes are known as Divisia quantity indexes; the corresponding Divisia price indexes for total output and total input, say q and p, have rates of growth:

$$\frac{\dot{q}}{q} = \sum w_i \frac{\dot{q}_i}{q_i};$$

$$\frac{\dot{p}}{p} = \sum v_j \frac{\dot{p}_j}{p_j};$$

In terms of Divisia index numbers a natural definition of total factor productivity, say P, is the ratio of the quantity of total output to the quantity of total input:

$$P = \frac{Y}{X} \qquad (15)$$

Using the definitions of Divisia quantity indexes, Y and X, the rate of growth of total factor productivity may be expressed as

$$\frac{\dot{P}}{P} = \frac{\dot{Y}}{X} - \frac{\dot{X}}{X} = \sum w_i \frac{\dot{Y}_i}{Y_i} - \sum v_j \frac{\dot{X}_j}{X_j} \qquad (16)$$

Or, alternatively, as:

$$\frac{\dot{P}}{P} = \frac{\dot{p}}{p} - \frac{\dot{q}}{q} = \sum v_j \frac{\dot{p}_j}{p_j} - \sum w_i \frac{\dot{q}_i}{q_i}$$

These two definitions of total factor productivity are dual to each other and are equivalent by (14). This implies that in general, any index of total factor productivity can be computed either from indexes of the quantity of total output and total input or from the corresponding price indexes.

3. RESEARCH METHOD AND APPROACH

3.1. INTRODUCTION

As discussed in the earlier chapters, understanding the relationship between technological improvements, the volumes of oil and gas produced, amount of capital investment, and the price of crude oil and natural gas requires an investigation into the levels and rates of technological improvement and the insights into their main drivers.

I will use different methods for the research analysis – index number theory, growth accounting, and regression analysis. Adapting and applying these methods requires a deep understanding of their underlying principles; the selection and identification of the right type of data sets, their quality (and quantity, referring to the number of observations for the regression analysis); and the length of the time interval over which these relationships can be identified and analyzed.

This chapter provides details into the research methods and approaches for this thesis.

3.2. GENERAL DESCRIPTION

As mentioned in Chapter 2, most of the research on the topics of productivity and TFP for the oil and gas sector has been done at the industry level – analyzing the oil and gas extraction industry within a country. In my research I attempt to carry out my analysis differently, I aggregate data from selected key players within the oil and gas extraction industry and then attempt to estimate productivity and total factor productivity for the industry aggregates. I use publicly available annual reports (see Appendix C for the list of company reports) as a source of my data and the data were compiled for private oil and gas producing companies (POC) and national oil companies (NOC).

In this chapter I define the requirements for the choice of the companies and then explain the source of the data and the time period over which the data were selected.

3.3. THE CHOICE OF OIL AND GAS COMPANIES

To effectively achieve the objective of this thesis, selecting the companies on which the data are built is a critical step of the research approach. I created the following requirements for the selection of the companies from which data are gathered:

- The sample of companies should be a mix of major global (international) producers and major national producers.
- The sample should represent a substantial percentage of the total global production.
- That sample of companies should have reliable and publicly available data to support the necessary analysis.

Eight major producers were identified from the "Top 25 producers" list provided in Table 2. These eight producers were broken down into four private and four national oil and gas companies. Together, these eight companies produced about 40% of the production from the top twenty-five companies in 2012.

Ranking	Oil & Gas company	Production[1] (Mboed)	Publicly available Data?
1	Saudi Aramco*	12.5	No
2	Gazprom**	9.7	Yes
3	National Iranian Oil Co*	6.4	No
4	ExxonMobil	5.3	Yes
5	PetroChina**	4.4	Yes
6	BP	4.1	Yes
7	Shell	3.9	Yes
8	Pemex*	3.6	No
9	Chevron	3.5	Yes
10	Kuwait Pet Corp*	3.2	No
11	ADNO*	2.9	No
12	Sonatrach*	2.7	No
13	Total	2.7	Yes
14	Petrobras**	2.6	Yes
15	Rosneft**	2.6	Yes
16	Iraqi Oil Ministry*	2.3	
17	Qatar Pet*	2.3	
18	Lukoil**	2.2	
19	Eni	2.2	Yes
20	Statoil	2.1	Yes
21	ConocoPhillips	2	Yes
22	PDVSA*	1.9	
23	Sinopec**	1.6	
24	Nigerian Nat Pet	1.4	
25	Petronas*	1.4	
	Total Production (Mboed)	**89.5**	
	% of 8 companies	**40%**	

[1] 2012 produced volumes (MBOE)

* National companies, fully owned by the state.

** Publicly traded national companies with some state control (semi-public company)

[salmon shading] Private companies selected

[yellow shading] National companies selected

Source: (Rapier, 2016)

Table 2 – Top 25 Producing Oil and Gas Companies

The four private companies (POC) include ExxonMobil, BP, Shell, and Chevron and these represent the four largest privately owned oil and gas companies in the world. They are also all integrated companies with international operations that span across multiple continents covering conventional and unconventional forms of oil and gas production. These companies are similar in terms of organization and production activities. They also have similar labor and capital structures, adopt similar technologies, and collaborate extensively with each other on a number of joint venture projects.

The four national companies (NOC) are Gazprom, PetroChina, Petrobras, and Rosneft. These companies mostly operate out of their home countries with Rosneft and Gazprom based out of Russia, Petrobras from Brazil, and PetroChina from China. These companies are semi-public companies with a significant amount of the company owned and controlled by their national governments. NOC also exhibit similar characteristics with each other and they have different organizational, labor and capital structures from the private companies.

All these companies have exploration and production of crude oil and natural gas to be their primary productive activity. This implies that fundamentally they have a similar production process with the same input factors.

The data for these companies were sourced from their company investor webpages and the Thomson One data for recent financial reports and operations document. The legacy annual reports were obtained from the ProQuest database. The details on the documents are provided in Appendix C.

3.3.1.1 Some Factors, Assumptions, and Decisions Applicable to Data for the Oil and Gas Companies

In compiling the data across the eight major oil and gas companies, a number of factors were considered. These factors and their subsequent decision are as follows:

- Due to the complexity (defined broadly on the basis of the size, cost, and risk) of oil and gas projects, the idea of risk-sharing is common to most of the larger industry players. As a result, most oil and gas companies participate as partners on multiple E&P projects. To clearly disclose projects in which they are directly in charge of (i.e., the "operator") from those where they have an investment share, oil and gas companies divide their financial records into subsidiary and affiliate categories. I focus only on the subsidiary category to avoid a case of double counting output quantities across multiple companies.

- The national oil companies have substantial transactions both in their domestic and foreign currencies. I adjust for inflation, convert financial flows to constant 2014 prices, and convert local currency to dollars at 2014 exchange rate. The step of converting to 2014 dollars also applies to POC – including those whose financial statements are in US dollars. All dollar prices were also deflated to 2014 dollars by applying the CPI inflation values for the US ("Inflation - Current and Historic Inflation by Country," 2016). As a result, all financial data are converted to the same units – 2014 dollars.
- The oil and gas industry is not immune to merger and acquisition activities and these activities are taken into consideration in the analysis. The assumption made is that irrespective of the structure of the parent company, the combined input factors, as long as they are traceable to a subsidiary, should be captured under that subsidiary to reflect its contribution to the production of output – revenue from sales of crude oil and gas. This means that the total sum of output (prices and physical units from produced oil and gas) and its respective input factors are captured for all periods and from all subsidiaries of the companies pre and post a merger or acquisition activity. For example, volumes produced and input factors for ExxonMobil post the merger between Mobil and Exxon in 1999 are taken from the data for ExxonMobil after 1999 and from individual reports for Mobil and Exxon pre-1999.

3.4. Crude Oil Price Periods and the Time Intervals

I considered the time interval from 1970 – 2014 (introduced in Chapter 1) to be an interval with a good representation of crude oil price dynamics. There are prolonged periods of increasing and decreasing oil prices. This period is broken into the three distinct periods: 1970 – 1981 (a period of rising oil price), 1981 – 1999 (declining oil price), and 1999 – 2014 (rising oil price).

It is worth noting that companies have some data limitations across the 45 years span from 1970 to 2014. These data limitations range from some of these companies (especially the NOCs) being founded in the late 80s and early 90s to the unavailability of earlier version of financial statements for some specific companies. Table 3 provides a summary of available data for the three periods of study.

Companies	1970 – 1981	1981 – 1999	1999 - 2014
Private Oil Companies (POC)	Gulf Standard Oil Texaco	Chevron Texaco	Chevron
	Exxon Mobil	Exxon (Mobil – no data)	ExxonMobil
	Shell	Shell	Shell
	(BP – no data) (Amoco – no data)	(BP – no data) (Amoco – no data)	BP
National Oil Companies (NOC)			Gazprom
			Rosneft
			Petrochina
	(Petrobras – no data)	(Petrobras – no data)	Petrobras
All			POC NOC

Table 3 – Available Data for 1970 – 2014

3.5. Input Data

I use different concepts (described in the previous chapters) to measure the rate of technical change: growth accounting (based on the Cobb-Douglas function), index number theory and regression analysis. These methods are applied to different levels of the data. Table 4 provides an overview of the methods (growth accounting, index number theory, regression analysis) and where they are applied (individual companies, an aggregate for POCs, an aggregate for NOCs, all companies).

Productivity Measurement Method	Individual Firms	Private Oil Companies	National Oil Company	All
Growth Accounting	Yes	Yes	Yes	Yes
Index Number Theory	-	Yes	Yes	Yes
Regression Analysis	-	Yes	Yes	Yes

Table 4 – Application of Methods across Firms and Aggregates

For production function accounting, data have to be obtained for output (Y), the input factors: capital (K) and labor (L), and their respective input shares (α and $1-\alpha$). I collected these data from the individual companies and then aggregate them for the three aggregates – POC, NOC, and All.

3.5.1. The Output Variable (Y)

At the firm's level, I consider the output or total production per firm per period. The output can be reported in three ways: in quantities (millions of oil equivalent), in value terms (price times quantity) at current prices (the product of the average market price of crude oil and natural gas over a specific period with the amount of oil and gas produced during the same period), and in total revenue (which is also price times quantity, but instead of using quantities produced and their market prices, I used the values for revenue reported in the financial statements of the companies). In this analysis, I use the firm's total revenue as a measure of output. Each period represents a year.

The amount of oil and gas, revenues, and current prices for each period are obtained from the annual reports of the firms.

3.5.2. The Capital Input Factor Variable (K)

Capital input (K) represents the real value of all machinery, equipment, buildings, oil and gas platforms, reserves acreages, pipelines, etc. In the financial statements it is reflected in capital stock, property, plant, and equipment (PPE) and in all capital expenditures and acquisitions. The capital employed each year is a fraction of the total capital input. This fraction may be likened to the yearly rent the firm may have charged for access to its PPE, reserves, and new acquisitions. The rent is related to the rate of a return applied to the sum of the depreciated value on gross property, plant, and equipment plus all capital acquisition and expenditure investment made during the period (Paltsev, 2004). The depreciation rate is δ, the cost of capital r, and the capital expenditure and acquisitions k_t for period *t*.

$$K_t = (PPE_t + k_t) * (\delta + r)$$

This defined the capital input variable, K_t, corresponding to a fraction of the PPE and capital expenditures for period *i* and I represent it in millions of dollars. I assumed a depreciation rate of 4 per cent and a cost of capital of 5 per cent. The depreciation rate was obtained by assuming a straight line depreciation over 25 years on all capital stock operated by the firm and the cost of capital was the median interest rate charged to ExxonMobil[15]'s long term debt in 2014.

3.5.3. The Labor Input Factor Variable (L)

Labor input (L) can be represented in two ways: the number of workers of total expenditure for labor services in millions of dollars. These numbers were derived directly from the financial statements of these companies.

3.5.4. The Capital Share (α) and Labor Share (1- α)

Capital and Labor shares are the fractions of capital and labor inputs, respectively, in the total output (the revenue for each company) for each period. They are obtained by finding the ratio of each of the input factors to the revenue. It is a simple calculation using figures obtained directly from the financial statements of the company.

$$\alpha_t = \frac{(PPE_t + k_t) * (\delta + r)}{Y_t} \tag{3}$$

Equation (3) defines the capital share, α_t, corresponding to ratio of contribution of the capital stock to the revenue for period *t* .

[15] Before April 2016, ExxonMobil had a S&P rating of Aaa – the only oil producing company with the highest possible rating. This makes the assumed cost of capital conservative in respect to other POC firms with lower ratings however it is a fair estimate when compared to the NOC firm who are considered to have access to cheaper sources of capital. Future work could focus on determining the sensitivities of the result to changes in selected cost of capital and depreciation rates.

The labor share is derived directly from the capital share based on the assumption that the both sum up to one, i.e., assuming a constant return to scale – all services paid for in the exploration and production sector are broken into capital and labor services.

4. DATA ANALYSIS

Chapter 3 introduced the research method and approach. In this chapter I extend the discussion to provide the findings of this thesis research. This chapter is divided in two sections. The first section covers analysis and findings related to productivity trends at the industry level aggregates. These aggregates fall in three buckets - Private oil and gas companies (POC), National oil and gas companies (NOC), and, an overall industry representation (referred to as "All"). The second part of the chapter provides some analysis to identify the major drivers to these trends and estimates their contribution margins to the overall aggregate productivity growth. The various analysis and findings will be carried out across the three time periods – 1970 to 1981, 1981 to1999, and 1999 to 2014 – with the objective of communicating how these trends may have changed across the time periods.

4.1. PRODUCTIVITY TRENDS AT THE OIL AND GAS INDUSTRY LEVEL

The section will detail the findings for the industry level across the three time periods of interest. First, I explore the trends for the rate of technical change in the oil and gas exploration and production industry. Then, I examine the elements that impact technical change: labor productivity, capital productivity, capital intensity, and total factor productivity will also be presented. I use the three methods presented in Table 5.

LEVEL 1 – DEFINE INDEPENDENT VARIABLES:	***LEVEL 2 – GROWTH ACCOUNTING:***	***LEVEL 3 – INDEX NUMBER THEORY METHOD:***	***LEVEL 4 – ECONOMETRICS METHOD:***
Annual Production (Y) **Annual Revenue (Y)** **E&P Employee Count (L)** **Annual E&P Wages (L)** **Capital Stock + Capex (K)** **Annual Production & Development costs** **Average Price of Crude oil**	**Annual Revenue per Employee (Y/L)** **Annual E&P Wages per Employee (Y/L)** **Annual Revenue per Capital Stock (Y/K)** **Capital Stock per Employee (K/L)** **Total Factor Productivity (A)** **Capital shares**	**Tornquist Indexes for input & output** **Weighted shares**	**Regression analysis**

Table 5 – Data Analysis Layout and Transition

To refresh the reader, the aggregate "POC" which is the private oil companies are made up from nine companies, which are Gulf Oil, Texaco, Standard Oil of California, Chevron, Exxon, Mobil, ExxonMobil, BP and Shell. The aggregate "NOC", the national oil companies, are made up of four companies, Gazprom, PetroChina, Petrobras, and Rosneft. As over time, these companies merge, a reader is referred to Table 3 for an overview on how the data are aggregated across each of the time periods.

4.1.1. Output

In this section I report output as measured in revenues (in constant 2014 dollars) and in millions of barrels of oil equivalent (MBOE) over the various time periods. In terms of the revenue, for the period with the most company representation, 1999 – 2014, the "All" aggregate grew at an average annual rate of 9.7 per cent, the POC aggregate grew at an average annual rate of 7.2 per cent, and the NOC aggregate grew at an average annual rate of 14.2 per cent. In terms of physical output (in millions of barrels of oil equivalent), the average annual growth rates for the "All" aggregate for 1999 – 2014 was 1.3 per cent, POC declined at a rate of 1.2 per cent, and NOC grew at a rate of 3.2 per cent. For this period, crude prices grew at an average annual rate of 9.4 per cent.

The second period, 1981 – 1999, output in constant dollar revenue for POC declined at an average annual rate of 2.4 per cent with constant crude oil price falling at an average annual rate of 7 per cent. The quantity of oil produced over this period increased at an average annual rate of 1.8 per cent. For the third period (the earliest), 1970 – 1981, revenue for POC increased at an average annual rate of 9.3 per cent and total oil production declined at an average annual rate of 5.7 per cent. For the same period, crude oil price increased at an average annual rate of 21.3 per cent. Cumulatively, over the period, the POC aggregate's output in constant dollar revenue increased at an average annual rate of 3.6 per cent per year and its output in quantity of oil equivalent declined at an annual rate of 1.1 per cent.

Table 6 summarizes output for each of the aggregates across the various time periods. It also provides a change in oil price during these periods.

		Output CAGR (%)			
		1970 - 1981	1981 - 1999	1999 - 2014	1970 - 2014
ALL	Revenue (2014 $)	-	-	9.7 (↑)	-
	Total Production (MBOE)	-	-	1.3 (↑)	-
POC	Revenue (2014 $)	9.3 (↑)	-2.4 (↓)	7.2 (↑)	3.6 (↑)
	Total Production[16] (MBOE)	-5.7 (↓)	1.8 (↑)	-1.2 (↓)	-1.1 (↓)
NOC	Revenue (2014 $)	-	-	14.2 (↑)	-
	Total Production (MBOE)	-	-	3.2 (↑)	-
	Crude Oil Price (2014 $)	21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 6 – Output summary

In the period 1970 – 1981, oil prices rose rapidly – increasing at an average annual rate of 21.3 per cent. With increasing prices it was unsurprising to observe revenue (output) increasing at a rate faster than those observed during the other time periods – see output performance for POC across the time period in table 6. One could argue that prices were the sole driver to the increasing revenues because actual produced quantities for the period were declining at an annual rate of 5.7

[16] Total production from private oil companies were derived by summing up production from only subsidiary companies to prevent the error of double counting produced volumes across affiliates. POCs to have a good number of affiliations and joint venture partnerships amongst themselves and some national companies hence the choice to avoid accounting affiliates. This decision makes the result conservative and biased downwards. Also, one of the four POC firms, BP, has had to divest aggressively to fund expenses and losses tied to its major oil spill in 2010.

per cent. The period 1981 – 1999 exhibited a different dynamic, as crude oil prices were dwindling the actual produced volumes were increasing but overall revenues were falling – crude oil prices fell at a rate faster than the rate of increase of produced oil.

For NOC the data are available only for the period of 1999 – 2014. During this period, NOC's output (measured in revenue) outgrew all the other aggregates – 14.2 per cent. NOC also have the highest rate of growth in produced oil equivalent barrels among the available data in Table 6. This result was significantly influenced by the Russian firms, Gazprom and Rosneft, both witnessed double digits growths in revenue primarily due to double digits growth in total oil and gas production over the period and favorable crude oil prices.

Two issues arise from the data on oil production in physical unites. The first issue is the question whether increasing crude oil prices incentivizes increased investments during that period resulting in an increased production (in oil equivalent barrels available) in the next period – POC average annual production growth rate was decreasing in the period 1970 – 1981 (-5.7 per cent), but then rose in the next period to 1.8 per cent. This simple analysis seems to confirm that an increased production in the future periods is due to an increased investment at the time of increasing oil prices. It also supports the case that decreasing oil prices discourage investment and the future production is decreasing (average annual production growth rate was negative for POCs in 1999 – 2014) In 2015 with the declining crude oil prices, general reports from energy analysts suggest that firms have cut back significantly on capital investments – potentially affecting the amount of crude production available to be produced in the "next" period (Wood MacKenzie, 2016). The second issue is if the relationship between production and revenue exhibited by the national oil companies is sustainable. NOC show faster increase in output in 1999 – 2014 in comparison to POC. One reason might be NOC have easier access to cheaper and more easily extracted resources and this might increase their ability to produce larger quantities of oil equivalents in the short term. Diminishing returns will set in at some point along their marginal cost curve and increasing production will be more constrained by both economics and geology (which relates directly to technology). In addition, 1999 – 2014 period is when Gazprom, Rosneft, and PetroChina were reorganized and expanded.

4.1.2. Labor Input

Labor input is measured as the number of workers available each year and the annual total expenditure associated with labor each year. Table 7 presents the results for labor input. The number of workers has increased for the "All" aggregate over the period 1999 – 2014 by an average annual rate of 1.6 per cent. For the same period, both the POC and NOC aggregates in terms of number of workers have also grown at average annual rates of 3.4 and 1.3 per cent respectively. In terms of total labor income (or wages), measured in constant 2014 dollars paid to labor, "All", POC, and NOC aggregates have all experienced an average annual growth rate of 4.8, 3.7, and 6.3 per cent respectively.

For the period 1981 – 1999, POC aggregate's number of workers decreased at an average annual rate of 6.1 per cent and labor income also decreased at an average annual rate of 6.3 per cent. For the earliest period, 1970 – 1981 and for the same aggregate, number of workers increased at an average annual rate of 2.8 per cent and labor income also increased at an average annual rate of 2.6 per cent. Over the entire period, 1970 – 2014, number of workers and total wages (in constant dollars) decreased at an average annual rate of 0.7 and 0.8 per cent respectively for POC.

		Labor Input CAGR (%)			
		1970 - 1981	**1981 - 1999**	**1999 - 2014**	**1970 - 2014**
ALL	Labor (# workers)	-	-	1.6 (↑)	-
	Labor income (2014 $)	-	-	4.8 (↑)	-
POC	Labor (# workers)	2.8 (↑)	-6.1 (↓)	3.4 (↑)	-0.7 (↓)
	Labor income (2014 $)	2.6 (↑)	-6.3 (↓)	3.7 (↑)	-0.8 (↓)
NOC	Labor (# workers)	-	-	1.3 (↑)	-
	Labor income (2014 $)	-	-	6.3 (↑)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 7 – Labor Input Summary

In absolute numbers, the numbers of workers for the NOC remained significantly higher than their counterparts in the POC. This could be related to the NOC companies having national responsibilities to create jobs and their lower wage structures (compared to wages in POC which were consistently higher) together provide more incentives to hire more workers. Adjustment for quality of labor across NOC and POC was not factored into my analysis and therefore there is no means of comparing if NOC could be trying to compensate for lower labor quality by increasing staffing levels.

Overall, the labor input increased steadily with increasing crude oil prices and decreased when crude oil prices were declining. One can observe that for POC the rate of change for number of workers and labor income changed by almost the same magnitude indicating that both parameters changed in tandem. The case seems different in the case of the NOC, the labor income grows at a faster rate than the rate of increase in the number of workers – this could be indicative of improving worker compensation structures amongst the NOC.

4.1.3. Capital Services Input

Capital input represent the total capital services used in the production process and measured in constant dollars. Table 8 present the results for capital input. For the most recent time period, 1999 – 2014, the "All" aggregate had its capital input increase at an average annual growth rate of 10.3 per cent. In this period, both POC and NOC had their capital input increase at average annual rates of 8 per cent and 15.2 per cent respectively. Across the other two time periods, POC first saw its capital stock increase at an average rate of 6.1 per cent from 1970 to 1981 then it decelerated but continued to increase at an average annual growth rate of 0.4 per cent. Overall, POC witnessed an increase in capital productivity from 1970 to 2014 of 4.3 per cent compound annual growth rate.

		Capital Input CAGR (%)			
		1970 - 1981	**1981 - 1999**	**1999 - 2014**	**1970 - 2014**
ALL	Capital Services (2014 $)	-	-	10.3 (↑)	-
POC		6.1 (↑)	0.4 (↑)	7.9 (↑)	4.3 (↑)
NOC		-	-	15.2 (↑)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 8 – Capital Input Summary

Table 8 shows that there is a positive relationship between growth in capital input and crude oil prices. Capital input increases steadily when crude oil prices increase and vice versa. Observe that the rate of growth of capital input is highest relative to the rate of growth in crude oil prices in the most recent period 1999 – 2014 for both NOC and POC – an indication of aggressively increasing capital investment. In further sections of this chapter, I will be reviewing the output relative to capital investment to further explore a relationship between capital and output.

Also in earlier sections of this chapter, I mentioned that NOC in 1999 – 2014 were seeing positive growth of output – revenue and volumes. Aside increasing crude oil prices, I think it is logical to also assume that their aggressive rate of capital investment is driving some of the increase in production in the current period (and possibly in the next period).

4.1.4. Labor Productivity

Labor productivity is measured as the total output (in constant dollars or quantity of oil equivalent) per worker. The labor productivity is another representation of the output but this time relative to how much output each worker is able to produce. The expectation for the rational firm is to maximize this parameter at the lowest possible cost. Table 9 summarized the data for labor productivity. In constant dollar measurements, the "All" aggregate for the period 1999 – 2014 witnessed an increase in labor productivity of 7.6 per cent per year, while labor productivity for the POC and NOC increased at an average annual rate of 3.6 per cent and 12.0 per cent respectively. For the same period in oil equivalent units, the "All" aggregate fell at an annual rate of 0.3 per cent. POC experienced a drop at an average annual rate of 4.5 per cent, while NOC had a growth of 1.9 per cent per year. For the period, 1970 – 1981, labor productivity for POC measured in constant dollar revenue per worker increased at an average annual rate of 6.1 per cent. In the next period, 1981 – 1999, growth in labor productivity slowed down, although it continued to grow at an average annual rate of 3.9 per cent. In oil equivalent units, POC experienced a decline in labor productivity from 1970-1981 at an average annual rate of 8.3 per cent and in the next period, 1981 – 1999, an increase of 8.5 per cent per year. Over the entire period, 1970 – 2014, labor productivity for POC in constant dollars increased at an average annual growth rate of 4.3 per cent and in oil equivalent units decreased by 0.4 per cent per year.

		Labor Productivity CAGR (%)			
		1970 - 1981	**1981 - 1999**	**1999 - 2014**	**1970 - 2014**
ALL	Revenue per worker (2014 $/worker)	-	-	7.6 (↑)	-
	Barrels per worker (KBOE/worker)	-	-	-0.3 (↓)	-
POC	Revenue per worker (2014 $/worker)	6.1 (↑)	3.9 (↑)	3.6 (↑)	4.3 (↑)
	Barrels per worker (KBOE/worker)	-8.3 (↓)	8.5 (↑)	-4.5 (↓)	-0.4 (↓)
NOC	Revenue per worker (2014 $/worker)	-	-	12.0 (↑)	-
	Barrels per worker (KBOE/worker)	-	-	1.9 (↑)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 9 – Labor Productivity Summary

4.1.5. Capital Productivity

Capital productivity measures output (in terms of revenues and physical quantities) per dollar of capital input. This parameter speaks to the efficiency of capital and helps to explore the following question: is each unit of capital producing more or less output? Table 10 provides a summary for capital productivity. The "All" aggregate for the period 1999 – 2014 witnessed a decrease in capital productivity of 0.6 per cent per year, while capital productivity in POC and NOC decreased at an average annual rate of 0.2 per cent and 0.8 per cent, respectively. For the period, 1970 – 1981, capital productivity for POC increased at an average annual rate of 3.0 per cent. In the next period, 1981 – 1999, capital productivity decreased by an average annual rate of 3.2 per cent. Over the entire period, 1970 – 2014, capital productivity for the aggregate, POC, decreased by an average annual rate of 0.6 per cent.

		Capital Productivity CAGR (%)			
		1970 - 1981	1981 - 1999	1999 - 2014	1970 - 2014
ALL	Revenue/Capital input	-	-	-0.6 (↓)	-
	Output (MBOE)/Capital input	-	-	-8.2 (↓)	-
POC	Revenue/Capital input	3.0 (↑)	-3.2 (↓)	-0.2 (↓)	-0.6 (↓)
	Output (MBOE)/Capital input	-11.1 (↓)	1.6 (↑)	-8.5 (↓)	-5.2 (↓)
NOC	Revenue/Capital input	-	-	-0.8 (↓)	-
	Output (MBOE)/Capital input	-	-	-8.2 (↓)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 10 – Capital Productivity Summary

The capital productivity across each aggregate declines except for the period 1970 – 1981 for the POC. Decreasing growth in capital productivity can also be an indication of the fact that new finds of oil and gas are more expensive to produce.

4.1.6. Capital Intensity

Capital intensity is measured as the amount of capital services in constant dollars available to each worker in the production process. Table 12 shows a summary for the capital intensity results. The "All" aggregate for the period 1999 – 2014 witnessed an increase in capital intensity of 5.3 per cent per year, while capital intensity in POC and NOC increased at an average annual rate of 4.4 per cent and 8.4 per cent respectively. For the period, 1970 – 1981, capital intensity for POC increased at an average annual rate of 3.2 per cent. In the next period, 1981 – 1999, capital intensity increased at an average annual rate of 6.8 per cent. Over the entire period, 1970 – 2014, capital intensity for the POC aggregate increased by an average annual rate of 5.1 per cent.

		Capital Intensity CAGR (%)			
		1970 - 1981	**1981 - 1999**	**1999 - 2014**	**1970 - 2014**
ALL	Capital Intensity (2014 $ capital services/worker)	-	-	5.3 (↑)	-
POC		3.2 (↑)	6.8 (↑)	4.4 (↑)	5.1 (↑)
NOC		-	-	8.4 (↑)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 11 – Capital Intensity Summary

Over time, capital intensity across all aggregates have been observed to rise steadily. This could be a result of increasing capital investments (in absolute terms) to enable access to harder to reach oil reservoirs (and, therefore, less profitable). Another perspective could be suggested from gleaning information from the capital intensity, labor input and capital input tables. There are flexibility differences in adjusting labor input compared to capital input. For example, in 1981 – 1999 when the industry witnessed a drop in crude oil prices, POC decrease labor input at a faster rate than capital input. The effect was an increase in that period in capital intensity versus other periods. This suggestion (though in multiple contexts) has been voiced in series of literature focused on the measurements of productivity. A number of these publications have suggested that it is erroneous to assume that all factors in the production function are fully flexible or fully fixed throughout the production process (Hulten, 1986)(Morrison, 1985).

4.1.7. Total Factor of Productivity

Table 12 compares the findings from two methods to account for the total factor productivity: growth accounting versus index number theory. As discussed in Chapter 2, growth accounting assumes a summation of the values for individual companies and derivation of TFP based on these aggregate numbers. As a result, TFP calculation is likely to be affected when one company dominates the sample, like ExxonMobil for POC and Gazprom for NOC. Index number approach uses weights to represent contribution of individual companies. Therefore, it is more reflective of the whole industry.

The growth accounting method shows TFP for the “All” aggregate from 1999 – 2014 to be increasing at an average annual rate of 3.0 percent compared to the index number theory method that shows TFP increasing at an annual rate of 1.7 percent. The POC aggregate increases at an average annual rate of 0.5 per cent using the Cobb-Douglas method compared to the index number theory method that shows TFP increasing at an annual rate of 0.1 per cent. For the NOC aggregate, over the same period, the Cobb-Douglas method shows TFP increasing at an average annual rate of 6.5 per cent and 4.0 per cent with the index number theory method.

		TFP CAGR (%)			
		1970 - 1981	**1981 - 1999**	**1999 - 2014**	**1970 - 2014**
ALL	Growth Accounting	-	-	3.0 (↑)	-
	Index number	-	-	1.7 (↑)	-
POC	Growth Accounting	6.7 (↑)	2.6 (↑)	0.5 (↑)	2.9 (↑)
	Index number	4.8 (↑)	0.5 (↑)	0.1 (↑)	1.4 (↑)
NOC	Growth Accounting	-	-	6.5 (↑)	-
	Index number	-	-	4.0 (↑)	-
Crude Oil Price (2014 $)		21.3 (↑)	-7.0 (↓)	9.4 (↑)	5.1 (↑)

Table 12 – TFP Summary: Growth Accounting vs. Index number

Consistently, the index number theory method shows a more conservative TFP value compared to the growth accounting direct summation method. This is because the index number approach adjusts both the output and input shares to reflect the weight scales of the individual firms (components). This adjustment is possible because the index number method applies the Divisia indexes (see equations 4 and 6 in Chapter 2).

The table reveals the substantial difference in the rate of TFP growth between the NOC and the POC for the most recent period – 1999 - 2014. The TFP trend at the NOC level was growing faster (4 per cent) than the growth rate of the POC (0.1 per cent) for the same period. Since the residual (A in equation 4) represents everything and anything driving the production process outside the use of capital and labor input, it raises the questions – could the level of growth seen at the NOC level be reasonable and a good representation of what could be considered a fair estimation of the projected global industry level TFP productivity? Considering the innate characteristics of the NOCs and how much different they are from those of the POCs – more access to cheaper resources (lower marginal costs of production), emphasis on production growth and rapid expansion, mostly localized operations in their various home countries vs. the global operations of POCs, activities influenced mostly by national interest and politics then economic factor (e.g., Russia, China), etc. – it is not clear if these growth numbers are stable and sustainable going forward. It also should be noted that the TFP growth seen in the NOC aggregate was driven mainly by Gazprom and Rosneft aggressive growth[17], while the other NOC individual firms have TFP growth rates similar to POC (and their individual firms). Another consideration is that I compare growth rates rather than levels, and faster growth in NOC might mean that productivity grows from a lower level to catch up with productivity at POC.

In my opinion (and based on subsets of the data presented), the estimate of the global technical change growth should be closer to the "All" aggregation. This value, to a very large degree, is more representative of the current structure of the global oil and gas industry than the individual POC or NOC aggregates standing alone. Also if one looks to the first time period for the POC aggregate, the TFP growth rate is similar to that of the NOC period in the most recent period suggesting that the NOC aggregate in the most recent period could be experiencing similar economic and geologic situations like access to more easily extractable and profitable resources, larger revenue surpluses from crude oil price increases, focus on expansion and capital investments, etc.

The rapid TFP growth for the POC in 1970 – 1981 was not sustained in the later periods. It is not clear if the same will be true for NOC in the periods after 2014. The cumulative rate of TFP growth of the POC for the entire period, 1970 – 2014, might be more suggestive to how the NOC might continue to perform. Hence, one reasonable guess for the future TFP growth is a range

[17] Gazprom is responsible for 10% of Russia's GDP and about 13% of the worldwide production (Forbes, 2016).

between 1.4 – 1.7 per cent per year when projecting TFP growth for the industry. Next I test this number using the regression method.

The regression method was also applied to the "All", POC, and NOC aggregates across the corresponding time periods. The essence was to test the validity of the results from growth accounting and Index number theory methods. The results for "All", POC, and NOC are presented in Tables 13 - 16 – α represents the residual and β the coefficient of capital in the production process.

Parameters		α	β	R^2	p-value
$\frac{Y}{L}$	$\frac{K}{L}$	0.178	5.302	0.759	1.1E-5
$\frac{Y}{L}$	$Log\frac{K}{L}$	2.537	0.783	0.833	8.0E-7
$\frac{Y}{L}$	$-1/\frac{K}{L}$	1.780	0.099	0.863	2.0E-7
$Log\frac{Y}{L}$	$Log\frac{K}{L}$	1.750	0.940	0.829	9.4E-7
$Log\frac{Y}{L}$	$-1/\frac{K}{L}$	0.863	0.121	0.891	4.0E-8

Table 13 – Regression Analysis for "All" aggregate, 1999-2014

Parameters		α	β	R^2	p-value
$\frac{Y}{L}$	$\frac{K}{L}$	0.121	6.036	0.863	2.2E-6
$\frac{Y}{L}$	$Log\frac{K}{L}$	4.256	1.612	0.786	5.4E-6
$\frac{Y}{L}$	$-1/\frac{K}{L}$	3.366	0.273	0.584	1.0E-9
$Log\frac{Y}{L}$	$Log\frac{K}{L}$	1.666	0.859	0.828	2.2E-16
$Log\frac{Y}{L}$	$-1/\frac{K}{L}$	1.225	0.151	0.664	9.6E-12

Table 14 – Regression Analysis for POC aggregate, 1970-2014

Parameters		α	β	R^2	p-value
$\frac{Y}{L}$	$\frac{K}{L}$	0.097	5.347	0.832	8.6E-7
$\frac{Y}{L}$	$Log\frac{K}{L}$	1.569	0.379	0.888	4.9E-8
$\frac{Y}{L}$	$-1/\frac{K}{L}$	0.914	0.019	0.857	2.7E-7
$Log\frac{Y}{L}$	$Log\frac{K}{L}$	1.680	0.919	0.899	2.2E-8
$Log\frac{Y}{L}$	$-1/\frac{K}{L}$	0.142	0.049	0.957	5.6E-11

Table 15 – Regression Analysis for NOC aggregate, 1999-2014

Observing the results from tables above reveal that the regression for the Cobb-Douglas function ($Log\frac{Y}{L} = \alpha + \beta Log\frac{K}{L}$) yield coefficients closest to the index number theory method especially for the POC aggregate. The POC residual is 1.67 per cent per year and the capital share is 0.86 and close to the average of 0.83. At the same time, note the small p-values. The results for NOC and "All" are surprisingly not as accurate as that for POC. The unreliability of results for

NOC and "All" could be linked to a data insufficiency problem and this been recognized and referred to by a number of authors who wrote to provide pros and cons to the econometric approach to productivity measurements (OECD, 2001; Morrison, 1985).

4.2. DRIVERS OF GLOBAL OIL AND GAS INDUSTRY PRODUCTIVITY

The above sections of this chapter presented findings for labor productivity, capital intensity, and total factor productivity for the various aggregates across the applicable time periods. Now I explore these results side by side to decipher if there are common trends and possible insights that can be obtained to explain possible drivers of total factor productivity.

From the index number equation (3), the TFP growth can be decomposed into the equation below to identify the sources of growth to labor productivity.

$$\left[\log\left(\frac{Y_{t+s}}{L_{t+s}}\right) - \log\left(\frac{Y_t}{L_t}\right)\right]/s = [\log A_{t+s} - \log A_t\,]/s + \; w_k\left[\log\left(\frac{K_{t+s}}{L_{t+s}}\right) - \log\left(\frac{K_t}{L_t}\right)\right]/s$$

The following table shows individual growth accounting across the three time periods for the aggregates.

		CAGR (%)	
		Due to TFP	**Due to K/L**[18]
POC	1970 - 2014	1.4	2.9
	1970 - 1981	4.8	1.3
	1981 - 1999	0.5	3.4
	1999 - 2014	0.1	3.5
NOC	1999 - 2014	4.0	8.0
ALL	1999 - 2014	1.7	5.9

Table 16 – Growth accounting for Aggregates

The findings from Tables 16 and 17 suggest that the drivers behind labor productivity (henceforth referred to as productivity) have been different over the three time periods. Looking at data for the POC, productivity in the earliest period, 1970 – 1981, seems to be driven mainly by total factor productivity – possibly technical change improvement from optimized production processes, access to relatively easier to reach oil and gas resources, lower regulatory and safety requirements, etc. In the next two subsequent periods, productivity seems to be relatively even and it is driven primarily by capital intensity. An increase in capital intensity implies that an increase in capital stock is faster than an increase in labor input. The last period, 1999 – 2014, shows a slight decline in productivity and TFP growth rates and an increasing growth rate in capital intensity – the highest seen across the three time periods. Productivity in this time period is driven mostly by capital intensity – investments in capital and/or labor services.

[18] The share of capital services, w_k is applied to capital intensity parameter.

Compound Annual Growth Rate (%)						
	Labor Productivity	**Capital Productivity**	**Capital Intensity**	**Capital Stock**	**Labor input**	**Total Factor Productivity**
1970 – 2014	4.3	-0.6	5.1	4.3	-0.7	1.4
1970 – 1981	6.1	3.0	3.2	6.1	2.8	4.8
1981 – 1999	3.9	-3.2	6.8	0.4	-6.1	0.5
1999 - 2014	3.6	-0.2	4.4	7.9	3.4	0.1

Table 17 – Labor Productivity Growth Accounting for POC

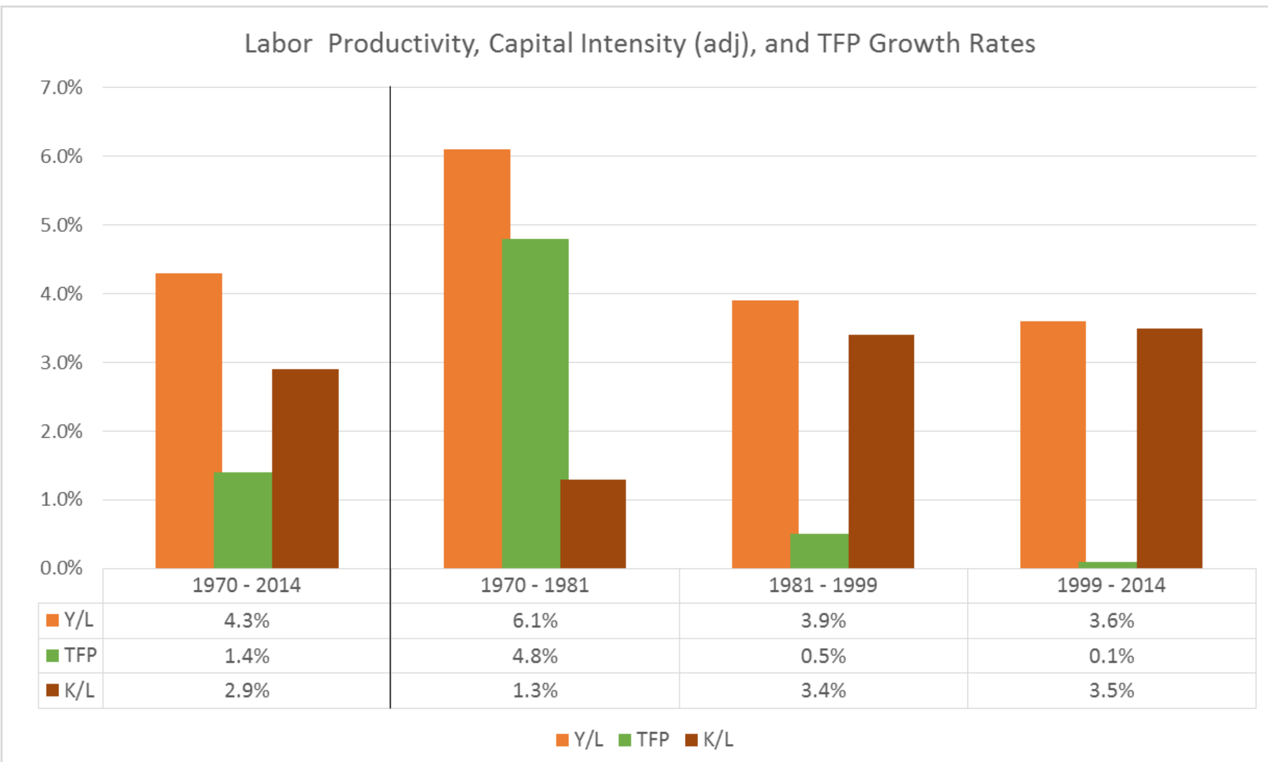


Figure 9 – Labor Productivity Growth Accounting for POC

Figure 9 shows that over the periods in this study, adjusted capital intensity (i.e., capital intensity by capital share) has been increasing while TFP has shrunk significantly (note that Table 17 reports unadjusted capital intensity, while Figure 9 reports adjusted capital intensity). A plausible argument could be that this disembodied technical change is being diminished as firms continue to optimize and push for cost minimized operations – risk sharing through the joint venture partnership, industry best practices being shared between firms, etc. Concurrently, governmental and environmental constraints continue to get tighter via the introduction of stringent regulatory and safety requirements, all of these further erode any possible remaining residuals that could have contributed in some way to increasing TFP growth. Another perspective to the rapidly declining TFP is that most of the technological progress now seen in the industry may have moved from disembodied form to the embodied form – ingrained in the capital vintages and labor input. If this is the case, then calculating for the TFP as a residual might not be sufficient in fully measuring for the technological progress being made in the industry. This could be an area of investigation for future work.

The next logical question to ask after realizing that most of productivity is being driven by increasing capital intensity is how much could more increases in capital intensity have on productivity – in other words, could diminishing returns on increasing capital intensity set in? This question can be answered by adopting similar concept used by Solow (1957). In this case, using data for the POC, in Figure 10 I plotted labor productivity adjusted for gain from total factor productivity ($^{Y}/_{L}$ divided by A) over capital intensity ($^{K}/_{L}$) – the adjusted labor productivity represents only the part of productivity contributed directly by capital intensity.

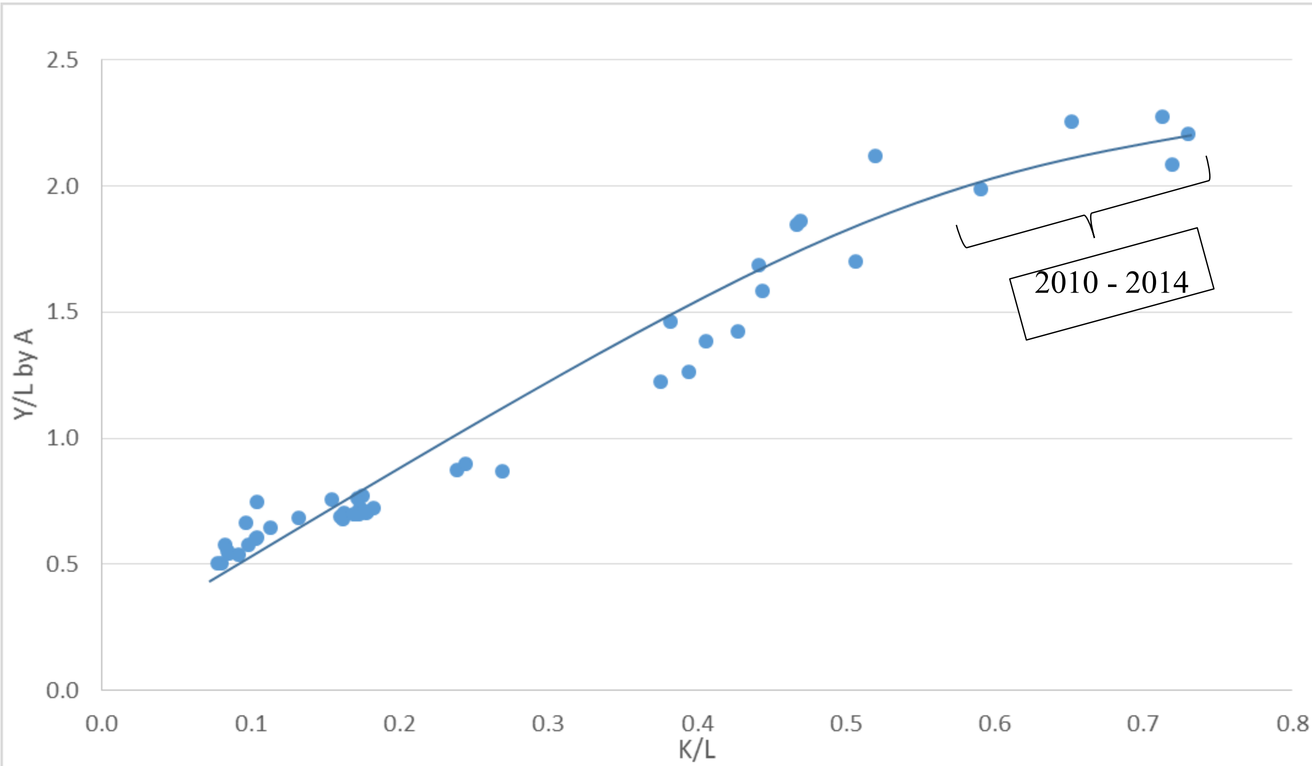


Figure 10 – Adjusted Labor productivity by Capital Intensity

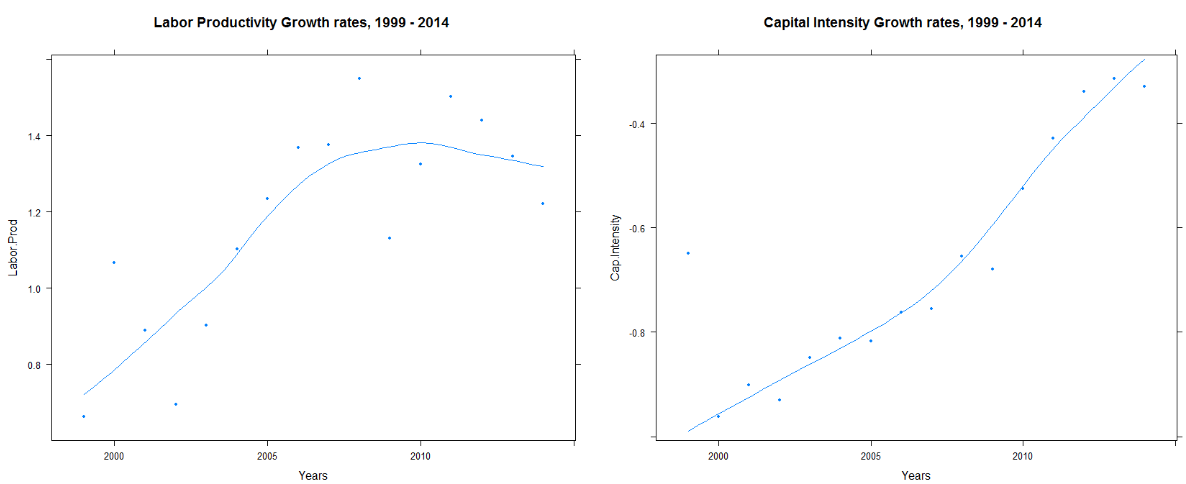


Figure 11 – POC's Labor Productivity Growth rates vs. Capital Intensity, 1999 – 2014

Loess trend line (α = 0.65, λ = 1).

These plots – Figures 10 and 11 – reveal that diminishing returns might be already achieved for capital intensity. The plots show that from around the year 2010, the relationship between capital intensity and adjusted labor productivity begins to show some curvature that exhibits diminishing returns – at (and beyond) this stage the diminishing returns implies less and less output is being generated from marginal additions of capital. This could mean that to maintain the future crude oil and natural gas reserves and meet crude oil demand, greater (and unproportional) amounts of capital investments have to be made. Figure 11 shows labor productivity side by side with capital intensity for the period 1999 – 2014, which illustrates the drop from 2010 in labor productivity and an increase in capital intensity.

4.3. SUMMARY

My findings are only a demonstration of what may be happening at the global industry level. Although the research's data set is a fair representation of the make-up of the global industry and its output mix, it does not exhaustively characterize all key players within the industry. For example, since 2010 tight oil output in the United States has produced about four million additional barrels per day of oil to global production. This output is driven primarily by the proliferation of new industry players called the independent oil and gas producers. This study did not include any of these producers to its data set mainly due to constraints of data limitations and the assumption that the additional weighted impact of an independent producer will be minimal on the entire sample size. With all the caveats, a growth in TFP for the oil and gas industry is assessed to be in the range of 1.4 – 1.7 per cent per year.

5. CONCLUSIONS AND FUTURE RESEARCH OPPORTUNITIES

This chapter presents the conclusions and recommendations drawn from this research with respect to the research questions. First, I present answers to the questions around which this thesis was built. Next, I provide my perspective to some limitations of the study and how these limitations could affect some of the observed results. I provide guidance on some of the future directions that could be investigated in response to the limitations to provide more robust evaluation of the research topic. Lastly, I present my conclusions and recommendations, and highlight the context through which these conclusions and recommendations are presented.

5.1. RESEARCH ANSWERS TO RESEARCH QUESTIONS

This research started with a dive into the measurement of productivity at the global industry level to better understand how much impact technical change could be having on the supply of crude oil and natural gas and ultimately its effect on their prices. A number of questions were raised and this section delves into providing answers based on the findings and results from my research.

5.1.1. Question #1: Can productivity and technical change at the global industry level be estimated?

This question was considered the bedrock of this research. This research hypothesized that if one could use publicly available industry data and apply acceptable neo-classical economics theories one should be able to provide a consistent, standardized, and repeatable way to measure the productivity and technical change for the global industry. Also, although a lot of work has been done around the topic of productivity measurements, most of these have been focused on national accounts of countries and local sectoral industries within countries. To the best of my knowledge, no work has been done yet in attempting to measure productivity at the global industry level – another reason why this research is important.

The results of my research shows that from 1999 – 2014, a period observed to have crude prices rising at an average annual rate of 9.4 per cent per year and the most recent period considered for the global industry, productivity (i.e., labor productivity measured as revenue per worker) and technical change grow at a yearly compounded rate of 7.6 per cent and 1.7 per cent, respectively, for the aggregate "All", which represented 40 per cent of global production. These results for technical change growth rates were driven mainly by the national oil companies – representing 22 per cent of global oil production and 53 per cent of total production from the 8 major players comprising the data set – had corresponding rates of 12 per cent and 4 per cent respectively. The remaining 18 per cent of global oil production and 47 per cent of total production from the 8 major players comprising the data set was represented by the private oil companies. The measured productivity and technical change for this aggregate was 3.6 per cent and 0.1 per cent, respectively.

Exploring the data for the private oil companies (POC) aggregate from 1970 – 2014 revealed that for the earliest period, 1970 – 1981, the measured productivity and technical change were was 6.1 per cent and 4.8 per cent, respectively. These figures were comparatively similar to rates seen for the national oil companies (NOC) aggregate in the most recent period 1999 – 2014. The next period, 1981 – 1999, the POC aggregate had measured productivity and technical change growth rates of 3.9 per cent and 0.5 per cent, respectively. The measured values for POC across the time period 1970 – 2014 showed that the overall productivity and technical change differ in three time periods considered in my study. These changes for the POC over time suggest that the relatively high growth rates of technical change observed for the national oil companies (NOC) in the period from 1999 to 2014 might not be sustainable and may be rather an upper bound estimate for future projections of productivity. To reflect this, I measured the growth rate in productivity and technical change for the POC aggregate as the cumulative growth rates for productivity and technical change observed over the entire period 1970 – 2014. These values were calculated to be 4.3 per cent for productivity and 1.4 per cent for technical change. A value of 1.7 per cent average annual growth rate was also obtained using the regression analysis method for the POC over the entire time period. These values suggest that for estimating future rates of technical change, a value range between 1.4 to 1.7 per cent a year can be used as the first order approximation of what may be seen in the global industry.

5.1.2. Question #2: Can this assessment of productivity and technical change be useful in quantifying the changes in the supply and price of crude oil and natural gas?

It is important to provide some context to what the impact of this improvement might mean on the total global supply of oil and consequentially on its price. To estimate this impact, I will be employing a very simplistic illustration that tries to mimic how long run energy models may try to estimate the depletion[19] of crude oil reserves. The illustration is based on the following simplifying assumptions**:**

1. That the model lumps crude oil production (and depletion) on a 5 yearly basis.
2. Some external factors (that are not represented in the illustration) may change the demand curve, but these changes are left out in this example.
3. The prices of crude oil covers for both the marginal cost and any other margins (like trade and transport, monopoly margins, etc.).

The illustration builds off the following numbers (see Table 18):

[19] Depletion in this context is equal to global oil production in that period.

1. The average annual total crude oil production: This number is calculated by dividing the average yearly revenue by the average yearly crude oil price over the period 1999 – 2014 for the "All" aggregate. This is 6.0 billion barrels of oil equivalents (Bboe) per year.
2. Technical change (TFP) contribution to average annual total crude oil production: Estimated by applying the TFP rate of growth to the average annual total crude oil production. This is 84.2 million barrels of oil equivalent (Mboe) per year.

The number for annual production (6 Bboe) includes a contribution from TFP. The difference (5.9 Bboe) between the above numbers (1 and 2) represents the amount that would be produced without accounting for the annual growth in technical change. Over a five year period, the cumulative oil production is the base amount (without TFP growth) multiplied by 5, which is 29.6 Bboe. The cumulative oil production with TFP growth compounded over five years is 30.9 Bboe.

	"All", 1999 - 2014
Average yearly revenue	$430B
Average annual oil price	$71.5
Average annual total oil production	6.0Bboe
TFP contribution of annual production (TFP growth rate of 1.4%)	84.2Mboe
Average annual total oil production less contribution from TFP (Base annual production)	5.9Bboe
Cumulative base production over 5 years	29.6Bboe
Cumulative total production over 5 years factoring TFP CAGR of 1.7%	30.9Bboe

Table 18 – 5 years production with CAGR TFP of 1.4%

The difference between the cumulative production in a five year period due to TFP growth amounts to about 1.3 Bboe. (or annual production of 260 Mboe or daily production of 712 Kboed[20]). Figure 12 shows a simplistic representation of an estimate for market prices with respect to the cumulative depletion amount over the five year period. The cumulative produced (and depleted) amount of 29.6 Bboe would yield a projected price close to the average yearly price of $71.50. Over the next consecutive five years, without factoring for TFP growth, the model will tend to move up along the supply curve S_1 suggesting an immediate increase in market prices. However, because I have shown that there exists some growth in TFP that contributes an extra 1.4 per cent each year to the total production, factoring this into this example would shift the supply curve to the right (S_1 moves to S_2) by the amount equivalent to the increased production resulting

[20] Kboed – thousand barrels oil equivalent per day

from the compounded growth of TFP – 1.3 Bboe as shown in Figure 13. This shift might result in lower oil prices (or at least lower that the model without a representation of technical change).

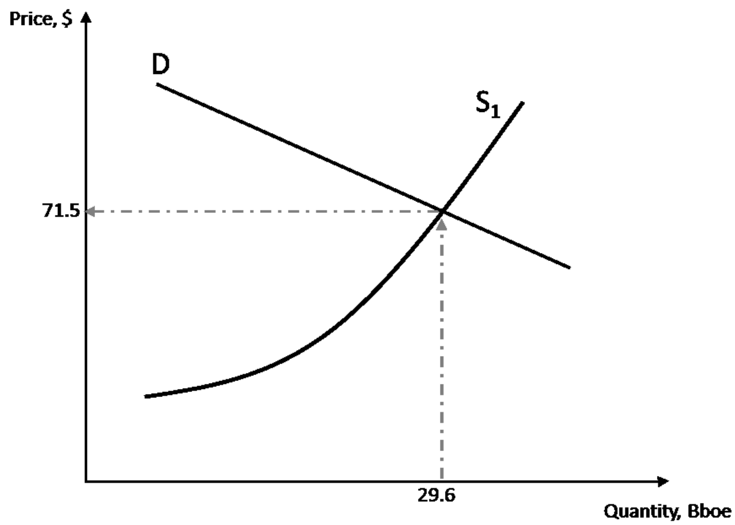


Figure 12 – Oil Depletion Curve Illustration

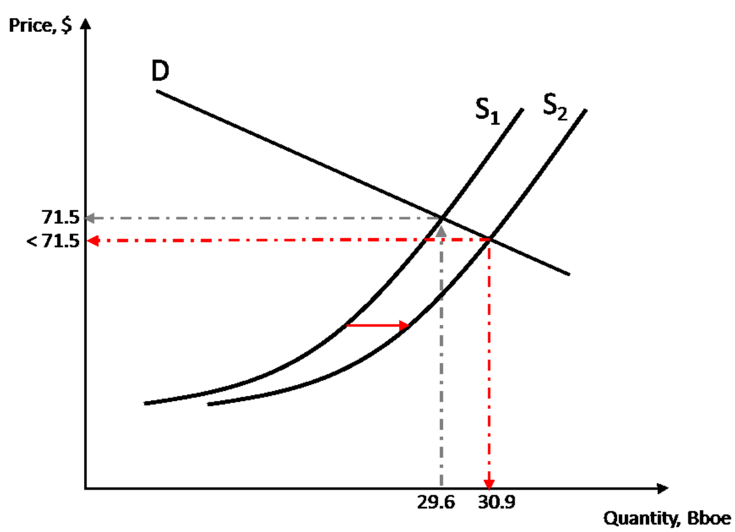


Figure 13 – Oil Depletion Curve Illustration with TFP contribution

My simple example illustrates that an introduction of an oil and gas specific technology improvement coefficient may reflect better relative costs of different energy sources (and it will affect the competitiveness of different forms of energy).

5.1.3. Question #3: What are the underlying drivers influencing the changes in productivity and technical change?

First, the results from the data showed that there were distinctive time periods within which the behavior of the measured productivity trends and their drivers were different. These changes coincide with changes in the price of crude oil. The data indicates that it might be a positive relationship between labor productivity measured in constant revenue per worker and crude oil prices. Also I observed that as prices increased, revenue surpluses increased and companies were incentivized to increase their capital investments in search of more difficult to reach oil. Finally, an increase in capital investment has increased capital intensity significantly and this in turn has been the most significant driver to increasing trends in the productivity. On the other hand, total factor productivity which reflects the disembodied technical change has been declining since 1981 to levels in the most recent periods – reference to data from POC aggregate. As mentioned in the earlier chapter, care must be taken not to discount the presence of potentially increasing embodied technical change which could be present in the vintages of capital services and stock.

My research concludes that based on the data available and the type of analysis conducted, capital intensity and capital investment has been the dominating contributor to productivity in the global industry. This finding seems consistent with similar results from CSLS in 2014 which showed a declining rate of TFP in the north America oil and gas industry (Sharpe & Waslander, 2014).

5.2. Current Research's Limitations and Future Research Opportunities

This section highlights some of the limitations in the data that I observed. It also highlights the areas where possible future research opportunities exist.

- Insufficient data availability, especially for the national oil companies, prevented the expansion of the time periods used for the analysis. Some sections of data for POC for certain periods of time (like BP and Mobil) are also missing. The analysis for POC was adjusted to reflect this. Future work could focus on expanding the data time series or increasing the sample size to cover a larger representation of the industry. Also other analysis could be carried out including newer (and increasingly influential) producers like the North American independent oil companies.
- The analysis carried out did not adjust the labor input and capital services for changes in quality. Assuming that all labor and capital across all the producers are the same might be an overly simplistic assumption. If quality adjustments are incorporated, measured productivity and TFP could be revised.
- No adjustment was made for the heterogeneity that may exist between the individual producers that made up the data set. This means that the current result includes various sources of noise from all the individual producers aggregated by their weighted shares. For future research work, inclusion of some fixed effects at the level of the company or region might correct for this.
- In measuring the total factor productivity for the industry, it will be necessary to look into the embodied portion of TFP embedded in other input factors especially capital vintages. Accounting for this will provide a better perspective to the total TFP growth of the

industry. This research only focused on the disembodied portion of TFP and future work can be focused on analysis for both types of TFP.

- This research did not account for the lag effect that might exist between capital invested, total factor productivity, and labor productivity. It is known that the oil and gas industry has a long lead cycle between exploration and production of oil. This could mean that a significant portion of capital investments made in a certain time period might yield output in the next period. This effect could be investigated in future research undertakings.

5.3. CONCLUSIONS

The following conclusions can be made with respect to measuring the productivity and technical of the global oil and gas industry using representative major players.

- Three distinct periods of TFP growth rate are identified – driven by the underlying oil price and capital investments (1970-1981, 1981-1999, and 1999-2014).
- Productivity and TFP growth can be measured for the global industry level using data that presents a fair representation of the industry.
- TFP growth for NOCs and POCs differs, but the public data for NOCs are limited to 1999-2014, a period of rising oil prices and structural changes in NOCs (Gazprom, Rosneft, Petrobras, and PetroChina), which may not be representative for the longer-term projections.
- Over the period of study, 1970 – 2014, rate of technical change grew between 0.1 – 4 per cent per year (NOCs in 1999-2014 grew at a comparatively similar rate as POCs in 1970-1981).
- During 1999-2014, aggregate TFP yearly growth rate is 1.7 per cent (4% for NOCs and 0.1% for POCs).

- The suggested rate to use in long-run energy economic models is between 1.4 – 1.7 per cent per year.
- Introduction of an oil and gas specific technology improvement coefficient may reflect better the relative costs of different energy sources (and it will affect the competitiveness of different forms of energy).

5.4. RESEARCH CONTRIBUTIONS

This research contributes directly to the body of knowledge focused on the measurement of productivity and technical change in the following ways:

1. The creation of a data set for the oil and gas industry that captures useful information from publicly available financial records for a number of major companies over a forty-five year time frame. This data set is available at the granular level for the individual companies and also for the aggregates.
2. Provision of insights to the application of a number of simple economics theories to measuring productivity and technical change using aggregated data. The information and analysis are carried out over three distinct time periods during which the movement of crude prices were different and the resultant behavior of the firms (and their aggregates) was explored. These results are classified into private and national oil companies and also available at the level of the individual companies.
3. The confirmation that productivity and technical change can be measured for aggregates using constituent firms with similar primary activity. The research shows that a number in the range 1.4 – 1.7 per cent per year for the rate of technical change in oil and gas industry is a reasonable approximation and can be incorporated into long-run energy models.

4. The presentation of what growth in TFP could mean to the industry and the global market. The findings stress an importance of including technical change in the long-term projections. Technology improvements may lead to a decrease in fossil fuel production costs, which means that new low-carbon technologies have to compete with even lower prices. Incorporation of technical change calls for more realistic assessment of the future energy trajectories.

6. REFERENCES

Adeleman, M. a. (2004). The Real Oil Problem. *Regulation*, *24*, 16–21.

Andrade de Sá, S., & Daubanes, J. (2014). OxCarre Research Paper 136 Limit Pricing and the (In) Effectiveness of the Carbon Tax Saraly Andrade de Sá ETH Zurich Limit Pricing and the (In) Effectiveness of, *44*(0).

Aspromourgos, T. (2013). *Adam Smith on Labour and Capital*. Oxford University Press. http://doi.org/10.1093/oxfordhb/9780199605064.013.0014

Barnett, W. (2004). Dimensions and Economics: Some Problems William. *The Quarterly Journal of Austrian Economics*, *7*(3), 95–104.

Blackhurst, C. (2006). Is This the End of Oil? Retrieved May 17, 2016, from https://www.questia.com/read/1G1-141647271/is-this-the-end-of-oil-shell-has-just-declared-record

Celeste, B. S., & Andrew. (2009). A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada, (September).

Cobb, C., & Douglas, P. (1928). A Theory of Production. *American Economic Association*. http://doi.org/10.1515/humr.1998.11.2.161

Comin, D. (2006). Total Factor Productivity. *Journal of the American Dietetic Association*, *91*(9), 1088–92. http://doi.org/10.1057/9781137336583.1849

Daly, H. E. (1997). Georgescu-Roegen versus Solow/Stiglitz. *Ecological Economics*, *22*(3), 261–266. http://doi.org/http://dx.doi.org/10.1016/S0921-8009(97)00080-3

Deffeyes, K. S., & Silverman, M. P. (2004). *Hubbert's Peak: The Impending World Oil Shortage*. *American Journal of Physics* (Vol. 72). http://doi.org/10.1119/1.1636165

Department of Economic and Social Affairs. (2008). *International Standard Industrial Classification of All Economic Activities*.

Dodder, R., McConnell, J., Mostashari, A., & Sgouridis, S. (2007). The CLIOS process: A User's Guide, 1–12.

Ellerman, A. D. (1995). The World Price of Coal. *Electronics and Power*, *23*(6), 499–506. http://doi.org/10.1049/ep.1975.0599

Ellerman, D., Stoker, T., & Berndt, E. R. (2001). Sources of Productivity Growth in the American Coal Industry 1972–95. *New Developments in Productivity Analysis*, (January), 373–418.

Energy Information Administration. (2014). Total Petroleum and Other Liquids Production - 2014 ›. Retrieved May 16, 2016, from http://www.eia.gov/beta/international/

European_Commission_IMF_OECD_UN. (1993). System of national accounts, 1993. *Journal of Government Information*, 814. http://doi.org/10.1016/1352-0237(95)90103-5

Fattouh, B., & Stern, J. (2011). *Natural gas markets in the Middle East and North Africa. Ed. Bassam Fattouh and Jonathan Stern*. Oxford: Oxford University Press, for the Oxford Institute for Energy Studies. Retrieved from http://libproxy.mit.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&Aut

hType=cookie,sso,ip,uid&db=ich&AN=ICHM462207&site=eds-live

Felipe, J. (2006). Aggregate production functions , neoclassical growth models and the aggregation problem. *Estudios de Economía Aplicada*, *5731*. Retrieved from jfelipe@adb.org-ffisher@mit.edu

Fisher, F. (1971). Aggregate Production Functions and the Explanation of Wages.pdf. *The Review of Economics and Statistics*, *53*(4), 305–25.

Forbes. (2016). The world's biggest public energy companies 2016. Retrieved April 23, 2016, from http://www.forbes.com/pictures/hefj45fim/no-1-gazprom/

Fusco, L. (2004). Peak Oil Theory, 1–6.

Gaudet, G. (2007). Natural Resource Economics under the Rule of Hotelling (L ' économie des ressources naturelles à la lumière de la règle d ' Hotelling) Author (s): Gérard Gaudet Source : The Canadian Journal of Economics / Revue canadienne d ' Economique , Vol . 40 , *40*(4), 1033–1059.

Gold, R. (2014). Why Peak-Oil Predictions Haven't Come True. Retrieved May 4, 2016, from http://www.wsj.com/articles/why-peak-oil-predictions-haven-t-come-true-1411937788

Heinberg, R. (2003). *The party's over : oil, war and the fate of industrial societies.* Gabriola, BC : New Society Publishers, c2003. Retrieved from http://libproxy.mit.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,sso,ip,uid&db=cat00916a&AN=mit.001274645&site=eds-live

Hong, B. (2008). Cobb-Douglas Production Function. *Discovery*, 1–7.

http://doi.org/10.2307/1237508

Hotelling, H. (1931). THE ECONOMICS OF EXHAUSTIBLE RESOURCES, *53*(1), 281–312.

Hubbert, M. K. (1956). Nuclear Energy and the Fossil Fuels. *Spring Meeting of the Southern District. Division of Production.*

Hulten, C. R. (1986). Productivity change, capacity utilization, and the sources of efficiency growth. *Journal of Econometrics*, *33*(1-2), 31–50. http://doi.org/10.1016/0304-4076(86)90026-6

Inflation - Current and Historic Inflation by Country. (2016). Retrieved from http://www.inflation.eu/

Inman, M. (2014). Fracking and the (supposed) death of peak oil. Retrieved May 4, 2016, from https://www.beaconreader.com/mason-inman/fracking-and-the-supposed-death-of-peak-oil

Jorgenson, D. W. (1990). *Productivity and Economic Growth*. *Fifty Years of Economic Measurement: The Jubilee Conference on Research in Income and Wealth*. http://doi.org/10.2307/2233624

Jorgenson, D. W., & Griliches, Z. (1967). The Explanation of Productivity Change. *The Review of Economic Studies*, *34*(3), 249. http://doi.org/10.2307/2296675

Li, Q. (2015). ANALYSIS OF OIL MARKET FUNDAMENTALS Master of Science in Engineering and Management.

Lynch, D. (2005). “Running out of oil” is an old fear. Retrieved May 17, 2016, from http://www.deseretnews.com/article/635153864/Running-out-of-oil-is-an-old-fear.html?pg=all

Mitchell, J., Mitchell, B., & Marcel, V. (2012). What Next for the Oil and Gas Industry?, (October), 20–29.

Morrison, C. (1985). *Productivity Measurement with Nonstatic Expectations and Varying Capacity Utilization: An Integrated Approach* (Vol. 33). Cambridge, MA. Retrieved from http://www.nber.org/papers/w1561.pdf

OECD. (2001). Overview of productivity measures. *Measuring Productivity - OECD Manual*, *2*, 11–21. http://doi.org/10.1787/9789264194519-en

Paltsev, S. (2004). Moving from Static to Dynamic General Equilibrium Economic Models. *MIT Joint Program on the Science and Policy of Global Change*, (4), 36.

Ramberg, D. J., & Webster, M. D. (2015). *General Equilibrium Impacts of New Energy Technologies on Sectoral Energy Usage by*.

Rapier, R. (2016). The 25 Biggest Oil And Gas Companies In The World. Retrieved May 19, 2016, from http://www.forbes.com/sites/rrapier/2016/03/30/the-worlds-largest-public-oil-and-gas-companies/#3bb8cd7a6cf1

Resources, C. S. for U. (2012). Understanding Tight Oil. *Resources, Canadian Society for Unconventional*, 19. http://doi.org/10.2118/79914-MS

Sharpe, A., & Waslander, B. (2014). The Impact of the Oil Boom on Canada's Labour Productivity Performance, 2000-2012. *CSLS Research Report 2014-05*, (December), 2000–2012.

Smolny, W. (2000). Sources of productivity growth: An empirical analysis with German sectoral data. *Applied Economics*, *32*, 305–314. Retrieved from http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0034688613&partnerID=40

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, *39*(3), 312. http://doi.org/10.2307/1926047

Tordo, S., & Arfaa, N. (2011). *National Oil Companies and Value Creation*. *World Bank Working Paper no. 218*. http://doi.org/10.1596/978-0-8213-8831-0

Törnqvist, L. (1981). Collected scientific papers of Leo Törnqvist. Research Institute of the Finnish Economy. Retrieved from http://libproxy.mit.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,sso,ip,uid&db=edshtl&AN=inu.39000004079120&site=eds-live

US Census Bureau Special Projects Staff, S. (2012). US Census Bureau Site North American Industry Classification System main page. Retrieved March 26, 2016, from http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012

Wellenius, K., Ellerman, A. D., Marks, D. H., & Sussman, M. (1996). Technological Progress and Environmental Regulation as Drivers of Productivity Growth : Evidence from the U . S . Coal Industry , 1972-1994 by Technological Progress and Environmental Regulation as Drivers of Productivity Growth : Evidence from the U . S, 1972–1994.

Wood MacKenzie. (2016). Pre-FID 2016: US$380bn of capex deferred. Retrieved May 11, 2016, from http://www.woodmac.com/analysis/PreFID-2016-USD380bn-capex-deferred

Wooster, R., & Moor Sanders, C. (1952). Spindletop Oilfield | The Handbook of Texas Online|

Texas State Historical Association (TSHA). Retrieved March 19, 2016, from

https://www.tshaonline.org/handbook/online/articles/dos03

APPENDIX A – TABLES FOR AGGREGATES

POC	Change in Output 1	Change in Output 1	Change in Capital 2	Weighted Capital shares 3	Adjusted Capital Input 2 x 3	Change in Labor 4	Weighted Labor shares 3	Adjusted Labor Input 5	Change in TFP 6	TFP levels 7
Periods	**LnY(t)-LnY(t-1) (Quantity)**	**LnY(t)-LnY(t-1) (Revenue)**	**LnK(t)-LnK(t-1)**	**α**	**α x δK/K**	**LnL(t)-LnL(t-1)**	**β**	**β4**	**δA/A**	**A(t)**
1970 - 1971	0.058	0.169	-0.048	0.350	-0.017	-0.016	0.650	-0.010	0.196	1.000
1971 - 1972	0.042	0.036	0.141	0.357	0.050	-0.020	0.643	-0.013	-0.001	1.196
1972 - 1973	-0.010	0.203	0.042	0.370	0.016	-0.027	0.630	-0.017	0.204	1.195
1973 - 1974	-0.142	0.607	0.062	0.373	0.023	0.000	0.627	0.000	0.584	1.399
1974 - 1975	-0.256	-0.219	-0.083	0.361	-0.030	-0.003	0.639	-0.002	-0.187	1.983
1975 - 1976	-0.117	-0.011	0.102	0.363	0.037	0.256	0.637	0.163	-0.210	1.796
1976 - 1977	0.004	-0.122	0.032	0.392	0.013	0.015	0.608	0.009	-0.144	1.585
1977 - 1978	-0.073	-0.052	0.027	0.397	0.011	0.016	0.603	0.009	-0.073	1.441
1978 - 1979	-0.207	0.219	0.255	0.414	0.105	0.061	0.586	0.036	0.078	1.369
1979 - 1980	0.098	0.036	0.027	0.426	0.011	0.019	0.574	0.011	0.014	1.447
1980 - 1981	-0.040	0.113	0.093	0.430	0.040	0.005	0.570	0.003	0.070	1.461
1981 - 1982	-0.470	-0.478	-0.379	0.427	-0.162	-0.529	0.573	-0.303	-0.014	1.531
1982 - 1983	0.017	0.019	0.008	0.418	0.003	-0.149	0.582	-0.087	0.102	1.517
1983 - 1984	0.126	-0.021	0.161	0.453	0.073	0.037	0.547	0.020	-0.114	1.620
1984 - 1985	-0.047	0.018	0.014	0.488	0.007	0.033	0.512	0.017	-0.006	1.506
1985 - 1986	0.008	-0.414	-0.115	0.487	-0.056	-0.103	0.513	-0.053	-0.305	1.500
1986 - 1987	-0.017	0.071	-0.017	0.487	-0.008	-0.042	0.513	-0.022	0.101	1.195
1987 - 1988	-0.004	-0.220	-0.051	0.496	-0.025	-0.046	0.504	-0.023	-0.171	1.296
1988 - 1989	-0.054	0.087	-0.093	0.488	-0.045	-0.017	0.512	-0.009	0.141	1.125
1989 - 1990	-0.023	0.040	0.001	0.472	0.001	-0.016	0.528	-0.008	0.047	1.266
1990 - 1991	-0.057	-0.231	-0.050	0.460	-0.023	-0.042	0.540	-0.023	-0.186	1.313
1991 - 1992	0.023	-0.012	-0.059	0.450	-0.027	-0.109	0.550	-0.060	0.074	1.127
1992 - 1993	-0.015	-0.145	-0.025	0.452	-0.011	-0.076	0.548	-0.041	-0.092	1.202
1993 - 1994	0.119	-0.059	-0.055	0.456	-0.025	-0.050	0.544	-0.027	-0.007	1.109
1994 - 1995	0.004	0.058	-0.015	0.451	-0.007	-0.039	0.549	-0.022	0.087	1.103
1995 - 1996	0.307	0.436	0.286	0.489	0.140	-0.009	0.511	-0.004	0.300	1.189
1996 - 1997	-0.009	-0.084	-0.053	0.527	-0.028	-0.029	0.473	-0.013	-0.043	1.490
1997 - 1998	0.011	-0.316	0.072	0.534	0.039	-0.047	0.466	-0.022	-0.333	1.447
1998 - 1999	0.424	0.818	0.434	0.647	0.281	0.101	0.353	0.036	0.501	1.114
1999 - 2000	0.001	0.410	0.045	0.771	0.035	0.027	0.229	0.006	0.369	1.615
2000 - 2001	0.000	-0.160	0.079	0.794	0.063	0.018	0.206	0.004	-0.227	1.984
2001 - 2002	0.008	-0.034	0.129	0.801	0.104	0.159	0.199	0.032	-0.169	1.758
2002 - 2003	-0.014	0.164	0.038	0.804	0.030	-0.044	0.196	-0.009	0.142	1.588
2003 - 2004	-0.029	0.162	0.000	0.797	0.000	-0.037	0.203	-0.008	0.169	1.731
2004 - 2005	-0.038	0.254	0.116	0.790	0.092	0.122	0.210	0.026	0.136	1.900
2005 - 2006	0.016	0.184	0.105	0.794	0.083	0.049	0.206	0.010	0.091	2.036
2006 - 2007	-0.026	0.031	0.030	0.796	0.024	0.023	0.204	0.005	0.002	2.127
2007 - 2008	-0.045	0.204	0.131	0.796	0.104	0.030	0.204	0.006	0.094	2.129
2008 - 2009	0.014	-0.410	-0.017	0.795	-0.013	0.008	0.205	0.002	-0.399	2.223
2009 - 2010	0.041	0.225	0.185	0.803	0.149	0.031	0.197	0.006	0.071	1.824
2010 - 2011	-0.051	0.196	0.116	0.821	0.095	0.019	0.179	0.003	0.097	1.895
2011 - 2012	-0.041	-0.059	0.092	0.831	0.077	0.003	0.169	0.000	-0.136	1.992
2012 - 2013	-0.012	-0.020	0.099	0.838	0.083	0.074	0.162	0.012	-0.115	1.855
2013 - 2014	-0.008	-0.105	0.005	0.837	0.004	0.020	0.163	0.003	-0.112	1.740
										1.628
1970-2014	-1.1%	3.6%	4.2%		3.0%	-0.7%		-0.8%	1.4%	
1970-1981	-5.8%	8.9%	5.9%		2.4%	2.8%		1.7%	4.8%	
1981-1999	1.9%	-2.4%	0.4%		0.7%	-6.3%		-3.6%	0.5%	
1999-2014	-1.2%	6.9%	7.7%		6.2%	3.3%		0.7%	0.1%	

Table 19 – Index Number Data for POC, 1970 - 2014

POC		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L	K/L									
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	Capital/Wages	TFP (Quantities)	TFP* (Quantities)	TFP* (all $$)	TFP (workers)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	6176.54	63765.47	10203.83	126684.60	18352.1	0.36	0.64	0.50	0.61	6.25	0.08	0.56	0.23	0.12	4.29	0.38	1.24	18.48%	16.07%	2.42%	1970 - 1971
1971	13.18	6546.69	75485.34	9726.71	124658.81	18598.0	0.34	0.66	0.61	0.67	7.76	0.08	0.52	0.23	0.13	5.07	0.45	1.45	5.63%	6.42%	-0.79%	1971 - 1972
1972	13.78	6829.97	78265.27	11195.66	122168.70	19079.6	0.37	0.63	0.64	0.61	6.99	0.09	0.59	0.26	0.14	5.00	0.53	1.55	22.97%	20.38%	2.60%	1972 - 1973
1973	17.32	6761.07	95845.21	11675.34	118901.30	19913.3	0.37	0.63	0.81	0.58	8.21	0.10	0.59	0.25	0.13	5.86	0.67	1.90	60.70%	60.10%	0.60%	1973 - 1974
1974	55.14	5867.32	175927.70	12426.72	118939.83	20525.4	0.38	0.62	1.48	0.47	14.16	0.10	0.61	0.21	0.12	10.36	1.31	3.47	-21.60%	-26.33%	4.73%	1974 - 1975
1975	50.13	4543.09	141359.70	11440.72	118613.26	21815.1	0.34	0.66	1.19	0.40	12.36	0.10	0.52	0.14	0.09	8.09	1.02	2.66	-26.63%	-11.87%	-14.76%	1975 - 1976
1976	53.33	4039.56	139853.27	12664.48	153153.61	20489.4	0.38	0.62	0.91	0.32	11.04	0.08	0.62	0.12	0.07	8.20	0.98	2.37	-13.76%	-9.39%	-4.36%	1976 - 1977
1977	53.54	4055.41	123751.27	13076.98	155508.55	19435.8	0.40	0.60	0.80	0.31	9.46	0.08	0.67	0.12	0.07	7.47	0.96	2.15	-6.80%	-9.75%	2.95%	1977 - 1978
1978	50.07	3769.69	117436.08	13436.32	157950.64	20830.7	0.39	0.61	0.74	0.28	8.74	0.09	0.65	0.10	0.06	6.70	0.90	1.95	15.79%	17.95%	-2.16%	1978 - 1979
1979	101.97	3064.53	146168.92	17331.97	167885.25	22505.5	0.44	0.56	0.87	0.18	8.43	0.10	0.77	0.08	0.05	7.28	1.21	2.34	1.72%	-2.93%	4.65%	1979 - 1980
1980	105.23	3379.61	151594.29	17798.66	171150.80	24992.7	0.42	0.58	0.89	0.19	8.52	0.10	0.71	0.08	0.05	6.99	1.23	2.27	10.81%	13.31%	-2.50%	1980 - 1981
1981	94.55	3245.60	169660.53	19526.21	171924.86	24422.8	0.44	0.56	0.99	0.17	8.69	0.11	0.80	0.08	0.05	7.67	1.52	2.59	5.06%	-8.41%	13.47%	1981 - 1982
1982	80.41	2029.06	105158.54	13368.29	101301.92	19181.7	0.41	0.59	1.04	0.15	7.87	0.13	0.70	0.07	0.05	6.36	1.41	2.38	16.79%	13.25%	3.54%	1982 - 1983
1983	70.36	2064.11	107180.95	13471.29	87290.49	18141.4	0.43	0.57	1.23	0.15	7.96	0.15	0.74	0.08	0.05	6.71	1.65	2.72	-5.74%	-1.51%	-4.23%	1983 - 1984
1984	65.41	2341.95	105000.00	15826.50	90570.10	17094.4	0.48	0.52	1.16	0.15	6.63	0.17	0.93	0.09	0.06	6.37	1.75	2.68	-1.52%	1.95%	-3.47%	1984 - 1985
1985	61.24	2235.50	106862.44	16050.00	93588.23	16353.7	0.50	0.50	1.14	0.14	6.66	0.17	0.98	0.08	0.06	6.60	1.83	2.73	-31.02%	-33.33%	2.31%	1985 - 1986
1986	31.37	2252.49	70659.65	14309.45	84387.64	15555.3	0.48	0.52	0.84	0.16	4.94	0.17	0.92	0.09	0.06	4.73	1.31	1.96	11.32%	12.99%	-1.67%	1986 - 1987
1987	38.41	2214.77	75866.68	14062.35	80909.04	14320.8	0.50	0.50	0.94	0.16	5.40	0.17	0.98	0.09	0.07	5.35	1.54	2.23	-17.41%	-16.89%	-0.52%	1987 - 1988
1988	29.85	2204.83	60901.16	13359.60	77298.54	13530.1	0.50	0.50	0.79	0.17	4.56	0.17	0.99	0.10	0.07	4.53	1.33	1.88	10.36%	10.79%	-0.43%	1988 - 1989
1989	35.05	2089.80	66415.03	12170.18	76003.26	13265.4	0.48	0.52	0.87	0.17	5.46	0.16	0.92	0.09	0.07	5.22	1.49	2.10	5.54%	2.52%	3.02%	1989 - 1990
1990	43.14	2042.01	69104.92	12186.19	74819.63	13948.2	0.47	0.53	0.92	0.17	5.67	0.16	0.87	0.08	0.06	5.28	1.56	2.15	-18.94%	-20.97%	2.04%	1990 - 1991
1991	34.49	1928.17	54837.53	11595.72	71750.05	13994.5	0.45	0.55	0.76	0.17	4.73	0.16	0.83	0.08	0.06	4.27	1.30	1.75	9.68%	6.19%	3.49%	1991 - 1992
1992	32.75	1973.22	54165.21	10929.66	64331.50	13565.1	0.45	0.55	0.84	0.18	4.96	0.17	0.81	0.09	0.07	4.40	1.39	1.86	-6.95%	-7.10%	0.16%	1992 - 1993
1993	27.82	1944.29	46852.00	10657.77	59648.36	12594.3	0.46	0.54	0.79	0.18	4.40	0.18	0.85	0.09	0.07	4.02	1.32	1.73	-0.87%	-1.56%	0.68%	1993 - 1994
1994	25.11	2189.65	44183.82	10090.43	56745.49	12178.0	0.45	0.55	0.78	0.22	4.38	0.18	0.83	0.10	0.08	3.95	1.32	1.70	9.74%	7.91%	1.83%	1994 - 1995
1995	26.59	2199.24	46826.16	9938.39	54557.51	12205.6	0.45	0.55	0.86	0.22	4.71	0.18	0.81	0.11	0.09	4.21	1.44	1.84	44.44%	42.67%	1.77%	1995 - 1996
1996	31.32	2989.64	72408.77	13224.00	54092.81	11729.6	0.53	0.47	1.34	0.23	5.48	0.24	1.13	0.15	0.12	5.79	2.32	2.82	-5.57%	-5.13%	-0.44%	1996 - 1997
1997	28.08	2961.82	66560.53	12547.59	52571.82	11390.5	0.52	0.48	1.27	0.24	5.30	0.24	1.10	0.15	0.12	5.55	2.23	2.68	-26.90%	-30.49%	3.59%	1997 - 1998
1998	18.43	2995.73	48532.94	13486.17	50164.48	11290.2	0.54	0.46	0.97	0.22	3.60	0.27	1.19	0.15	0.12	3.90	1.67	1.98	71.64%	73.61%	-1.97%	1998 - 1999
1999	25.67	4578.38	109920.93	20823.04	55500.65	7577.0	0.75	0.25	1.98	0.22	4.85	0.38	2.99	0.21	0.17	6.80	3.54	4.13	38.33%	41.04%	-2.71%	1999 - 2000
2000	39.03	4582.00	165649.96	21789.86	57010.65	5717.7	0.79	0.21	2.91	0.21	7.60	0.38	3.81	0.22	0.17	10.04	5.83	6.22	-17.81%	-22.32%	4.51%	2000 - 2001
2001	32.59	4583.19	141149.79	23583.48	58048.65	6052.7	0.80	0.20	2.43	0.19	5.99	0.41	3.90	0.20	0.16	7.90	4.70	4.98	-19.33%	-15.92%	-3.41%	2001 - 2002
2002	32.93	4618.47	136449.88	26837.53	68079.90	6434.2	0.81	0.19	2.00	0.17	5.08	0.39	4.17	0.18	0.14	6.70	4.03	4.25	20.77%	13.67%	7.10%	2002 - 2003
2003	36.96	4555.46	160757.57	27868.96	65164.70	6950.2	0.80	0.20	2.47	0.16	5.77	0.43	4.01	0.17	0.14	7.61	4.63	4.87	19.89%	16.33%	3.56%	2003 - 2004
2004	47.83	4424.22	189002.37	27878.96	62795.75	7261.1	0.79	0.21	3.01	0.16	6.78	0.44	3.84	0.16	0.13	8.95	5.47	5.73	13.17%	13.10%	0.07%	2004 - 2005
2005	66.49	4260.20	243547.96	31306.06	70933.00	8485.1	0.79	0.21	3.43	0.14	7.78	0.44	3.69	0.13	0.11	10.28	6.26	6.53	13.47%	10.13%	3.34%	2005 - 2006
2006	76.64	4327.86	292733.01	34767.00	74515.70	8673.8	0.80	0.20	3.93	0.12	8.42	0.47	4.01	0.12	0.11	11.11	7.00	7.23	0.76%	-0.41%	1.17%	2006 - 2007
2007	82.26	4216.13	301802.80	35809.77	76242.70	9407.9	0.79	0.21	3.96	0.12	8.43	0.47	3.81	0.11	0.10	11.13	7.01	7.20	17.38%	9.93%	7.45%	2007 - 2008
2008	106.87	4029.25	370057.68	40804.81	78569.25	10222.7	0.80	0.20	4.71	0.10	9.07	0.52	3.99	0.09	0.09	11.97	7.80	7.95	-41.85%	-40.49%	-1.36%	2008 - 2009
2009	67.77	4084.84	245478.89	40125.80	79206.05	10633.6	0.79	0.21	3.10	0.10	6.12	0.51	3.77	0.10	0.09	8.08	5.20	5.31	19.43%	8.55%	10.88%	2009 - 2010
2010	86.41	4254.87	307534.47	48291.11	81705.45	10934.6	0.82	0.18	3.76	0.09	6.37	0.59	4.42	0.09	0.08	8.38	5.69	5.78	17.71%	10.19%	7.52%	2010 - 2011
2011	117.11	4044.41	374005.85	54246.16	83238.60	11437.7	0.83	0.17	4.49	0.07	6.89	0.65	4.74	0.07	0.07	9.04	6.34	6.40	-6.18%	-13.21%	7.03%	2011 - 2012
2012	115.12	3883.71	352591.74	59483.57	83473.10	11659.2	0.84	0.16	4.22	0.07	5.93	0.71	5.10	0.06	0.06	7.74	5.58	5.61	-9.48%	-11.42%	1.94%	2012 - 2013
2013	110.88	3837.86	345462.40	65648.99	89920.75	12600.4	0.84	0.16	3.84	0.06	5.26	0.73	5.21	0.06	0.06	6.86	4.99	5.00	-12.43%	-11.34%	-1.09%	2013 - 2014
2014	98.95	3805.92	311167.77	65989.99	91710.60	13042.0	0.83	0.17	3.39	0.06	4.72	0.72	5.06	0.05	0.05	6.16	4.47	4.47				
1970-2014	5.07%	-1.09%	3.67%	4.33%	-0.73%	-0.77%	1.95%	-3.04%	4.43%	-5.20%	-0.64%	5.10%	5.15%	-3.22%	-1.77%	0.83%	5.75%	2.96%	4.34%	2.92%	1.42%	**1970-2014**
1970-1981	21.35%	-5.68%	9.30%	6.08%	2.81%	2.63%	2.00%	-1.31%	6.31%	-11.09%	3.04%	3.17%	3.36%	-9.58%	-7.71%	5.44%	13.36%	6.95%	6.12%	6.72%	-0.60%	**1970-1981**
1981-1999	-6.99%	1.93%	-2.38%	0.36%	-6.09%	-6.30%	2.95%	-4.33%	3.95%	1.57%	-3.19%	6.86%	7.61%	5.81%	7.15%	-0.67%	4.83%	2.62%	3.87%	2.58%	1.29%	**1981-1999**
1999-2014	9.41%	-1.22%	7.18%	7.99%	3.40%	3.69%	0.72%	-2.74%	3.65%	-8.54%	-0.19%	4.44%	3.57%	-8.61%	-7.36%	-0.66%	1.55%	0.52%	3.59%	0.52%	3.07%	**1999-2014**

Table 20 – Growth Accounting data for POC, 1970 - 2014

NOC	Change in Output 1	Change in Output 1	Change in Capital 2	Weighted Capital shares 3	Adjusted Capital Input 2 x 3	Change in Labor 4	Weighted Labor shares 3	Adjusted Labor Input 5	Change in TFP 6	TFP levels 7
Periods	**LnY(t)-LnY(t-1) (Quantity)**	**LnY(t)-LnY(t-1) (Revenue)**	**LnK(t)-LnK(t-1)**	**α**	**α x δK/K**	**LnL(t)-LnL(t-1)**	**β**	**β4**	**δA/A**	**A(t)**
1970 - 1971	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1971 - 1972	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1972 - 1973	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1973 - 1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1974 - 1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1975 - 1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1976 - 1977	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1977 - 1978	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1978 - 1979	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1979 - 1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1980 - 1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981 - 1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982 - 1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983 - 1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984 - 1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985 - 1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986 - 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987 - 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988 - 1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989 - 1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990 - 1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991 - 1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992 - 1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993 - 1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1994 - 1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1995 - 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996 - 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997 - 1998	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998 - 1999	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999 - 2000	0.028	0.537	0.094	0.655	0.062	-0.048	0.060	-0.017	0.492	1.000
2000 - 2001	0.023	0.043	0.074	0.676	0.050	-0.010	0.052	-0.003	-0.003	1.492
2001 - 2002	0.032	0.182	0.090	0.668	0.060	0.035	0.055	0.012	0.110	1.488
2002 - 2003	0.032	0.253	0.178	0.621	0.110	0.018	0.071	0.007	0.136	1.599
2003 - 2004	0.045	0.178	0.285	0.582	0.166	0.030	0.087	0.013	0.000	1.735
2004 - 2005	0.114	0.414	0.139	0.562	0.078	0.023	0.096	0.010	0.325	1.735
2005 - 2006	0.054	0.256	0.388	0.592	0.230	-0.001	0.083	0.000	0.026	2.060
2006 - 2007	0.030	0.137	0.318	0.613	0.195	0.013	0.075	0.005	-0.063	2.086
2007 - 2008	0.008	0.140	0.007	0.629	0.005	-0.020	0.068	-0.008	0.143	2.023
2008 - 2009	-0.076	-0.246	0.140	0.682	0.096	0.031	0.050	0.010	-0.352	2.166
2009 - 2010	0.065	0.217	0.189	0.713	0.135	0.011	0.041	0.003	0.079	1.814
2010 - 2011	0.019	0.246	-0.036	0.728	-0.026	0.015	0.037	0.004	0.269	1.893
2011 - 2012	-0.007	0.056	0.143	0.725	0.104	0.008	0.038	0.002	-0.050	2.162
2012 - 2013	0.102	-0.020	0.181	0.741	0.134	0.044	0.033	0.011	-0.165	2.111
2013 - 2014	0.011	-0.394	-0.065	0.809	-0.052	0.046	0.017	0.009	-0.351	1.946
										1.595
1970-2014	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1970-1981	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1981-1999	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1999-2014	3.2%	13.3%	14.2%		9.0%	1.3%		0.4%	4.0%	

Table 21 – Index Number Data for NOC, 1999 - 2014

NOC		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L									
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP (Quantities)	TFP* (Quantities)	TFP* (all $$)	TFP (workers)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	4397.07	38273.70	8357.74	393854.79	4657.2	0.64	0.36	0.10	0.53	4.58	0.02	0.17	0.13	5.65	1.02	1.15	58.48%	58.63%	-0.15%	1999 - 2000
2000	39.03	4521.53	65463.36	9181.79	375384.28	4580.8	0.67	0.33	0.17	0.49	7.13	0.02	0.18	0.14	8.99	1.87	2.07	5.36%	6.41%	-1.06%	2000 - 2001
2001	32.59	4626.93	68345.97	9882.54	371475.98	4533.5	0.69	0.31	0.18	0.47	6.92	0.03	0.18	0.15	8.84	2.02	2.21	14.70%	-1.62%	16.32%	2001 - 2002
2002	32.93	4777.33	81986.74	10812.49	384686.69	5812.4	0.65	0.35	0.21	0.44	7.58	0.03	0.15	0.13	9.42	1.98	2.18	23.54%	-6.74%	30.28%	2002 - 2003
2003	36.96	4930.88	105601.44	12914.53	391548.51	8896.1	0.59	0.41	0.27	0.38	8.18	0.03	0.11	0.09	9.52	1.84	2.03	14.79%	-6.51%	21.31%	2003 - 2004
2004	47.83	5158.92	126201.65	17167.29	403577.53	12827.2	0.57	0.43	0.31	0.30	7.35	0.04	0.09	0.08	8.33	1.73	1.91	39.08%	25.85%	13.22%	2004 - 2005
2005	66.49	5779.05	190834.54	19730.79	412873.25	16093.1	0.55	0.45	0.46	0.29	9.67	0.05	0.08	0.07	10.60	2.26	2.47	25.68%	25.95%	-0.26%	2005 - 2006
2006	76.64	6098.54	246456.50	29096.61	412435.14	16893.4	0.63	0.37	0.60	0.21	8.47	0.07	0.09	0.08	10.34	3.01	3.20	12.35%	-16.38%	28.73%	2006 - 2007
2007	82.26	6282.00	282524.89	39974.00	417857.50	27510.7	0.59	0.41	0.68	0.16	7.07	0.10	0.07	0.06	8.23	2.58	2.72	16.00%	31.25%	-15.25%	2007 - 2008
2008	106.87	6335.59	324830.72	40263.96	409387.05	20266.9	0.67	0.33	0.79	0.16	8.07	0.10	0.08	0.07	10.15	3.60	3.71	-27.74%	-27.52%	-0.23%	2008 - 2009
2009	67.77	5871.19	253994.76	46330.06	422468.85	19953.0	0.70	0.30	0.60	0.13	5.48	0.11	0.07	0.07	7.06	2.74	2.82	20.58%	13.95%	6.63%	2009 - 2010
2010	86.41	6266.00	315478.43	55966.82	427130.06	20954.3	0.73	0.27	0.74	0.11	5.64	0.13	0.07	0.06	7.37	3.17	3.24	23.13%	26.97%	-3.84%	2010 - 2011
2011	117.11	6389.14	403599.86	53973.14	433593.54	20154.9	0.73	0.27	0.93	0.12	7.48	0.12	0.07	0.07	9.77	4.18	4.24	4.77%	-6.43%	11.20%	2011 - 2012
2012	115.12	6347.54	426743.07	62292.61	437100.04	24085.6	0.72	0.28	0.98	0.10	6.85	0.14	0.06	0.06	8.93	3.95	3.98	-6.37%	-8.95%	2.58%	2012 - 2013
2013	110.88	7031.65	418276.57	74650.41	456596.52	23368.7	0.76	0.24	0.92	0.09	5.60	0.16	0.06	0.06	7.39	3.62	3.64	-44.01%	-17.29%	-26.72%	2013 - 2014
2014	98.95	7107.79	282024.34	69974.89	478085.43	11696.6	0.86	0.14	0.59	0.10	4.03	0.15	0.08	0.08	5.21	3.06	3.06				
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970-2014
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970-1981
1981-1999	-6.99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981-1999
1999-2014	9.41%	3.25%	14.24%	15.22%	1.30%	6.33%	1.94%	-5.92%	12.78%	-10.38%	-0.85%	13.74%	-5.01%	-3.54%	-0.54%	7.63%	6.72%	12.02%	6.50%	5.52%	1999-2014

Table 22 – Growth Accounting Data for NOC, 1999 - 2014

All	Change in Output 1	Change in Output 1	Change in Capital 2	Weighted Capital shares 3a	Adjusted Capital Input 2 x 3	Change in Labor 4	Weighted Labor shares 3b	Adjusted Labor Input 5	Change in TFP 6	TFP levels 7
Periods	**LnY(t)-LnY(t-1) (Quantity)**	**LnY(t)-LnY(t-1) (Revenue)**	**LnK(t)-LnK(t-1)**	**α**	**α x δK/K**	**LnL(t)-LnL(t-1)**	**β**	**β x 4**	**δA/A**	**A(t)**
1970 - 1971	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1971 - 1972	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1972 - 1973	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1973 - 1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1974 - 1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1975 - 1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1976 - 1977	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1977 - 1978	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1978 - 1979	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1979 - 1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1980 - 1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1981 - 1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1982 - 1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1983 - 1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1984 - 1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1985 - 1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1986 - 1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1987 - 1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1988 - 1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1989 - 1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1990 - 1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1991 - 1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1992 - 1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1993 - 1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1994 - 1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1995 - 1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1996 - 1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1997 - 1998	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1998 - 1999	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999 - 2000	0.014	0.444	-0.002	0.734	-0.001	-0.038	0.266	-0.010	0.456	1.000
2000 - 2001	0.012	-0.098	0.077	0.755	0.058	-0.007	0.245	-0.002	-0.155	1.456
2001 - 2002	0.020	0.042	0.118	0.757	0.089	0.053	0.243	0.013	-0.060	1.301
2002 - 2003	0.010	0.198	0.080	0.737	0.059	0.009	0.263	0.002	0.137	1.241
2003 - 2004	0.010	0.168	0.099	0.706	0.070	0.021	0.294	0.006	0.092	1.378
2004 - 2005	0.046	0.321	0.125	0.683	0.085	0.037	0.317	0.012	0.224	1.470
2005 - 2006	0.038	0.216	0.224	0.695	0.156	0.006	0.305	0.002	0.058	1.694
2006 - 2007	0.007	0.080	0.171	0.693	0.119	0.015	0.307	0.004	-0.043	1.752
2007 - 2008	-0.013	0.173	0.067	0.700	0.047	-0.013	0.300	-0.004	0.130	1.709
2008 - 2009	-0.040	-0.330	0.064	0.733	0.047	0.028	0.267	0.007	-0.385	1.839
2009 - 2010	0.055	0.221	0.187	0.752	0.141	0.014	0.248	0.004	0.077	1.454
2010 - 2011	-0.008	0.222	0.037	0.770	0.029	0.016	0.230	0.004	0.189	1.531
2011 - 2012	-0.020	0.002	0.118	0.774	0.091	0.007	0.226	0.002	-0.091	1.720
2012 - 2013	0.061	-0.020	0.142	0.785	0.111	0.049	0.215	0.010	-0.142	1.630
2013 - 2014	0.004	-0.253	-0.031	0.821	-0.026	0.042	0.179	0.007	-0.234	1.488
										1.254
1970-2014	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1970-1981	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1981-1999	N/A	N/A	N/A		N/A	N/A		N/A	N/A	
1999-2014	1.3%	9.2%	9.9%		7.2%	1.6%		0.4%	1.7%	

Table 23 – Index number Data for "All", 1999 - 2014

All		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Revenue)	K/L							
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (all $$)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	8975.45	148194.63	31025.66	449355.44	12234.2	0.72	0.28	0.33	4.78	0.07	0.14	6.21	2.24	48.29%	54.42%	-6.14%	1999 - 2000
2000	39.03	9103.53	231113.32	30971.66	432394.93	10298.5	0.75	0.25	0.53	7.46	0.07	0.15	9.82	3.87	-9.15%	-13.11%	3.96%	2000 - 2001
2001	32.59	9210.12	209495.77	33466.02	429524.63	10586.1	0.76	0.24	0.49	6.26	0.08	0.15	8.25	3.39	-1.09%	-7.31%	6.22%	2001 - 2002
2002	32.93	9395.80	218436.61	37650.02	452766.59	12246.6	0.75	0.25	0.48	5.80	0.08	0.14	7.64	3.15	18.97%	5.28%	13.68%	2002 - 2003
2003	36.96	9486.34	266359.01	40783.49	456713.21	15846.2	0.72	0.28	0.58	6.53	0.09	0.12	8.51	3.32	14.74%	2.41%	12.33%	2003 - 2004
2004	47.83	9583.14	315204.02	45046.25	466373.28	20088.3	0.69	0.31	0.68	7.00	0.10	0.10	8.98	3.40	28.40%	18.56%	9.84%	2004 - 2005
2005	66.49	10039.25	434382.50	51036.85	483806.25	24578.2	0.67	0.33	0.90	8.51	0.11	0.09	10.79	4.10	20.97%	14.23%	6.74%	2005 - 2006
2006	76.64	10426.39	539189.51	63863.61	486950.84	25567.2	0.71	0.29	1.11	8.44	0.13	0.09	10.97	4.72	6.58%	-12.41%	19.00%	2006 - 2007
2007	82.26	10498.13	584327.70	75783.77	494100.20	36918.6	0.67	0.33	1.18	7.71	0.15	0.07	9.76	4.17	18.58%	22.95%	-4.37%	2007 - 2008
2008	106.87	10364.84	694888.40	81068.77	487956.30	30489.6	0.73	0.27	1.42	8.57	0.17	0.08	11.20	5.25	-35.79%	-36.35%	0.55%	2008 - 2009
2009	67.77	9956.04	499473.65	86455.86	501674.90	30586.6	0.74	0.26	1.00	5.78	0.17	0.07	7.58	3.65	20.68%	12.20%	8.49%	2009 - 2010
2010	86.41	10520.87	623012.91	104257.93	508835.51	31888.9	0.77	0.23	1.22	5.98	0.20	0.07	7.89	4.12	20.61%	20.24%	0.37%	2010 - 2011
2011	117.11	10433.56	777605.71	108219.30	516832.14	31592.6	0.77	0.23	1.50	7.19	0.21	0.07	9.49	5.05	-0.50%	-9.22%	8.72%	2011 - 2012
2012	115.12	10231.25	779334.82	121776.18	520573.14	35744.8	0.77	0.23	1.50	6.40	0.23	0.06	8.45	4.60	-6.89%	-10.96%	4.08%	2012 - 2013
2013	110.88	10869.51	763738.97	140299.40	546517.27	35969.1	0.80	0.20	1.40	5.44	0.26	0.06	7.19	4.12	-29.44%	-16.44%	-13.00%	2013 - 2014
2014	98.95	10913.70	593192.11	135964.88	569796.03	24738.6	0.85	0.15	1.04	4.36	0.24	0.06	5.67	3.50				
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.41%	1.31%	9.69%	10.35%	1.60%	4.81%	1.11%	-3.97%	7.96%	-0.60%	8.62%	-4.86%	-0.61%	3.01%	7.66%	2.97%	4.70%	**1999-2014**

Table 24 – Growth Accounting Data for "All", 1999 - 2014

APPENDIX B – TABLES FOR INDIVIDUAL FIRMS

BP		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	1055.40	27093.84	5340.09	13300	1314.88	0.80	0.20	2.04	0.20	5.07	0.40	0.17	4.24	26.27%	14.67%	11.60%	1999 - 2000
2000	39.03	1098.49	42386.30	7752.70	16000	1363.07	0.85	0.15	2.65	0.14	5.47	0.48	0.13	4.91	-15.64%	-18.34%	2.69%	2000 - 2001
2001	32.59	1150.40	37493.82	8227.44	16550	1530.74	0.84	0.16	2.27	0.14	4.56	0.50	0.13	4.08	-11.62%	-12.26%	0.64%	2001 - 2002
2002	32.93	1168.43	33885.53	8504.53	16800	1428.74	0.86	0.14	2.02	0.14	3.98	0.51	0.12	3.61	26.07%	10.90%	15.17%	2002 - 2003
2003	36.96	1098.71	40180.77	9233.54	15350	1651.03	0.85	0.15	2.62	0.12	4.35	0.60	0.11	4.03	5.71%	10.26%	-4.55%	2003 - 2004
2004	47.83	1019.99	43375.00	8764.99	15650	1894.46	0.82	0.18	2.77	0.12	4.95	0.56	0.10	4.46	20.04%	21.84%	-1.80%	2004 - 2005
2005	66.49	992.13	57573.17	9145.87	17000	2315.83	0.80	0.20	3.39	0.11	6.29	0.54	0.10	5.55	13.36%	18.62%	-5.27%	2005 - 2006
2006	76.64	959.56	73540.74	9592.73	19000	2385.31	0.80	0.20	3.87	0.10	7.67	0.50	0.09	6.69	-0.13%	-1.49%	1.36%	2006 - 2007
2007	82.26	930.45	76538.94	10098.72	19800	2640.14	0.79	0.21	3.87	0.09	7.58	0.51	0.08	6.59	13.51%	7.29%	6.22%	2007 - 2008
2008	106.87	918.94	94692.31	11777.14	21400	3138.94	0.79	0.21	4.42	0.08	8.04	0.55	0.07	7.09	-40.70%	-21.28%	-19.43%	2008 - 2009
2009	67.77	979.84	63325.27	8272.92	21500	3594.27	0.70	0.30	2.95	0.12	7.65	0.38	0.09	5.73	14.76%	8.62%	6.14%	2009 - 2010
2010	86.41	910.00	72028.26	9236.10	21100	3387.84	0.73	0.27	3.41	0.10	7.80	0.44	0.08	6.25	4.72%	-3.45%	8.18%	2010 - 2011
2011	117.11	764.40	79447.37	11203.99	22200	3453.99	0.76	0.24	3.58	0.07	7.09	0.50	0.06	6.04	-14.28%	-7.59%	-6.69%	2011 - 2012
2012	115.12	716.77	74458.76	10757.75	24000	3882.54	0.73	0.27	3.10	0.07	6.92	0.45	0.05	5.59	-6.50%	-6.61%	0.11%	2012 - 2013
2013	110.88	688.67	71810.20	11039.01	24700	4067.81	0.73	0.27	2.91	0.06	6.51	0.45	0.05	5.24	-8.09%	-7.70%	-0.39%	2013 - 2014
2014	98.95	693.11	65424.00	10833.22	24400	4014.62	0.73	0.27	2.68	0.06	6.04	0.44	0.05	4.85				
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.4%	-2.8%	6.1%	4.8%	4.1%	7.7%	-0.6%	2.1%	1.8%	-7.2%	1.2%	0.7%	-7.5%	0.9%	1.8%	0.9%	0.9%	**1999-2014**

Table 25 – Growth Accounting Data for BP, 1999 - 2014

Gulf		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	**Price***	**Output (MBOE)**	**Output* (Act Rev, $M)**	**Capital* stock, $M**	**Labor (workers)**	**Labor* (Wages, $M)**	**Capital* share**	**Labor* share**	**Total* Rev/Worker ($M/staff)**	**Total Prod*/Cap (MBOE/$M)**	**Total Rev/Capital**	**Capital*/Worker ($M/staff)**	**TFP* (Quantities)**	**TFP* (workers)**	**ΔLn(Y/L)**	**ΔLn(A)**	**ΔLn(K/L)**	**Periods**
1970	11.25	1332.63	14992.06	1220.63	8373.58	527.62	0.70	0.30	1.79	1.09	12.28	0.15	0.61	6.87	25.52%	24.93%	0.58%	1970 - 1971
1971	13.18	1420.64	18719.06	1120.76	8100.38	535.15	0.68	0.32	2.31	1.27	16.70	0.14	0.67	8.81	5.93%	2.12%	3.81%	1971 - 1972
1972	13.78	1397.90	19259.95	1171.00	7854.50	542.61	0.68	0.32	2.45	1.19	16.45	0.15	0.65	9.00	30.75%	19.75%	11.01%	1972 - 1973
1973	17.32	1357.55	23507.02	1333.89	7048.56	531.30	0.72	0.28	3.34	1.02	17.62	0.19	0.63	10.97	99.37%	92.10%	7.27%	1973 - 1974
1974	55.14	1176.06	64851.04	1645.71	7198.82	526.89	0.76	0.24	9.01	0.71	39.41	0.23	0.50	27.55	-35.39%	-29.42%	-5.97%	1974 - 1975
1975	50.13	897.71	45002.65	1312.04	7116.86	571.94	0.70	0.30	6.32	0.68	34.30	0.18	0.41	20.53	-4.07%	-10.66%	6.59%	1975 - 1976
1976	53.33	785.43	41889.58	1417.88	6900.00	600.35	0.70	0.30	6.07	0.55	29.54	0.21	0.35	18.45	-59.56%	-62.10%	2.54%	1976 - 1977
1977	53.54	752.13	27107.69	1968.92	8100.00	594.76	0.77	0.23	3.35	0.38	13.77	0.24	0.28	9.92	-49.91%	-48.46%	-1.45%	1977 - 1978
1978	50.07	340.82	17065.44	1851.43	8400.00	692.11	0.73	0.27	2.03	0.18	9.22	0.22	0.12	6.11	59.64%	48.15%	11.48%	1978 - 1979
1979	101.97	318.32	32458.14	2446.55	8800.00	729.88	0.77	0.23	3.69	0.13	13.27	0.28	0.10	9.89	-26.06%	-17.97%	-8.09%	1979 - 1980
1980	105.23	301.72	29560.00	2473.71	10400.00	856.11	0.74	0.26	2.84	0.12	11.95	0.24	0.08	8.26	-57.33%	-51.63%	-5.70%	1980 - 1981
1981	94.55	321.38	17302.63	2190.08	10800.00	919.19	0.70	0.30	1.60	0.15	7.90	0.20	0.09	4.93				1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1999 - 2000
2000	39.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000 - 2001
2001	32.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2001 - 2002
2002	32.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2002 - 2003
2003	36.96	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003 - 2004
2004	47.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004 - 2005
2005	66.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2005 - 2006
2006	76.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2006 - 2007
2007	82.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2007 - 2008
2008	106.87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2008 - 2009
2009	67.77	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2009 - 2010
2010	86.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2010 - 2011
2011	117.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2011 - 2012
2012	115.12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2012 - 2013
2013	110.88	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2013 - 2014
2014	98.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	-12.13%	1.31%	5.46%	2.34%	5.18%	0.08%	-0.19%	-1.01%	-16.68%	-3.93%	3.05%	-15.84%	-2.97%	-1.01%	-3.02%	2.01%	**1970-1981**
1981-1999	-6.99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.4%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#DIV/0!	#DIV/0!	#DIV/0!	**1999-2014**

Table 26 – Growth Accounting Data for Gulf, 1970 - 1981

Std. Oil		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)		K/L						
Years	**Price***	**Output (MBOE)**	**Output* (Act Rev, $M)**	**Capital* stock, $M**	**Labor (workers)**	**Labor* (Wages, $M)**	**Capital* share**	**Labor* share**	**Total* Rev/Worker ($M/staff)**	**Total Prod*/Cap (MBOE/$M)**	**Total Rev/Capital**	**Capital/Worker ($M/staff)**	**Capital*/Worker ($M/staff)**	**TFP* (Quantities)**	**TFP* (workers)**	**ΔLn(Y/L)**	**ΔLn(A)**	**ΔLn(K/L)**	**Periods**
1970	11.25	981.83	11045.64	1416.94	15831.55	982.03	0.59	0.41	0.70	0.69	7.80	0.01	0.09	0.26	2.90				1970 - 1971
1971	13.18	1105.08	13104.67	1353.71	15075.20	958.46	0.59	0.41	0.87	0.82	9.68	0.02	0.09	0.30	3.56	21.99%	20.55%	1.44%	1971 - 1972
1972	13.78	1263.04	13995.36	1393.50	14523.95	952.45	0.59	0.41	0.96	0.91	10.04	0.02	0.10	0.35	3.88	10.30%	8.42%	1.88%	1972 - 1973
1973	17.32	1264.41	17361.68	1377.47	13753.60	1039.77	0.57	0.43	1.26	0.92	12.60	0.02	0.10	0.34	4.68	27.00%	18.90%	8.11%	1973 - 1974
1974	55.14	863.19	32077.86	1232.14	13839.00	946.59	0.57	0.43	2.32	0.70	26.03	0.02	0.09	0.24	9.10	60.77%	66.43%	-5.66%	1974 - 1975
1975	50.13	759.66	28561.35	1100.74	13580.35	979.91	0.53	0.47	2.10	0.69	25.95	0.02	0.08	0.21	7.95	-9.72%	-13.58%	3.86%	1975 - 1976
1976	53.33	814.76	34708.33	1067.25	13438.95	997.17	0.52	0.48	2.58	0.76	32.52	0.02	0.08	0.22	9.57	20.54%	18.56%	1.97%	1976 - 1977
1977	53.54	821.30	30276.92	1109.77	13399.05	980.81	0.53	0.47	2.26	0.74	27.28	0.02	0.08	0.23	8.48	-13.36%	-12.08%	-1.28%	1977 - 1978
1978	50.07	760.42	33710.71	1249.71	13151.25	972.25	0.56	0.44	2.56	0.61	26.97	0.03	0.10	0.22	9.63	12.61%	12.75%	-0.14%	1978 - 1979
1979	101.97	727.49	35112.90	1541.90	13886.60	1017.04	0.60	0.40	2.53	0.47	22.77	0.03	0.11	0.20	9.51	-1.37%	-1.30%	-0.06%	1979 - 1980
1980	105.23	935.93	38937.14	1618.46	14076.30	1063.20	0.60	0.40	2.77	0.58	24.06	0.04	0.11	0.25	10.21	8.98%	7.09%	1.89%	1980 - 1981
1981	94.55	987.15	44815.79	2315.61	15148.35	1120.82	0.67	0.33	2.96	0.43	19.35	0.06	0.15	0.23	10.49	6.72%	2.74%	3.98%	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1999 - 2000
2000	39.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000 - 2001
2001	32.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2001 - 2002
2002	32.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2002 - 2003
2003	36.96	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003 - 2004
2004	47.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004 - 2005
2005	66.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2005 - 2006
2006	76.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2006 - 2007
2007	82.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2007 - 2008
2008	106.87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2008 - 2009
2009	67.77	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2009 - 2010
2010	86.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2010 - 2011
2011	117.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2011 - 2012
2012	115.12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2012 - 2013
2013	110.88	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2013 - 2014
2014	98.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	0.05%	13.58%	4.57%	-0.40%	1.21%	1.21%	-2.04%	14.03%	-4.32%	8.62%	13.58%	4.99%	-1.00%	12.39%	13.77%	12.57%	1.20%	**1970-1981**
1981-1999	-6.99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.4%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1999-2014**

Table 27 – Growth Accounting Data for Standard Oil, 1970 - 1981

Texaco		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	808.9	9100.02	2527.99	25807	1543.94	0.621	0.379	0.35	0.32	3.60	0.10	0.13	1.49	15.31%	13.32%	1.99%	1970 - 1971
1971	13.18	820.8	10815.70	2524.94	26317	1635.94	0.607	0.393	0.41	0.33	4.28	0.10	0.13	1.70	2.48%	1.36%	1.12%	1971 - 1972
1972	13.78	866.8	11279.48	2627.07	26774	1694.78	0.608	0.392	0.42	0.33	4.29	0.10	0.13	1.73	32.27%	27.23%	5.05%	1972 - 1973
1973	17.32	881.0	15254.72	2632.13	26221	1814.66	0.592	0.408	0.58	0.33	5.80	0.10	0.13	2.27	8.66%	9.49%	-0.83%	1973 - 1974
1974	55.14	805.8	16967.56	2598.19	26747	1826.83	0.587	0.413	0.63	0.31	6.53	0.10	0.12	2.49	-70.96%	-75.43%	4.47%	1974 - 1975
1975	50.13	719.3	8215.96	2241.02	26332	1928.35	0.537	0.463	0.31	0.32	3.67	0.09	0.10	1.17	2.19%	-0.91%	3.10%	1975 - 1976
1976	53.33	666.5	8122.26	2093.45	25468	1950.96	0.518	0.482	0.32	0.32	3.88	0.08	0.10	1.16	11.70%	10.34%	1.35%	1976 - 1977
1977	53.54	628.9	8864.02	2010.46	24726	1931.73	0.510	0.490	0.36	0.31	4.41	0.08	0.09	1.29	38.94%	35.57%	3.37%	1977 - 1978
1978	50.07	578.3	12564.64	1974.21	23744	1966.25	0.501	0.499	0.53	0.29	6.36	0.08	0.08	1.84	11.35%	10.55%	0.81%	1978 - 1979
1979	101.97	497.8	13654.84	1864.45	23035	1921.61	0.492	0.508	0.59	0.27	7.32	0.08	0.07	2.04	16.63%	19.86%	-3.23%	1979 - 1980
1980	105.23	686.7	16354.29	2095.20	23361	1882.00	0.527	0.473	0.70	0.33	7.81	0.09	0.10	2.49	22.70%	21.96%	0.74%	1980 - 1981
1981	94.55	529.5	20515.79	2155.26	23355	1911.18	0.530	0.470	0.88	0.25	9.52	0.09	0.08	3.11	2.48%	0.98%	1.50%	1981 - 1982
1982	80.41	465.7	19014.63	2311.02	21116	1785.85	0.564	0.436	0.90	0.20	8.23	0.11	0.08	3.14	1.84%	-0.96%	2.80%	1982 - 1983
1983	70.36	455.1	17554.76	2284.07	19139	1695.83	0.574	0.426	0.92	0.20	7.69	0.12	0.08	3.11	-29.55%	-32.11%	2.56%	1983 - 1984
1984	65.41	605.7	16265.91	3837.48	23831	2030.00	0.654	0.346	0.68	0.16	4.24	0.16	0.08	2.25	64.07%	59.05%	5.01%	1984 - 1985
1985	61.24	578.7	24700.00	3378.60	19068	1731.33	0.661	0.339	1.30	0.17	7.31	0.18	0.10	4.07	-25.09%	-20.90%	-4.20%	1985 - 1986
1986	31.37	584.5	18335.62	2905.04	18192	1587.93	0.647	0.353	1.01	0.20	6.31	0.16	0.11	3.30	-19.03%	-6.56%	-12.46%	1986 - 1987
1987	38.41	559.6	13833.33	2446.69	16602	1127.29	0.685	0.315	0.83	0.23	5.65	0.15	0.13	3.09	-12.85%	-15.23%	2.38%	1987 - 1988
1988	29.85	524.0	11102.00	1971.72	15150	1152.20	0.631	0.369	0.73	0.27	5.63	0.13	0.13	2.65	0.60%	-1.81%	2.41%	1988 - 1989
1989	35.05	438.3	10192.31	1873.38	13826	1091.54	0.632	0.368	0.74	0.23	5.44	0.14	0.11	2.61	17.91%	16.35%	1.56%	1989 - 1990
1990	43.14	432.4	11125.45	1771.36	12617	1016.78	0.635	0.365	0.88	0.24	6.28	0.14	0.12	3.07	-12.44%	-14.54%	2.10%	1990 - 1991
1991	34.49	422.5	8965.52	1707.21	11514	949.97	0.642	0.358	0.78	0.25	5.25	0.15	0.13	2.65	0.37%	-3.04%	3.41%	1991 - 1992
1992	32.75	394.2	8211.86	1621.37	10507	920.09	0.638	0.362	0.78	0.24	5.06	0.15	0.12	2.57	1.23%	-1.34%	2.57%	1992 - 1993
1993	27.82	389.5	7586.89	1531.48	9588	876.80	0.636	0.364	0.79	0.25	4.95	0.16	0.13	2.54	5.14%	3.83%	1.32%	1993 - 1994
1994	25.11	413.9	7288.89	1354.86	8750	836.44	0.618	0.382	0.83	0.31	5.38	0.15	0.15	2.64	2.79%	0.88%	1.90%	1994 - 1995
1995	26.59	403.5	7332.81	1253.25	8561	869.74	0.590	0.410	0.86	0.32	5.85	0.15	0.15	2.66	21.59%	18.04%	3.55%	1995 - 1996
1996	31.32	416.7	8903.03	1356.95	8376	890.87	0.604	0.396	1.06	0.31	6.56	0.16	0.15	3.19	-0.80%	-2.73%	1.93%	1996 - 1997
1997	28.08	416.7	8641.18	1317.04	8195	913.36	0.590	0.410	1.05	0.32	6.56	0.16	0.15	3.10	4.24%	-7.08%	11.31%	1997 - 1998
1998	18.43	479.6	8820.29	1862.74	8018	950.81	0.662	0.338	1.10	0.26	4.74	0.23	0.16	2.89	19.22%	16.78%	2.44%	1998 - 1999
1999	25.67	448.8	10458.57	1844.87	7844	990.00	0.651	0.349	1.33	0.24	5.67	0.24	0.15	3.42	N/A	N/A	N/A	1999 - 2000
2000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000 - 2001
2001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2001 - 2002
2002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2002 - 2003
2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003 - 2004
2004	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004 - 2005
2005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2005 - 2006
2006	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2006 - 2007
2007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2007 - 2008
2008	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2008 - 2009
2009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2009 - 2010
2010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2010 - 2011
2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2011 - 2012
2012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2012 - 2013
2013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2013 - 2014
2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1970-2014	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	-3.78%	7.67%	-1.44%	-0.90%	1.96%			8.65%	-2.37%	9.24%	-0.54%	-4.47%	6.89%	8.30%	6.67%	1.63%	**1970-1981**
1981-1999	-6.99%	-0.91%	-3.67%	-0.86%	-5.88%	-3.59%			2.35%	-0.05%	-2.84%	5.33%	3.42%	0.54%	2.32%	0.53%	1.78%	**1981-1999**
1999-2014	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1999-2014**

Table 28 – Growth Accounting Data for Texaco, 1970 - 1999

Chevron		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	547.49	30195.12	2355.37	21296	1618.54	0.59	0.41	1.42	0.23	12.82	0.11	0.09	5.23	58.31%	36.75%	21.55%	1982 - 1983
1983	70.36	556.05	33571.43	2427.00	13216	1348.33	0.64	0.36	2.54	0.23	13.83	0.18	0.13	7.55	-4.65%	-1.66%	-2.99%	1983 - 1984
1984	65.41	556.05	32045.45	2316.68	13216	1287.05	0.64	0.36	2.42	0.24	13.83	0.18	0.13	7.43	-62.96%	-38.88%	-24.08%	1984 - 1985
1985	61.24	547.49	27511.11	2146.00	21296	1474.67	0.59	0.41	1.29	0.26	12.82	0.10	0.10	5.03	-34.21%	-44.66%	10.45%	1985 - 1986
1986	31.37	523.07	16408.48	1268.41	17883	1404.45	0.47	0.53	0.92	0.41	12.94	0.07	0.10	3.22	15.31%	23.25%	-7.95%	1986 - 1987
1987	38.41	503.78	19348.17	1833.19	18094	1310.32	0.58	0.42	1.07	0.27	10.55	0.10	0.11	4.06	-29.66%	-23.57%	-6.09%	1987 - 1988
1988	29.85	500.30	14932.85	1779.66	18786	1224.63	0.59	0.41	0.79	0.28	8.39	0.09	0.11	3.21	17.62%	18.45%	-0.83%	1988 - 1989
1989	35.05	519.00	18191.23	1122.06	19189	1146.38	0.49	0.51	0.95	0.46	16.21	0.06	0.11	3.86	19.92%	28.50%	-8.59%	1989 - 1990
1990	43.14	534.28	21950.37	1599.87	18973	1055.18	0.60	0.40	1.16	0.33	13.72	0.08	0.12	5.13	-20.69%	-14.86%	-5.83%	1990 - 1991
1991	34.49	526.25	18149.78	1534.19	19293	974.13	0.61	0.39	0.94	0.34	11.83	0.08	0.13	4.43	4.76%	0.45%	4.30%	1991 - 1992
1992	32.75	519.26	17004.19	1508.19	17236	932.29	0.62	0.38	0.99	0.34	11.27	0.09	0.14	4.45	-15.50%	-17.63%	2.12%	1992 - 1993
1993	27.82	505.65	14068.40	1903.87	16652	877.87	0.68	0.32	0.84	0.27	7.39	0.11	0.13	3.73	-2.05%	15.43%	-17.47%	1993 - 1994
1994	25.11	528.02	13256.83	1920.00	16015	535.00	0.78	0.22	0.83	0.28	6.90	0.12	0.17	4.35	10.08%	-7.09%	17.17%	1994 - 1995
1995	26.59	518.48	13785.54	1854.42	15057	756.88	0.71	0.29	0.92	0.28	7.43	0.12	0.15	4.05	24.83%	21.93%	2.90%	1995 - 1996
1996	31.32	535.44	16767.86	1895.05	14287	730.23	0.72	0.28	1.17	0.28	8.85	0.13	0.16	5.04	-5.58%	-13.55%	7.97%	1996 - 1997
1997	28.08	544.62	15291.42	2032.68	13777	789.04	0.72	0.28	1.11	0.27	7.52	0.15	0.16	4.41	-39.84%	-55.29%	15.45%	1997 - 1998
1998	18.43	554.65	10221.35	2040.91	13717	1135.72	0.64	0.36	0.75	0.27	5.01	0.15	0.14	2.53	113.41%	66.46%	46.94%	1998 - 1999
1999	25.67	993.41	25502.32	4242.34	11011	1119.50	0.79	0.21	2.32	0.23	6.01	0.39	0.19	4.93	38.51%	50.74%	-12.24%	1999 - 2000
2000	39.03	960.19	37481.01	3970.36	11011	647.61	0.86	0.14	3.40	0.24	9.44	0.36	0.21	8.18	-10.71%	-24.37%	13.66%	2000 - 2001
2001	32.59	924.85	30142.55	4251.84	9856	576.20	0.88	0.12	3.06	0.22	7.09	0.43	0.20	6.41	-65.62%	-21.45%	-44.17%	2001 - 2002
2002	32.93	894.25	29443.48	4221.47	18555	1066.13	0.80	0.20	1.59	0.21	6.97	0.23	0.16	5.17	11.63%	9.90%	1.73%	2002 - 2003
2003	36.96	853.74	31556.13	4176.92	17704	1002.03	0.81	0.19	1.78	0.20	7.55	0.24	0.15	5.71	24.92%	18.78%	6.14%	2003 - 2004
2004	47.83	790.96	37832.37	4225.50	16543	1001.25	0.81	0.19	2.29	0.19	8.95	0.26	0.14	6.89	20.38%	0.26%	20.12%	2004 - 2005
2005	66.49	788.77	52444.30	6368.82	18704	1236.65	0.84	0.16	2.80	0.12	8.23	0.34	0.10	6.91	17.91%	12.95%	4.96%	2005 - 2006
2006	76.64	855.93	65598.15	7121.12	19559	1318.49	0.84	0.16	3.35	0.12	9.21	0.36	0.10	7.87	1.33%	-4.23%	5.56%	2006 - 2007
2007	82.26	855.56	70378.64	8061.03	20707	1482.41	0.84	0.16	3.40	0.11	8.73	0.39	0.09	7.54	17.30%	9.07%	8.23%	2007 - 2008
2008	106.87	816.14	87224.71	9339.53	21586	1610.57	0.85	0.15	4.04	0.09	9.34	0.43	0.08	8.26	-40.52%	-45.87%	5.35%	2008 - 2009
2009	67.77	857.75	56551.65	9694.19	20987	1632.01	0.86	0.14	2.69	0.09	5.83	0.46	0.08	5.22	25.57%	17.03%	8.54%	2009 - 2010
2010	86.41	874.91	70966.30	10425.23	20393	1725.82	0.86	0.14	3.48	0.08	6.81	0.51	0.08	6.19	22.14%	6.11%	16.03%	2010 - 2011
2011	117.11	843.88	87195.79	12493.52	20082	1779.61	0.88	0.12	4.34	0.07	6.98	0.62	0.06	6.58	-10.71%	-20.67%	9.96%	2011 - 2012
2012	115.12	823.44	79585.57	14258.13	20400	1914.56	0.88	0.12	3.90	0.06	5.58	0.70	0.06	5.35	-8.29%	-18.53%	10.24%	2012 - 2013
2013	110.88	804.83	77100.00	16878.58	21471	2156.69	0.89	0.11	3.59	0.05	4.57	0.79	0.05	4.45	-10.09%	-16.45%	6.36%	2013 - 2014
2014	98.95	798.99	69825.00	18171.45	21510	2289.59	0.89	0.11	3.25	0.04	3.84	0.84	0.04	3.77				
1970-2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.50%	3.57%	-0.99%	3.52%	-3.81%	-2.15%	1.71%	-3.85%	2.93%	0.04%	-4.36%	7.62%	4.23%	-0.35%	2.89%	-0.35%	3.24%	**1981-1999**
1999-2014	9.41%	-1.44%	6.95%	10.18%	4.57%	4.89%	0.77%	-4.07%	2.28%	-10.55%	-2.94%	5.37%	-9.47%	-1.77%	2.25%	-1.78%	4.03%	**1999-2014**

Table 29 – Growth Accounting Data for Chevron, 1982 - 2014

Exxon		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	1702.73	18303.75	3145.39	24310	8837.50	0.26	0.74	0.75	0.54	5.82	0.13	0.12	1.29	9.72%	7.93%	1.79%	1970 - 1971
1971	13.18	1750.18	20172.94	2965.76	24310	9058.82	0.25	0.75	0.83	0.59	6.80	0.12	0.12	1.39	6.56%	4.63%	1.93%	1971 - 1972
1972	13.78	1813.32	21239.44	2872.50	23970	9327.78	0.24	0.76	0.89	0.63	7.39	0.12	0.12	1.46	18.91%	16.93%	1.98%	1972 - 1973
1973	17.32	1741.42	24931.58	2986.53	23290	9800.00	0.23	0.77	1.07	0.58	8.35	0.13	0.12	1.73	35.75%	33.42%	2.33%	1973 - 1974
1974	55.14	1558.92	34606.24	3314.57	22610	10628.57	0.24	0.76	1.53	0.47	10.44	0.15	0.11	2.42	-7.59%	-10.19%	2.59%	1974 - 1975
1975	50.13	820.89	33040.00	3328.43	23290	11713.04	0.22	0.78	1.42	0.25	9.93	0.14	0.05	2.18	-18.14%	-17.09%	-1.05%	1975 - 1976
1976	53.33	475.23	25345.60	3718.88	21420	11045.83	0.25	0.75	1.18	0.13	6.82	0.17	0.03	1.84	0.05%	-0.12%	0.18%	1976 - 1977
1977	53.54	477.42	25560.33	3657.81	21590	11126.92	0.25	0.75	1.18	0.13	6.99	0.17	0.03	1.84	35.04%	33.46%	1.58%	1977 - 1978
1978	50.07	838.52	37141.71	4021.71	22100	12160.71	0.25	0.75	1.68	0.21	9.24	0.18	0.06	2.57	-9.03%	-4.65%	-4.38%	1978 - 1979
1979	101.97	851.23	44114.00	4673.61	28730	13490.32	0.26	0.74	1.54	0.18	9.44	0.16	0.05	2.45	-21.56%	-24.58%	3.02%	1979 - 1980
1980	105.23	784.56	37240.00	5467.63	30090	15865.71	0.26	0.74	1.24	0.14	6.81	0.18	0.04	1.92	15.47%	17.85%	-2.38%	1980 - 1981
1981	94.55	760.52	44207.89	6478.58	30600	15347.37	0.30	0.70	1.44	0.12	6.82	0.21	0.04	2.29	-8.27%	-8.19%	-0.08%	1981 - 1982
1982	80.41	743.69	39114.63	5862.51	29410	14617.07	0.29	0.71	1.33	0.13	6.67	0.20	0.04	2.11	13.51%	12.08%	1.42%	1982 - 1983
1983	70.36	788.44	40371.43	5974.07	26520	13926.19	0.30	0.70	1.52	0.13	6.76	0.23	0.05	2.38	6.55%	8.25%	-1.71%	1983 - 1984
1984	65.41	840.91	41445.45	6561.82	25500	12613.64	0.34	0.66	1.63	0.13	6.32	0.26	0.05	2.59	-1.03%	-0.94%	-0.09%	1984 - 1985
1985	61.24	830.35	39926.67	7177.60	24820	11957.78	0.38	0.62	1.61	0.12	5.56	0.29	0.05	2.56	-29.17%	-32.45%	3.27%	1985 - 1986
1986	31.37	840.83	26376.60	7134.69	21951	11398.95	0.38	0.62	1.20	0.12	3.70	0.33	0.06	1.85	33.43%	30.73%	2.70%	1986 - 1987
1987	38.41	848.49	32587.26	6956.85	19414	10644.89	0.40	0.60	1.68	0.12	4.68	0.36	0.07	2.52	-8.69%	-11.68%	2.99%	1987 - 1988
1988	29.85	885.24	26422.31	6803.82	17170	9958.00	0.41	0.59	1.54	0.13	3.88	0.40	0.08	2.24	7.64%	9.37%	-1.74%	1988 - 1989
1989	35.05	853.65	29366.10	6672.74	17680	9867.31	0.40	0.60	1.66	0.13	4.40	0.38	0.07	2.46	-9.67%	-11.03%	1.35%	1989 - 1990
1990	43.14	809.08	26658.18	6441.90	17680	10692.73	0.38	0.62	1.51	0.13	4.14	0.36	0.07	2.20	-17.80%	-18.00%	0.20%	1990 - 1991
1991	34.49	803.89	21667.24	6244.14	17170	10484.48	0.37	0.63	1.26	0.13	3.47	0.36	0.07	1.84	5.11%	4.59%	0.52%	1991 - 1992
1992	32.75	807.12	21449.15	5808.66	16150	10144.07	0.36	0.64	1.33	0.14	3.69	0.36	0.07	1.93	-9.79%	-9.46%	-0.33%	1992 - 1993
1993	27.82	804.21	18629.51	5434.82	15470	9698.36	0.36	0.64	1.20	0.15	3.43	0.35	0.08	1.75	0.18%	-0.34%	0.52%	1993 - 1994
1994	25.11	999.99	17638.10	5170.57	14620	9334.92	0.36	0.64	1.21	0.19	3.41	0.35	0.10	1.75	10.37%	9.31%	1.07%	1994 - 1995
1995	26.59	1008.39	18656.25	5190.33	13940	9060.94	0.36	0.64	1.34	0.19	3.59	0.37	0.10	1.92	20.74%	20.57%	0.16%	1995 - 1996
1996	31.32	1003.37	22115.15	5131.91	13430	8651.52	0.37	0.63	1.65	0.20	4.31	0.38	0.11	2.36	-12.35%	-10.49%	-1.86%	1996 - 1997
1997	28.08	982.55	19794.12	4902.75	13600	8375.00	0.37	0.63	1.46	0.20	4.04	0.36	0.11	2.12	-36.87%	-36.86%	-0.02%	1997 - 1998
1998	18.43	969.81	13518.84	5024.22	13430	8082.61	0.38	0.62	1.01	0.19	2.69	0.37	0.11	1.47	0.00%	0.00%	0.00%	1998 - 1999
1999	25.67	969.81	13518.84	5024.22	13430	8082.61	0.38	0.62	1.01	0.19	2.69	0.37	0.11	1.47				1999 - 2000
2000	39.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000 - 2001
2001	32.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2001 - 2002
2002	32.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2002 - 2003
2003	36.96	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003 - 2004
2004	47.83	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004 - 2005
2005	66.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2005 - 2006
2006	76.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2006 - 2007
2007	82.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2007 - 2008
2008	106.87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2008 - 2009
2009	67.77	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2009 - 2010
2010	86.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2010 - 2011
2011	117.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2011 - 2012
2012	115.12	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2012 - 2013
2013	110.88	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2013 - 2014
2014	98.95	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1970-2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	-7.07%	8.35%	6.79%	2.11%	5.15%	1.12%	-0.43%	6.10%	-12.97%	1.46%	4.58%	-9.62%	5.37%	5.92%	5.23%	0.69%	**1970-1981**
1981-1999	-6.99%	1.36%	-6.37%	-1.40%	-4.47%	-3.50%	1.43%	-0.73%	-1.99%	2.80%	-5.04%	3.21%	5.61%	-2.44%	-2.01%	-2.47%	0.47%	**1981-1999**
1999-2014	9.41%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1999-2014**

Table 30 – Growth Accounting Data for Exxon, 1970 - 1999

Mobil		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	972.94	6076.88	934.76	22680	4466.25	0.17	0.83	0.27	1.04	6.50	0.04	0.07	0.47	21.97%	21.15%	0.82%	1970 - 1971
1971	13.18	1060.40	7540.00	924.94	22590	4511.18	0.17	0.83	0.33	1.15	8.15	0.04	0.08	0.57	-4.80%	14.68%	-19.48%	1971 - 1972
1972	13.78	1101.87	7158.33	2206.41	22500	4731.67	0.32	0.68	0.32	0.50	3.24	0.10	0.10	0.67	16.49%	16.35%	0.14%	1972 - 1973
1973	17.32	1146.77	8508.95	2470.17	22680	4960.53	0.33	0.67	0.38	0.46	3.44	0.11	0.11	0.78	81.20%	82.81%	-1.61%	1973 - 1974
1974	55.14	1123.99	18989.05	2599.37	22470	4844.80	0.35	0.65	0.85	0.43	7.31	0.12	0.11	1.79	-3.10%	-4.98%	1.87%	1974 - 1975
1975	50.13	1025.96	18064.78	2364.81	22050	4824.11	0.33	0.67	0.82	0.43	7.64	0.11	0.10	1.71	-83.03%	-36.99%	-46.04%	1975 - 1976
1976	53.33	984.92	21391.67	3163.50	59900	4623.10	0.41	0.59	0.36	0.31	6.76	0.05	0.05	1.18	8.17%	25.21%	-17.04%	1976 - 1977
1977	53.54	1068.95	23484.62	3062.50	60600	3633.70	0.46	0.54	0.39	0.35	7.67	0.05	0.07	1.52	-108.79%	-113.70%	4.91%	1977 - 1978
1978	50.07	978.49	8135.71	2958.07	62310	3891.43	0.43	0.57	0.13	0.33	2.75	0.05	0.06	0.49	24.19%	21.93%	2.26%	1978 - 1979
1979	101.97	402.31	10651.61	3047.81	64050	4127.42	0.42	0.58	0.17	0.13	3.49	0.05	0.02	0.61	32.19%	35.01%	-2.82%	1979 - 1980
1980	105.23	394.17	14648.57	3289.37	63840	4091.14	0.45	0.55	0.23	0.12	4.45	0.05	0.02	0.86	49.33%	52.01%	-2.68%	1980 - 1981
1981	94.55	365.66	23268.42	3410.76	61920	3921.32	0.47	0.53	0.38	0.11	6.82	0.06	0.02	1.45				1981 - 1982
1982	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1999 - 2000
2000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000 - 2001
2001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2001 - 2002
2002	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2002 - 2003
2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2003 - 2004
2004	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2004 - 2005
2005	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2005 - 2006
2006	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2006 - 2007
2007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2007 - 2008
2008	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2008 - 2009
2009	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2009 - 2010
2010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2010 - 2011
2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2011 - 2012
2012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2012 - 2013
2013	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2013 - 2014
2014	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
1970-2014	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	-8.51%	12.98%	12.49%	9.56%	-1.18%			3.12%	-18.67%	0.44%	2.67%	-10.22%	10.87%	3.07%	10.32%	-7.24%	**1970-1981**
1981-1999	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	N/A	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1999-2014**

Table 31 – Growth Accounting Data for Mobil, 1970 - 1981

XOM		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	1,567	32624.29	7279.07	18190	3189.20	0.70	0.30	1.79	0.22	4.48	0.40	0.16	3.39	47.58%	51.03%	-3.45%	1999 - 2000
2000	39.03	1,583	49067.12	6503.30	17000	2804.77	0.70	0.30	2.89	0.24	7.54	0.38	0.18	5.65	-10.85%	-14.33%	3.48%	2000 - 2001
2001	32.59	1,575	43097.33	6659.16	16643	2923.55	0.69	0.31	2.59	0.24	6.47	0.40	0.18	4.89	-0.24%	-8.64%	8.40%	2001 - 2002
2002	32.93	1,569	40623.68	7352.76	15725	2763.84	0.73	0.27	2.58	0.21	5.52	0.47	0.17	4.49	25.99%	15.63%	10.35%	2002 - 2003
2003	36.96	1,555	50287.18	8159.42	15011	2919.64	0.74	0.26	3.35	0.19	6.16	0.54	0.16	5.25	22.36%	19.21%	3.15%	2003 - 2004
2004	47.83	1,559	61176.25	8294.40	14603	2942.91	0.74	0.26	4.19	0.19	7.38	0.57	0.16	6.36	26.67%	23.18%	3.49%	2004 - 2005
2005	66.49	1,503	77830.49	8482.72	14229	2985.78	0.74	0.26	5.47	0.18	9.18	0.60	0.15	8.02	18.41%	13.75%	4.66%	2005 - 2006
2006	76.64	1,566	91775.29	8961.99	13957	2854.60	0.76	0.24	6.58	0.17	10.24	0.64	0.16	9.20	4.32%	1.80%	2.52%	2006 - 2007
2007	82.26	1,545	94307.95	9127.64	13736	2876.48	0.76	0.24	6.87	0.17	10.33	0.66	0.15	9.37	21.32%	19.62%	1.70%	2007 - 2008
2008	106.87	1,450	115424.18	9212.34	13583	2965.29	0.76	0.24	8.50	0.16	12.53	0.68	0.14	11.40	-48.33%	-58.52%	10.19%	2008 - 2009
2009	67.77	1,455	71897.80	10782.49	13719	2752.69	0.80	0.20	5.24	0.13	6.67	0.79	0.13	6.35	22.80%	-12.69%	35.49%	2009 - 2010
2010	86.41	1,649	93559.78	17165.64	14212	2713.16	0.86	0.14	6.58	0.10	5.45	1.21	0.10	5.59	24.93%	15.80%	9.13%	2010 - 2011
2011	117.11	1,672	117894.74	18669.41	13957	2681.17	0.87	0.13	8.45	0.09	6.31	1.34	0.09	6.55	-0.53%	-14.01%	13.47%	2011 - 2012
2012	115.12	1,573	109840.21	20215.58	13073	2432.05	0.89	0.11	8.40	0.08	5.43	1.55	0.08	5.69	1.11%	-8.00%	9.10%	2012 - 2013
2013	110.88	1,549	108318.37	21653.72	12750	2233.77	0.91	0.09	8.50	0.07	5.00	1.70	0.08	5.26	-16.06%	-14.87%	-1.20%	2013 - 2014
2014	98.95	1,472	92612.00	21423.15	12801	2141.66	0.91	0.09	7.23	0.07	4.32	1.67	0.07	4.53				
1970-2014	5.07%	-0.42%	7.20%	7.46%	-2.32%	-2.62%			9.74%	-7.33%	-0.24%	10.01%	-5.30%	1.95%	9.30%	1.93%	7.37%	**1970-2014**
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.50%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.41%	-0.42%	7.20%	7.46%	-2.32%	-2.62%			9.74%	-7.33%	-0.24%	10.01%	-5.30%	1.95%	9.30%	1.93%	7.37%	**1999-2014**

Table 32 – Growth Accounting Data for ExxonMobil, 1999 - 2014

Shell		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	377.52	4247.14	958.13	29682.6	1994.7	0.32	0.68	0.14	0.39	4.43	0.03	0.04	0.44				1970 - 1971
1971	13.18	389.56	5132.97	836.60	28266.0	1898.4	0.31	0.69	0.18	0.47	6.14	0.03	0.04	0.53	23.83%	20.10%	3.73%	1971 - 1972
1972	13.78	387.05	5332.70	925.18	26546.7	1830.3	0.34	0.66	0.20	0.42	5.76	0.03	0.05	0.62	10.09%	15.12%	-5.03%	1972 - 1973
1973	17.32	369.96	6281.26	875.14	25907.8	1767.0	0.33	0.67	0.24	0.42	7.18	0.03	0.04	0.74	18.81%	18.32%	0.49%	1973 - 1974
1974	55.14	339.32	8435.95	1036.72	26075.0	1751.7	0.37	0.63	0.32	0.33	8.14	0.04	0.04	1.07	28.85%	36.54%	-7.69%	1974 - 1975
1975	50.13	319.56	8474.96	1093.68	26243.8	1797.8	0.38	0.62	0.32	0.29	7.75	0.04	0.04	1.07	-0.18%	0.12%	-0.30%	1975 - 1976
1976	53.33	312.70	8395.83	1203.53	26026.6	1272.0	0.49	0.51	0.32	0.26	6.98	0.05	0.05	1.44	-0.11%	29.14%	-29.24%	1976 - 1977
1977	53.54	306.75	8457.69	1267.52	27093.4	1167.9	0.52	0.48	0.31	0.24	6.67	0.05	0.06	1.54	-3.28%	6.65%	-9.93%	1977 - 1978
1978	50.07	273.10	8817.86	1381.18	28245.0	1147.9	0.55	0.45	0.31	0.20	6.38	0.05	0.05	1.62	0.01%	5.45%	-5.44%	1978 - 1979
1979	101.97	267.42	10177.42	3757.65	29383.8	1219.2	0.76	0.24	0.35	0.07	2.71	0.13	0.04	1.64	10.39%	0.85%	9.53%	1979 - 1980
1980	105.23	276.52	14854.29	2854.29	29383.8	1234.5	0.70	0.30	0.51	0.10	5.20	0.10	0.05	2.57	37.81%	45.30%	-7.48%	1980 - 1981
1981	94.55	281.42	19550.00	2975.92	30101.7	1202.9	0.71	0.29	0.65	0.09	6.57	0.10	0.05	3.37	25.05%	27.08%	-2.03%	1981 - 1982
1982	80.41	272.15	16834.15	2839.39	29480.7	1160.2	0.71	0.29	0.57	0.10	5.93	0.10	0.05	3.01	-12.87%	-11.53%	-1.34%	1982 - 1983
1983	70.36	264.52	15683.33	2786.14	28415.4	1171.0	0.70	0.30	0.55	0.09	5.63	0.10	0.05	2.83	-3.40%	-6.03%	2.63%	1983 - 1984
1984	65.41	339.25	15243.18	3110.52	28022.9	1163.7	0.73	0.27	0.54	0.11	4.90	0.11	0.06	2.69	-1.46%	-4.99%	3.53%	1984 - 1985
1985	61.24	279.07	14724.44	3347.80	28404.1	1189.9	0.74	0.26	0.52	0.08	4.40	0.12	0.05	2.51	-4.81%	-7.03%	2.22%	1985 - 1986
1986	31.37	304.08	9538.94	3001.30	26360.9	1164.0	0.72	0.28	0.36	0.10	3.18	0.11	0.06	1.73	-35.95%	-37.14%	1.19%	1986 - 1987
1987	38.41	302.94	10097.92	2825.63	26799.4	1238.3	0.70	0.30	0.38	0.11	3.57	0.11	0.05	1.80	4.04%	3.90%	0.15%	1987 - 1988
1988	29.85	295.32	8444.00	2804.40	26192.1	1195.2	0.70	0.30	0.32	0.11	3.01	0.11	0.05	1.54	-15.60%	-15.35%	-0.24%	1988 - 1989
1989	35.05	278.87	8665.38	2502.00	25308.6	1160.1	0.68	0.32	0.34	0.11	3.46	0.10	0.05	1.66	6.02%	7.46%	-1.44%	1989 - 1990
1990	43.14	266.25	9370.91	2373.05	25550.1	1183.5	0.67	0.33	0.37	0.11	3.95	0.09	0.05	1.79	6.88%	7.35%	-0.47%	1990 - 1991
1991	34.49	175.57	6054.99	2110.19	23773.3	1586.0	0.57	0.43	0.25	0.08	2.87	0.09	0.03	1.02	-36.47%	-56.77%	20.30%	1991 - 1992
1992	32.75	252.66	7500.00	1991.44	20438.8	1568.7	0.56	0.44	0.37	0.13	3.77	0.10	0.05	1.35	36.52%	28.51%	8.01%	1992 - 1993
1993	27.82	244.93	6567.21	1787.61	17938.4	1141.2	0.61	0.39	0.37	0.14	3.67	0.10	0.06	1.50	-0.23%	10.26%	-10.49%	1993 - 1994
1994	25.11	247.78	6000.00	1645.00	17360.2	1471.6	0.53	0.47	0.35	0.15	3.65	0.09	0.05	1.20	-5.76%	-22.13%	16.37%	1994 - 1995
1995	26.59	268.88	7051.56	1640.39	17000.0	1518.0	0.52	0.48	0.41	0.16	4.30	0.10	0.05	1.40	18.25%	15.31%	2.93%	1995 - 1996
1996	31.32	1034.12	24622.73	4840.09	18000.0	1457.0	0.77	0.23	1.37	0.21	5.09	0.27	0.16	3.75	119.33%	98.84%	20.49%	1996 - 1997
1997	28.08	1017.95	22833.82	4295.12	17000.0	1313.1	0.77	0.23	1.34	0.24	5.32	0.25	0.17	3.85	-1.83%	2.58%	-4.41%	1997 - 1998
1998	18.43	991.68	15972.46	4558.30	15000.0	1121.1	0.80	0.20	1.06	0.22	3.50	0.30	0.17	2.77	-23.22%	-32.98%	9.76%	1998 - 1999
1999	25.67	962.17	24700.48	3961.54	13000.0	963.4	0.80	0.20	1.90	0.24	6.24	0.30	0.19	4.94	57.91%	57.89%	0.01%	1999 - 2000
2000	39.03	940.58	36715.53	3563.51	13000.0	902.3	0.80	0.20	2.82	0.26	10.30	0.27	0.20	7.93	39.64%	47.32%	-7.69%	2000 - 2001
2001	32.59	933.24	30416.09	4445.04	15000.0	1022.2	0.81	0.19	2.03	0.21	6.84	0.30	0.17	5.45	-33.13%	-37.52%	4.39%	2001 - 2002
2002	32.93	987.00	32497.18	6758.76	17000.0	1175.5	0.85	0.15	1.91	0.15	4.81	0.40	0.13	4.19	-5.90%	-26.21%	20.31%	2002 - 2003
2003	36.96	1047.92	38733.50	6299.08	17100.0	1377.5	0.82	0.18	2.27	0.17	6.15	0.37	0.14	5.14	16.97%	20.34%	-3.38%	2003 - 2004
2004	47.83	1054.12	46618.75	6594.08	16000.0	1422.5	0.82	0.18	2.91	0.16	7.07	0.41	0.14	6.04	25.18%	16.14%	9.03%	2004 - 2005
2005	66.49	976.24	55700.00	7308.66	21000.0	1946.8	0.79	0.21	2.65	0.13	7.62	0.35	0.11	6.10	-9.40%	1.04%	-10.43%	2005 - 2006
2006	76.64	946.41	61818.82	9091.16	22000.0	2115.4	0.81	0.19	2.81	0.10	6.80	0.41	0.09	5.76	5.77%	-5.88%	11.65%	2006 - 2007
2007	82.26	884.73	60577.27	8522.39	22000.0	2408.9	0.78	0.22	2.75	0.10	7.11	0.39	0.08	5.77	-2.03%	0.22%	-2.24%	2007 - 2008
2008	106.87	843.98	72716.48	10475.80	22000.0	2507.9	0.81	0.19	3.31	0.08	6.94	0.48	0.07	6.01	18.26%	4.19%	14.07%	2008 - 2009
2009	67.77	792.44	53704.16	11376.20	23000.0	2654.6	0.81	0.19	2.33	0.07	4.72	0.49	0.06	4.13	-34.75%	-37.54%	2.79%	2009 - 2010
2010	86.41	821.45	70980.13	11464.14	26000.0	3107.8	0.79	0.21	2.73	0.07	6.19	0.44	0.06	5.20	15.63%	22.98%	-7.34%	2010 - 2011
2011	117.11	763.96	89467.96	11879.24	27000.0	3522.9	0.77	0.23	3.31	0.06	7.53	0.44	0.05	6.24	19.37%	18.28%	1.10%	2011 - 2012
2012	115.12	770.54	88707.21	14252.10	26000.0	3430.0	0.81	0.19	3.41	0.05	6.22	0.55	0.05	5.54	2.92%	-11.95%	14.87%	2012 - 2013
2013	110.88	795.79	88233.83	16077.67	31000.0	4142.2	0.80	0.20	2.85	0.05	5.49	0.52	0.04	4.80	-18.12%	-14.38%	-3.75%	2013 - 2014
2014	98.95	841.94	83306.77	15562.17	33000.0	4596.1	0.77	0.23	2.52	0.05	5.35	0.47	0.05	4.51	-12.00%	-6.18%	-5.82%	
1970-2014	5.1%	1.8%	7.0%	6.5%	0.2%	1.9%	2.0%	-2.4%	6.7%	-4.4%	0.4%	6.3%	0.4%	5.5%	6.5%	5.3%	1.2%	**1970-2014**
1970-1981	21.4%	-2.6%	14.9%	10.9%	0.1%	-4.5%	7.4%	-7.5%	14.7%	-12.2%	3.6%	10.7%	2.1%	20.4%	13.8%	18.6%	-4.9%	**1970-1981**
1981-1999	-7.0%	7.1%	1.3%	1.6%	-4.6%	-1.2%	0.7%	-2.1%	6.1%	5.4%	-0.3%	6.5%	7.9%	2.1%	6.0%	2.1%	3.8%	**1981-1999**
1999-2014	9.4%	-0.9%	8.4%	9.6%	6.4%	11.0%	-0.3%	1.0%	1.9%	-9.5%	-1.0%	3.0%	-9.2%	-0.6%	1.9%	-0.6%	2.5%	**1999-2014**

Table 33 – Growth Accounting Data for Shell, 1970 - 2014

Gazprom		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	2967.52	6018.44	1551.26	117050	3713.26	0.29	0.71	0.05	1.91	3.88	0.01	0.09	0.18	103%	123.22%	-20.14%	1999 - 2000
2000	39.03	3028.93	17230.67	2014.37	119550	3560.66	0.36	0.64	0.14	1.50	8.55	0.02	0.11	0.63	46.21%	61.04%	-14.83%	2000 - 2001
2001	32.59	3090.34	27925.16	2473.48	122050	3465.71	0.42	0.58	0.23	1.25	11.29	0.02	0.13	1.16	30.25%	14.31%	15.95%	2001 - 2002
2002	32.93	3151.75	38564.93	2947.00	124550	4588.06	0.39	0.61	0.31	1.07	13.09	0.02	0.11	1.34	33.33%	4.41%	28.92%	2002 - 2003
2003	36.96	3262.42	54555.75	3788.49	126250	7516.39	0.34	0.66	0.43	0.86	14.40	0.03	0.08	1.40	14.42%	1.37%	13.05%	2003 - 2004
2004	47.83	3342.08	62843.58	5646.82	125900	11135.81	0.34	0.66	0.50	0.59	11.13	0.04	0.08	1.42	39.02%	25.08%	13.94%	2004 - 2005
2005	66.49	3432.58	91108.62	5831.74	123550	13841.54	0.30	0.70	0.74	0.59	15.62	0.05	0.07	1.82	39.54%	52.91%	-13.37%	2005 - 2006
2006	76.64	3616.93	127133.52	11176.48	116100	14006.49	0.44	0.56	1.10	0.32	11.38	0.10	0.09	3.09	21.85%	-4.27%	26.12%	2006 - 2007
2007	82.26	3572.22	151231.43	17582.13	111000	24079.95	0.42	0.58	1.36	0.20	8.60	0.16	0.07	2.97	-2.84%	17.32%	-20.16%	2007 - 2008
2008	106.87	3562.25	146532.23	14709.94	110650	15603.26	0.49	0.51	1.32	0.24	9.96	0.13	0.09	3.53	-16.70%	-12.02%	-4.68%	2008 - 2009
2009	67.77	3032.49	134420.81	16465.23	119950	15404.57	0.52	0.48	1.12	0.18	8.16	0.14	0.07	3.13	19.85%	15.97%	3.87%	2009 - 2010
2010	86.41	3322.58	148348.47	16750.32	108550	14958.08	0.53	0.47	1.37	0.20	8.86	0.15	0.08	3.67	8.57%	15.25%	-6.68%	2010 - 2011
2011	117.11	3357.91	163261.64	16340.50	109650	13171.23	0.55	0.45	1.49	0.21	9.99	0.15	0.09	4.27	7.30%	-4.87%	12.17%	2011 - 2012
2012	115.12	3217.97	178190.25	18928.40	111250	17028.66	0.53	0.47	1.60	0.17	9.41	0.17	0.07	4.07	-14.10%	-8.37%	-5.73%	2012 - 2013
2013	110.88	3238.70	159004.01	18361.90	114300	15566.03	0.54	0.46	1.39	0.18	8.66	0.16	0.08	3.74	-113.21%	-52.01%	-61.20%	2013 - 2014
2014	98.95	2991.66	52312.19	17188.29	116650	3362.80	0.84	0.16	0.45	0.17	3.04	0.15	0.13	2.22				
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.50%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.41%	0.05%	15.51%	17.39%	-0.02%	-0.66%			15.53%	-14.77%	-1.61%	17.42%	2.29%	18.08%	26.45%	23.82%	2.63%	**1999-2014**

Table 34 – Growth Accounting Data for Gazprom, 1999 - 2014

Petrobras		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	485.68	10564.29	1655.10	2972.2	182.9	0.70	0.30	3.55	0.29	6.38	0.56	0.25	5.35	42.83%	41.02%	1.81%	1999 - 2000
2000	39.03	547.36	16628.77	1742.05	3048.5	175.3	0.70	0.30	5.45	0.31	9.55	0.57	0.27	8.07	-29.97%	-26.01%	-3.96%	2000 - 2001
2001	32.59	575.24	13472.00	1799.88	3333.0	170.7	0.70	0.30	4.04	0.32	7.48	0.54	0.27	6.22	-33.13%	9.04%	-42.17%	2001 - 2002
2002	32.93	642.65	17165.79	1748.72	5914.8	232.9	0.70	0.30	2.90	0.37	9.82	0.30	0.25	6.81	59.98%	8.33%	51.65%	2002 - 2003
2003	36.96	656.50	20125.64	2353.85	3806.5	157.7	0.70	0.30	5.29	0.28	8.55	0.62	0.24	7.40	-53.00%	-17.34%	-35.66%	2003 - 2004
2004	47.83	645.01	23588.75	2816.10	7579.5	293.8	0.70	0.30	3.11	0.23	8.38	0.37	0.17	6.22	50.53%	27.61%	22.92%	2004 - 2005
2005	66.49	714.63	35151.22	3512.52	6814.3	436.6	0.70	0.30	5.16	0.20	10.01	0.52	0.17	8.20	1.10%	-2.48%	3.59%	2005 - 2006
2006	76.64	749.82	42044.71	4373.79	8061.1	541.2	0.70	0.30	5.22	0.17	9.61	0.54	0.14	8.00	77.29%	10.75%	66.55%	2006 - 2007
2007	82.26	753.69	47717.05	5929.47	4223.5	346.6	0.70	0.30	11.30	0.13	8.05	1.40	0.14	8.91	20.75%	27.51%	-6.76%	2007 - 2008
2008	106.87	737.77	64861.54	5946.82	4665.0	460.4	0.70	0.30	13.90	0.12	10.91	1.27	0.13	11.73	-13.69%	-59.07%	45.38%	2008 - 2009
2009	67.77	767.01	42592.31	8563.45	3512.9	353.8	0.70	0.30	12.12	0.09	4.97	2.44	0.12	6.50	27.95%	-7.50%	35.45%	2009 - 2010
2010	86.41	790.41	58992.39	14882.77	3679.1	473.9	0.70	0.30	16.03	0.05	3.96	4.05	0.08	6.03	30.72%	53.07%	-22.35%	2010 - 2011
2011	117.11	810.48	78017.89	10519.39	3578.5	514.7	0.70	0.30	21.80	0.08	7.42	2.94	0.11	10.25	-7.97%	-9.97%	2.00%	2011 - 2012
2012	115.12	805.01	77024.74	11573.63	3826.0	509.3	0.70	0.30	20.13	0.07	6.66	3.02	0.10	9.28	1.86%	-20.70%	22.56%	2012 - 2013
2013	110.88	790.48	69602.04	14168.76	3393.5	452.0	0.70	0.30	20.51	0.06	4.91	4.18	0.09	7.54	-0.76%	-5.42%	4.66%	2013 - 2014
2014	98.95	833.81	65616.00	14385.15	3223.4	440.0	0.70	0.30	20.36	0.06	4.56	4.46	0.09	7.14				
1970-2014	5.07%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.35%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.50%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.41%	3.67%	12.95%	15.51%	0.54%	6.03%			12.34%	-10.25%	-2.22%	14.88%	-6.43%	1.94%	13.34%	4.23%	9.11%	**1999-2014**

Table 35 – Growth Accounting Data for Petrobras, 1999 - 2014

Petrochina		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	848.05	20010.97	4588.31	262086.0	735.6	0.86	0.14	0.08	0.18	4.36	0.02	0.11	2.49	48.84%	34.03%	14.80%	1999 - 2000
2000	39.03	849.42	29992.96	4885.43	241039.2	820.3	0.86	0.14	0.12	0.17	6.14	0.02	0.10	3.51	-11.04%	-17.77%	6.73%	2000 - 2001
2001	32.59	857.42	25699.98	5077.40	230637.0	846.3	0.86	0.14	0.11	0.17	5.06	0.02	0.10	2.93	-5.70%	-13.04%	7.34%	2001 - 2002
2002	32.93	870.63	24617.46	5560.29	233885.0	942.0	0.86	0.14	0.11	0.16	4.43	0.02	0.09	2.58	16.22%	4.01%	12.21%	2002 - 2003
2003	36.96	888.75	29058.51	5958.10	234733.0	1159.2	0.84	0.16	0.12	0.15	4.88	0.03	0.08	2.68	23.68%	14.18%	9.50%	2003 - 2004
2004	47.83	960.25	37113.08	6779.71	236591.0	1301.4	0.84	0.16	0.16	0.14	5.47	0.03	0.08	3.09	30.25%	17.82%	12.43%	2004 - 2005
2005	66.49	1009.48	52486.90	7912.07	247258.0	1623.6	0.83	0.17	0.21	0.13	6.63	0.03	0.07	3.69	20.45%	0.74%	19.72%	2005 - 2006
2006	76.64	1063.65	64446.50	9185.26	247442.0	2192.8	0.81	0.19	0.26	0.12	7.02	0.04	0.06	3.72	2.65%	-10.09%	12.74%	2006 - 2007
2007	82.26	1117.28	70016.20	11098.60	261802.0	2759.2	0.80	0.20	0.27	0.10	6.31	0.04	0.05	3.36	36.27%	19.57%	16.70%	2007 - 2008
2008	106.87	1181.40	99477.60	13539.32	258821.0	3356.0	0.80	0.20	0.38	0.09	7.35	0.05	0.05	4.09	-44.77%	-47.61%	2.85%	2008 - 2009
2009	67.77	1195.53	65219.00	14740.18	265499.0	3502.3	0.81	0.19	0.25	0.08	4.42	0.06	0.05	2.54	21.33%	8.99%	12.34%	2009 - 2010
2010	86.41	1228.00	87609.31	17159.74	288142.0	4717.9	0.78	0.22	0.30	0.07	5.11	0.06	0.04	2.78	35.01%	24.64%	10.37%	2010 - 2011
2011	117.11	1285.60	126491.62	19363.26	293143.0	5586.3	0.78	0.22	0.43	0.07	6.53	0.07	0.04	3.56	2.40%	-6.74%	9.14%	2011 - 2012
2012	115.12	1343.00	129265.81	22936.90	292455.0	6004.5	0.79	0.21	0.44	0.06	5.64	0.08	0.03	3.32	1.22%	-8.25%	9.47%	2012 - 2013
2013	110.88	1400.00	130216.86	25747.39	291023.0	6727.1	0.79	0.21	0.45	0.05	5.06	0.09	0.03	3.06	-5.65%	-8.92%	3.27%	2013 - 2014
2014	98.95	1450.40	126022.92	27854.81	298014.0	7076.1	0.80	0.20	0.42	0.05	4.52	0.09	0.03	2.80				
1970-2014	5.1%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.4%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.5%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.4%	3.6%	13.1%	12.8%	0.9%	16.3%			12.1%	-8.1%	0.2%	11.8%	-7.6%	0.8%	13.5%	2.2%	11.3%	**1999-2014**

Table 36 – Growth Accounting Data for Petrochina, 1999 - 2014

Rosneft		Y (Quantities)	Y (Revenue)	K	L (Workers)	L (Wages)	α	β	Y/L	Y/K (Quantities)	Y/K (Revenue)	K/L						
Years	Price*	Output (MBOE)	Output* (Act Rev, $M)	Capital* stock, $M	Labor (workers)	Labor* (Wages, $M)	Capital* share	Labor* share	Total* Rev/Worker ($M/staff)	Total Prod*/Cap (MBOE/$M)	Total Rev/Capital	Capital*/Worker ($M/staff)	TFP* (Quantities)	TFP* (workers)	ΔLn(Y/L)	ΔLn(A)	ΔLn(K/L)	Periods
1970	11.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1970 - 1971
1971	13.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1971 - 1972
1972	13.78	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1972 - 1973
1973	17.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1973 - 1974
1974	55.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1974 - 1975
1975	50.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1975 - 1976
1976	53.33	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1976 - 1977
1977	53.54	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1977 - 1978
1978	50.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1978 - 1979
1979	101.97	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1979 - 1980
1980	105.23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1980 - 1981
1981	94.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1981 - 1982
1982	80.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1982 - 1983
1983	70.36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1983 - 1984
1984	65.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1984 - 1985
1985	61.24	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1985 - 1986
1986	31.37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1986 - 1987
1987	38.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1987 - 1988
1988	29.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1988 - 1989
1989	35.05	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1989 - 1990
1990	43.14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1990 - 1991
1991	34.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1991 - 1992
1992	32.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1992 - 1993
1993	27.82	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1993 - 1994
1994	25.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1994 - 1995
1995	26.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1995 - 1996
1996	31.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1996 - 1997
1997	28.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1997 - 1998
1998	18.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1998 - 1999
1999	25.67	95.82	1610.96	539.94	11746.6	24.5	0.96	0.04	0.14	0.18	2.98	0.05	0.16	2.61	0.00%	0.00%	0.00%	1999 - 2000
2000	39.03	95.82	1610.96	539.94	11746.6	24.5	0.96	0.04	0.14	0.18	2.98	0.05	0.16	2.61	-52.91%	-39.96%	-12.94%	2000 - 2001
2001	32.59	103.93	1248.84	531.78	15456.0	50.8	0.91	0.09	0.08	0.20	2.35	0.03	0.15	1.75	-0.28%	22.63%	-22.91%	2001 - 2002
2002	32.93	112.29	1638.55	556.48	20336.8	49.5	0.92	0.08	0.08	0.20	2.94	0.03	0.15	2.19	-14.68%	-20.90%	6.22%	2002 - 2003
2003	36.96	123.21	1861.54	814.09	26759.0	62.7	0.93	0.07	0.07	0.15	2.29	0.03	0.12	1.78	13.06%	-39.11%	52.17%	2003 - 2004
2004	47.83	211.59	2656.25	1924.65	33507.0	96.3	0.95	0.05	0.08	0.11	1.38	0.06	0.10	1.20	146.45%	120.93%	25.52%	2004 - 2005
2005	66.49	622.35	12087.80	2474.45	35251.0	191.5	0.93	0.07	0.34	0.25	4.89	0.07	0.21	4.04	-8.72%	-39.20%	30.47%	2005 - 2006
2006	76.64	668.14	12831.76	4361.08	40832.0	152.9	0.97	0.03	0.31	0.15	2.94	0.11	0.14	2.73	5.52%	-19.19%	24.71%	2006 - 2007
2007	82.26	838.81	13560.23	5363.80	40832.0	325.0	0.94	0.06	0.33	0.16	2.53	0.13	0.14	2.25	17.60%	-19.39%	36.99%	2007 - 2008
2008	106.87	854.17	13959.34	6067.88	35251.0	847.3	0.88	0.12	0.40	0.14	2.30	0.17	0.11	1.85	-12.05%	-18.94%	6.90%	2008 - 2009
2009	67.77	876.16	11762.64	6561.20	33507.0	692.3	0.90	0.10	0.35	0.13	1.79	0.20	0.11	1.53	78.18%	49.05%	29.13%	2009 - 2010
2010	86.41	925.01	20528.26	7173.98	26759.0	804.3	0.90	0.10	0.77	0.13	2.86	0.27	0.11	2.51	53.98%	48.40%	5.58%	2010 - 2011
2011	117.11	935.15	35828.70	7750.00	27222.0	882.6	0.90	0.10	1.32	0.12	4.62	0.28	0.11	4.07	8.24%	9.08%	-0.83%	2011 - 2012
2012	115.12	981.56	42262.27	8853.69	29569.0	543.1	0.94	0.06	1.43	0.11	4.77	0.30	0.10	4.45	-14.07%	-24.31%	10.25%	2012 - 2013
2013	110.88	1602.47	59453.66	16372.36	47880.0	623.5	0.96	0.04	1.24	0.10	3.63	0.34	0.09	3.49	-67.46%	-9.18%	-58.28%	2013 - 2014
2014	98.95	1831.92	38073.23	10546.64	60198.0	817.6	0.93	0.07	0.63	0.17	3.61	0.18	0.15	3.18				
1970-2014	5.1%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-2014**
1970-1981	21.4%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1970-1981**
1981-1999	-6.5%	N/A	N/A	N/A	N/A	N/A			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**1981-1999**
1999-2014	9.4%	21.7%	23.5%	21.9%	11.5%	26.4%			10.7%	-0.1%	1.3%	9.3%	-0.1%	1.3%	18.8%	3.7%	15.2%	**1999-2014**

Table 37 – Growth Accounting Data for Rosneft, 1999 - 2014

APPENDIX C – LIST OF DATA SOURCES BY COMPANY

Private Oil Companies

BP

BP Amoco Annual Reports & Account 1999

BP Annual Reports & Account 2000

BP Annual Reports & Account 2001

BP Annual Reports & Account 2002

BP Annual Reports & Account 2003

BP Annual Reports & Account 2004

BP Annual Reports & Account 2005

BP Annual Reports & Account 2006

BP Annual Reports & Account 2007

BP Annual Reports & Account 2008

BP Annual Reports & Account 2009

BP Annual Report and Form 20-F 2010

BP Annual Report and Form 20-F 2011

BP Annual Report and Form 20-F 2012

BP Annual Report and Form 20-F 2013

BP Annual Report and Form 20-F 2014

Chevron Corporation

Chevron Annual Report 1984

Chevron Annual Report 1985

Chevron Annual Report 1986

Chevron Annual Report 1987

Chevron Annual Report 1988

Chevron Annual Report 1989

Chevron Annual Report 1990

Chevron Annual Report 1991

Chevron Annual Report 1992

Chevron Annual Report 1993

Chevron Annual Report 1994

Chevron Annual Report 1995

Chevron Annual Report 1996

Chevron Annual Report 1997

Chevron Annual Report 1998

Chevron Annual Report 1999

Chevron Annual Report 2000

Chevron Annual Report 2001

Chevron Annual Report 2002

Chevron Annual Report 2003

Chevron Annual Report 2004

Chevron Annual Report 2005

Chevron Annual Report 2006

Chevron Annual Report 2007

Chevron Annual Report 2008

Chevron Annual Report 2009

Chevron Annual Report 2010

Chevron Annual Report 2011

Chevron Annual Report 2012

Chevron Annual Report 2013

Chevron Annual Report 2014

Exxon Corporation

Exxon Annual Report 1970

Exxon Annual Report 1971

Exxon Annual Report 1972

Exxon Annual Report 1973

Exxon Annual Report 1974

Exxon Annual Report 1975

Exxon Annual Report 1976

Exxon Annual Report 1977

Exxon Annual Report 1978

Exxon Annual Report 1979

Exxon Annual Report 1980

Exxon Annual Report 1981

Exxon Annual Report 1982

Exxon Annual Report 1983

Exxon Annual Report 1984

Exxon Annual Report 1985

Exxon Annual Report 1986

Exxon Annual Report 1987

Exxon Annual Report 1988

Exxon Annual Report 1989

Exxon Annual Report 1990

Exxon Annual Report 1991

Exxon Annual Report 1992

Exxon Annual Report 1993

Exxon Annual Report 1994

Exxon Annual Report 1995

Exxon Annual Report 1996

Exxon Annual Report 1997

Exxon Annual Report 1998

Gulf Oil Corporation

Gulf Annual Report 1970

Gulf Annual Report 1971

Gulf Annual Report 1972

Gulf Annual Report 1973

Gulf Annual Report 1974

Gulf Annual Report 1975

Gulf Annual Report 1976

Gulf Annual Report 1977

Gulf Annual Report 1978

Gulf Annual Report 1979

Gulf Annual Report 1980

Gulf Annual Report 1981

Mobil Oil Corporation

Mobil Annual Report 1970

Mobil Annual Report 1971

Mobil Annual Report 1972

Mobil Annual Report 1973

Mobil Annual Report 1974

Mobil Annual Report 1975

Mobil Annual Report 1976

Mobil Annual Report 1977

Mobil Annual Report 1978

Mobil Annual Report 1979

Mobil Annual Report 1980

Mobil Annual Report 1981

Standard Oil Company of California

Standard Oil Annual Report 1970

Standard Oil Annual Report 1971

Standard Oil Annual Report 1972

Standard Oil Annual Report 1973

Standard Oil Annual Report 1974

Standard Oil Annual Report 1975

Standard Oil Annual Report 1976

Standard Oil Annual Report 1977

Standard Oil Annual Report 1978

Standard Oil Annual Report 1979

Standard Oil Annual Report 1980

Standard Oil Annual Report 1981

Shell

Shell Annual Report 1970

Shell Annual Report 1971

Shell Annual Report 1972

Shell Annual Report 1973

Shell Annual Report 1974

Shell Annual Report 1975

Shell Annual Report 1976

Shell Annual Report 1977

Shell Annual Report 1978

Shell Annual Report 1979

Shell Annual Report 1980

Shell Annual Report 1981

Shell Annual Report 1982

Shell Annual Report 1983

Shell Annual Report 1984

Shell Annual Report 1985

Shell Annual Report 1986

Shell Annual Report 1987

Shell Annual Report 1988

Shell Annual Report 1989

Shell Annual Report 1990

Shell Annual Report 1991

Shell Annual Report 1992

Shell Annual Report 1993

Shell Annual Report 1994

Shell Annual Report 1995

Shell Annual Report 1996

Shell Annual Report 1997

Shell Annual Report 1998

Shell Annual Report 1999

Shell Annual Report 2000

Shell Annual Report 2001

Shell Annual Report 2002

Shell Annual Report 2003

Shell Annual Report 2004

Shell Annual Report 2005

Shell Annual Report 2006

Shell Annual Report & Form 20-F 2007

Shell Annual Report & Form 20-F 2008

Shell Annual Report & Form 20-F 2009

Shell Annual Report & Form 20-F 2010

Shell Annual Report & Form 20-F 2011

Shell Annual Report & Form 20-F 2012

Shell Annual Report & Form 20-F 2013

Shell Annual Report & Form 20-F 2014

Texaco Incorporated

Texaco Annual Report 1970

Texaco Annual Report 1971

Texaco Annual Report 1972

Texaco Annual Report 1973

Texaco Annual Report 1974

Texaco Annual Report 1975

Texaco Annual Report 1976

Texaco Annual Report 1977

Texaco Annual Report 1978

Texaco Annual Report 1979

Texaco Annual Report 1980

Texaco Annual Report 1981

Texaco Annual Report 1982

Texaco Annual Report 1983

Texaco Annual Report 1984

Texaco Annual Report 1985

Texaco Annual Report 1986

Texaco Annual Report 1987

Texaco Annual Report 1988

Texaco Annual Report 1989

Texaco Annual Report 1990

Texaco Annual Report 1991

Texaco Annual Report 1992

Texaco Annual Report 1993

Texaco Annual Report 1994

Texaco Annual Report 1995

Texaco Annual Report 1996

Texaco Annual Report 1997

Texaco Annual Report 1998

Texaco Annual Report 1999

Gazprom

Gazprom Financial Statement 2001

Gazprom Annual Report 2002

Gazprom Annual Report 2003

Gazprom Annual Report 2004

Gazprom Annual Report 2005

Gazprom Annual Report 2006

Gazprom Annual Report 2007

Gazprom Annual Report 2008

Gazprom Annual Report 2009

Gazprom Annual Report 2010

Gazprom Annual Report 2011

Gazprom Annual Report 2012

Gazprom Annual Report 2013

Gazprom Annual Report 2014

Petrobras

Petrobras Annual Report 2001

Petrobras Annual Report 2002

Petrobras Annual Report 2003

Petrobras Annual Report 2004

Petrobras Annual Report 2005

Petrobras Annual Report 2006

Petrobras Annual Report 2007

Petrobras Annual Report 2008

Petrobras Annual Report 2009

Petrobras Annual Report 2010

Petrobras Annual Report 2011

Petrobras Annual Report 2012

Petrobras Annual Report 2013

Petrobras Annual Report 2014

PetroChina

PetroChina Form F-20 2001

PetroChina Form F-20 2002

PetroChina Form F-20 2003

PetroChina Form F-20 2004

PetroChina Form F-20 2005

PetroChina Form F-20 2006

PetroChina Form F-20 2007

PetroChina Form F-20 2008

PetroChina Form F-20 2009

PetroChina Form F-20 2010

PetroChina Form F-20 2011

PetroChina Form F-20 2012

PetroChina Form F-20 2013

PetroChina Form F-20 2014

Rosneft

Rosneft Annual Report 2001

Rosneft Annual Report 2002

Rosneft Annual Report 2003

Rosneft Annual Report 2004

Rosneft Annual Report 2005

Rosneft Annual Report 2006

Rosneft Annual Report 2007

Rosneft Annual Report 2008

Rosneft Annual Report 2009

Rosneft Annual Report 2010

Rosneft Annual Report 2011

Rosneft Annual Report 2012

Rosneft Annual Report 2013

Rosneft Annual Report 2014

Sources

Most recent financial statements - Individual company's' investor pages

BP: http://www.bp.com/en/global/corporate/investors/results-and-reporting.html

ExxonMobil: http://ir.exxonmobil.com/phoenix.zhtml?c=115024&p=irol-publanding

Chevron: http://www.chevron.com/investors/financial-information

Shell: http://www.shell.com/investors/financial-reporting.html

Gazprom: http://www.gazprom.com/investors/disclosure/reports/

Rosneft: http://www.rosneft.com/Investors/results_and_presentations/

Petrobras: http://www.investidorpetrobras.com.br/en/financial-results#topo

PetroChina: http://www.petrochina.com.cn/ptr/ndbg/dqbg_list.shtml

Legacy financial statements - ProQuest

www.ProQuest.com (Restricted access, accessible through MIT certificate).

www.thomsonone.com (Restricted access, accessible through MIT certificate).