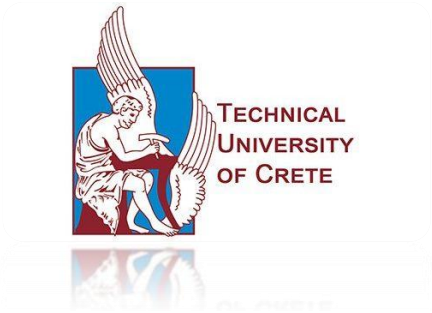

TECHNICAL UNIVERSITY OF CRETE
SCHOOL OF MINERAL RESOURCES ENGINEERING
MSc. IN PETROLEUM ENGINEERING

ERRORS IN CRUDE OIL PRICE FORECASTING ON SHORT-TERM BASIS

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Submission date:	**Jan 2019**
Location:	**Chania - Greece.**

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DEDICATION:

I dedicate this thesis, my success and my efforts to the soul of the only great man of my life who inspired me, loved me unconditionally and worked hard to make me the man who I am today, I dedicate this thesis to the man who granted me the opportunity of a good life in his presence but also made sure that I have the necessary means of success and comfort after he left, I dedicate this thesis to the man who watches me from heaven and I wish I could make him proud as much as I wish I could succeed to make his soul smile today, I dedicate this thesis to the soul of my father ***Rabah Al Alami…***

PREFACE AND ACKNOWLEDGEMENTS

The topic of my thesis is about the Most Common Errors in Short term forecasting of crude oil prices, I decided to investigate this area for two reasons; First, as an individual coming from the Middle East, and also throughout my professional previous experience as an industrial Engineer and a business consultant in which I have been introduced to various models covering wide spectrum of activities in manufacturing & production, I have realized that Oil & Energy have high impacts on the quality of our lives, and that Earth had given us great sources to convert into opportunities to benefit from.

Secondly, I strongly believe that the topic of this thesis integrated with the knowledge that I have already gained through the courses of this master's program will hugely assist me in empowering myself with the scientific knowledge, technical skills & tools to be able to penetrate the oil industry via opening me a gate to various excellent job opportunities in the field of Petroleum Economics which is a field that I have desired to be part of for a long time especially in the Gulf Region or even worldwide.

I also see in this thesis and this master's degree as an essential step towards my next PhD where I can join the field of Academia, to inspire the younger generation and help them become aware of the Oil industry within my home country.

I was always impressed by the beauty contest of Petroleum Economics throughout my study and with the exceptional way *Prof. Moustakis* had presented this course to us throughout his lectures and I believe that oil prices forecasting investigation, will be of a valuable importance to enlighten to the applications of forecasting approaches in Oil Industry & its limitations.

Concerning the research procedure, I am able to say that this thesis was a unique experience. As it gave me the opportunity to be engaged into a research area that I had limited previous knowledge. In fact, this made the whole thesis more challenging. *However*, "No Pain-No Gain". But my belief is that I learned something new, given the fact that one of the topics that I touched is forecasting, I feel that I gained insights which can be of value added for the future.

Of course, this work at hand would not have been completed without the help of many people who assisted me, first and foremost I am thankful to my *Mother* and to my *family members and to the important persons in my life*, as their support through my University endeavors was beyond than I could ask for. *Next,* I would like to thank my great supervisor; *Prof. Vasilis Moustakis* for his efforts, patience, understanding, professional guidance and support through the writing process, Prof Moustakis has granted me an exceptional experience that will last for years to come. Additionally, I would like to say that I am heavily indebted to *Prof. Nikos Pasadakis*, who have given me the chance to take part in this program and to the entire faculty members who have significantly made a huge difference and spent great effort to ensure the highest standards and best quality for a wonderful and complete learning experience. *Finally*, I would like to thank all the people who provided me with feedback concerning this thesis.

ABSTRACT

This thesis forecasts short-term crude oil price changes, based on several time-series forecasting models. The crude oil prices which are used are monthly crude oil spot prices quoted in US Dollar of a benchmark consisting of Brent, Dubai & West Texas Intermediate "WTI" equally weighed. The numerical input data for forecasting are monthly crude oil prices of the mentioned benchmark for 30 year between [1988-2018].

This thesis also addresses a careful qualitative and descriptive analysis of crude oil prices between 1988 & 2018, divided Into 8 periods, each is decided based on significant events that occurred within each period that influence the analysis leading to observable fluctuations in prices.

In this thesis I have used four different approaches for forecasting process of monthly crude oil prices including conventional forecasting approach, inflation-adjusted prices approach, unconventional "month by month" forecasting approach & the unconventional hybrid forecasting approach using the moving average and exponential smoothing models. The accuracy of all generated models was evaluated using different error measures including "MAD, MSE & MAPE", to investigate the capability of generated forecasting model in accurately forecasting the monthly crude spot prices.

Afterwards, a numerical comparison of the unconventional hybrid approach & the month by month approach to the conventional and inflation-adjusted approach is made. The error estimates of the different forecasting models show that unconventional approaches tend to provide significant improvement in forecasting results and can generate larger reductions in error values than those generated by conventional and/or the inflation-adjusted approaches.

My understanding for forecasting of crude oil prices on short term basis is that using direct numerical forecasting methods solely will generate models and forecasted results that suffer large errors deviating than those real ones, the sensitivity of oil industry and oil prices to external events and factors make the process of forecasting uneasy, and therefore a researcher must find ways that both can combine the numerical methods but with twists and may be combine different approaches to enhance these results. Additionally, a qualitative judgment of experts can play a good role while forecasting by watching and monitoring the global trend, regional events, political situations, environmental aspects, presence of technological advancements, seasonality and consumer behavior, then take into account all these factors while forecasting specially that oil prices are heavily impacted by global oil supply & demand.

CHAPTER –1: Introduction

1.1 Oil History in few lines:

Oil was formed hundreds of thousands years ago from the prehistoric plant and animals. It is believed that hydrocarbon formed by the thermal maturation of organic matter buried deep in earth. Over the millions of years under extreme pressure and high temperature these organic matter converted to hydrocarbons consisting of oil and gas. Hydrocarbons are present in the variety of forms, including; *Koregen, Asphalt, Crude Oil, Natural Gas, Condensates, and Coal in solid form.*

Petroleum and derivatives such as asphalt have been known and used for almost 6000 years and there is evidence of use of asphalt in building more than 600 years ago. Modern petroleum refining began in 1859 with discovery of petroleum in Pennsylvania and subsequent commercialization. The exploration of petroleum originated in the latter part of the nineteenth century.

Crude oil was first discovered and developed during the Industrial Revolution, and its industrial uses were first developed in the 19th century. Newly invented machines revolutionized the way we do work, and they depended on these resources to run.

Today, the world's economy is largely dependent on fossil fuels such as crude oil, and the demand for these resources often spark political unrest, since a small number of countries control the largest reservoirs. Like any industry, *supply and demand* heavily affects the prices and profitability of crude oil. *The United States, Saudi Arabia, and Russia* are the leading producers of oil in the world**.** [(1)]

1.2 What is Crude Oil?

Crude oil is a naturally occurring, unrefined petroleum product composed of hydrocarbon deposits and other organic materials. A type of fossil fuel, crude oil can be refined to produce usable products such as gasoline, diesel and various forms of petrochemicals. [(1)]

Crude oil has ranging viscosity and can vary in color and appearance from yellow to brownish green mobile liquid to black viscous and sometimes semisolid depending on its hydrocarbon composition.

Crude oil consists of mainly carbon **(83-87%)** and hydrogen **(12-14%**) having complex hydrocarbon mixture like *Paraffins, Naphthenes, Aromatic Hydrocarbons, Gaseous Hydrocarbons (from CH_4 to C_4H_{10}).* [(2)]

1.3 Crude Oil Major Benchmarks:[3]

The most commonly quoted benchmarks of Crude Oil are the same ones that have been under study throughout my thesis and they are the following; *please see assumptions in chapter-2*.

- **West Texas Intermediate (WTI):** WTI is priced out of the Cushing, Oklahoma storage hub and represents the North American benchmark for light, sweet crude.
- **Brent:** Brent is the international benchmark, light/sweet seaborne crude priced out of Sullom Voe, Scotland
- **Dubai Crude Oil**: Dubai Crude along with Brent and WTI trade on the Chicago Mercantile Exchange which is currently a part of the CME Group.

1.4 Breaking Down Crude Oil:

Crude oil is typically obtained through drilling, where it is usually found alongside other resources, such as natural gas and saline water, the processing of Petroleum from drilling is when petroleum is drilled and brought to the surface, the pressure drops resulting in separation of gases from the crude oil.

Further processing of crude involves separation of water and oil and salt, it is then refined and processed into a variety of forms, such as Gasoline, Kerosene and Asphalt, and sold to consumers. Distillation, the process by which oil is heated and separated in different components, is the first stage in refining**.**

1.5 Oil Pricing in few lines:

Several hundred streams of marketable crude are produced around the world every day. No two streams are exactly alike. Variances in grade and quality affect the selling price of every barrel, most crude streams are priced in reference to a major benchmark, adjusted for grade, quality and market access

The volatile nature of oil prices tends to attract the attention of many analysts. Oil price fluctuations are of particular importance since they directly influence decisions regarding production costs, investment opportunities, future economic growth and planning.

However, oil can also be viewed as a financial asset rather than just a consumption commodity. Since the deregulation of the oil markets during the decade of 1970, oil is traded on exchange markets and investors can buy and sell it, having pure financial objectives. Some of the motives underlying the investments in oil contracts are usually *the potential profits from future price changes*. Consequently, the need for a sound model that can capture the changes of oil prices is important for investment decisions. [4]

More importantly, oil prices reflect a specific point of sale, which has an even greater impact on its market value, in the following chapter I will discuss the major definitions of all expressions required to understand the context of this thesis, and I will also provide several number of assumptions that have been made throughout, analyzing and writing this thesis. [5]

Oil prices vary based on grade *(Sweet, Intermediate or Sour*) and location [6] i.e. how easy it is to get it from the field to the refinery and also based on supply in that area, the below is a real life example that shows how such a grade and location may affect oil price, All oil prices in the example reflects prices in $US for March-2013.

Example 1:

How Grade & Location Impact Crude Oil Price

"West Texas" which is a kind of crude oil, alone has three different prices,

- West Texas Intermediate - Area #1, **$90.50.**
- West Texas Intermediate - All Other Areas, **$91.00**,
- West Texas Sour*****: **$83.05.**
- South Texas Sour****** : **$79.00**

***** West Texas Sour is worse quality than West Texas Intermediate (requires more refining), that's why it is sold cheaper than WTI.

****** South Texas Sour only brings is sold even cheaper at $79.00 presumably because it is more difficult to transport than West Texas Sour due to a lack of pipeline capacity.

1.6 Crude Oil Quality:

Crudes of a similar specification are considered fungible which means that each barrel is largely interchangeable, regardless of origin. Although refineries have different tolerances for the types of crude they can process, they also have the ability to blend different grades to meet their desired feedstock specifications. That means oil prices largely rise and fall together, regardless of quality or marketability, ***this is why quality doesn't matter so much***[7]

1.7 Crude Oil Related Facts:

1. **There are a number of other popular crude benchmarks that also trade on the CME, including Russia's Urals and Canada's Western Canadian Select**
2. **About two thirds of the world's internationally traded crudes are priced in reference to Brent, largely outside of North America and outside of OPEC.**
3. **About one-fifth of the world's oil supply, particularly from China and the Middle East, does not trade on open markets. Instead, prices are negotiated between buyers and sellers.**
4. **It is not uncommon for state-owned oil producers to offer discounts or incentives to entice buyers from a specific region to gain market share.**

Figure -1: Crude Oil Interesting Facts

CHAPTER -2: Definitions & Assumptions

This thesis has been written in a way trying to allow the reader to understand and comprehend all the elements of its topic in a simple yet a scientific manner, therefore in this chapter, I have included some major scientific definition, and set up the basic assumptions that are followed throughout this investigation on hand which will grant the reader a better opportunity to facilitate a better understanding of the contents of this thesis.

2.1 Major Definitions

Figure-2 provides the basic definitions and differentiates between the general terms *of* **spot prices and future prices**; additionally **Figure-2** provides extra definitions of spot prices and future prices in relation to crude oil, it is important to mention that *all quoted prices within this thesis reflect spot prices only.*

Figure -2: Spot Prices VS. Future Prices

Example 2 reflects the predictions of oil market by comparing Spot prices to Future prices of Oil.

Example 2: Oil Market Predictions Vs Spot/Future Prices
If the futures prices are higher than the spot prices, this usually means that purchasers anticipate the market will improve, so they are willing to pay a premium for oil to be delivered at a future date.
If the futures prices are lower than the spot prices, this means that buyers expect the market to deteriorate.

2.2 Oil Market Types [9] :

There *are two* terms used to describe the relationship between expected future spot prices and actual futures prices, explained as follows **in figure-3:**

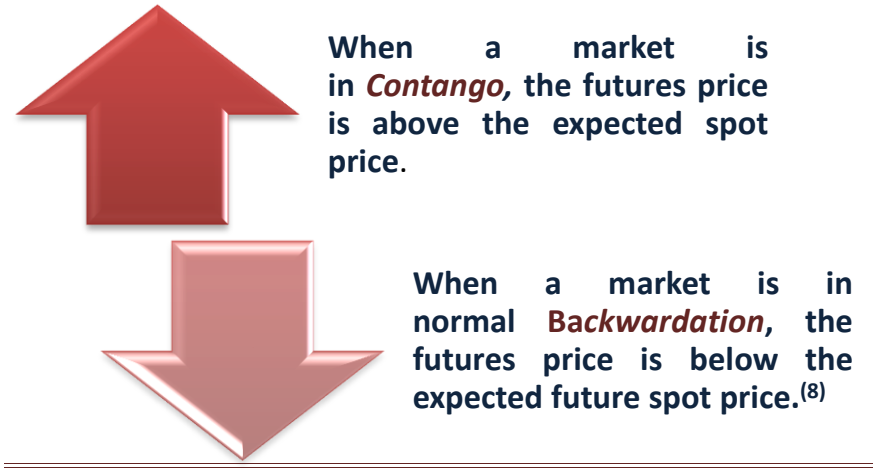


Figure -3: Oil Market Types

2.3 Further Relevant Definitions:

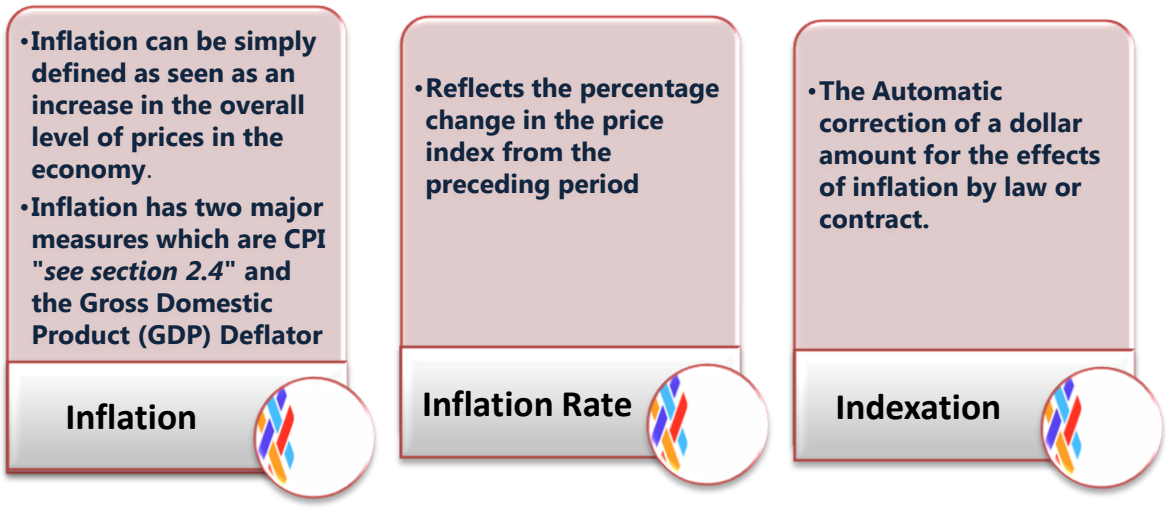


Figure -4: Inflation, Inflation Rate & Indexation Definitions.[8]

2.4 Consumer Price Index:

*Consumer price indices (**CPIs**)* are index numbers that measure changes in the prices of goods and services purchased or otherwise acquired by households, which households use directly, or indirectly, to satisfy their own needs and wants. Such changes affect the real purchasing power of consumers' incomes and their welfare. ***See table-2***, which represents all CPI Values for US-Dollar in USA, for the period of Study [1988-2018]. **(8)**

2.5 Major Assumptions:

In the context of this thesis, I have made basic 5 assumptions throughout the whole thesis, Figure-1 Summarizes the first four assumptions.

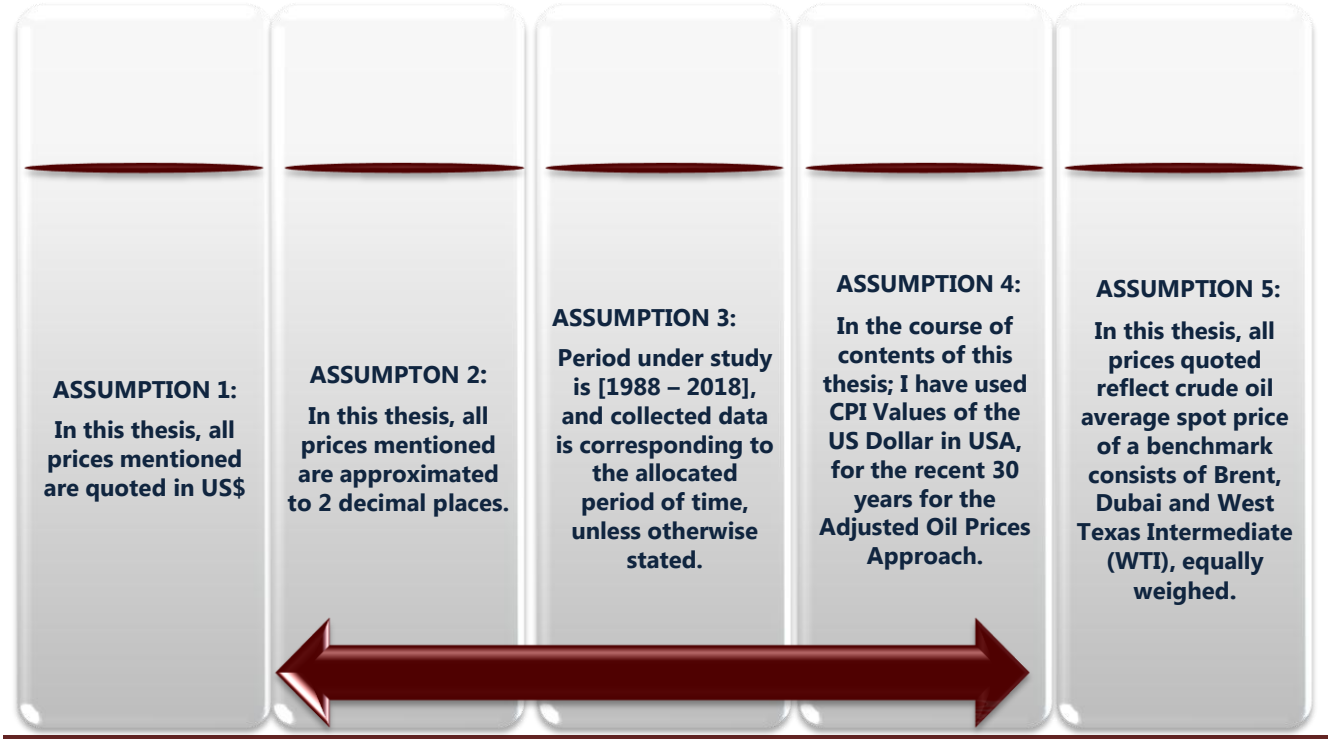


Figure -5: Thesis Assumptions [1 – 5]

2.5.1 Calculations of Nominal Monthly Spot Prices of Crude Oil :

- In this thesis, according to assumption-5; all prices represent the crude oil spot price of a ***benchmark consisting of Brent, WTI*** [(A)] ***& Dubai*** [(B)] ***equally weighed***. Therefore; In order to explain further the meaning of *Assumption 5*, I have prepared Example-3 below that clearly and simply shows the approach for calculating those average monthly spot prices, which are referred to throughout this thesis as ***Nominal Monthly Spot Prices***.

Example-3: Calculations of Nominal Monthly Spot Prices of Crude Oil

For June 2018, the following Monthly Average Spot Price of the 3 types of Crude Oil In this study were recorded as follows:

- West Texas Intermediate: $67.87/bbl
- Brent Crude Oil : $74.41/bbl
- Dubai Crude Oil: $73.22/bbl

Then using those 3 values, the quoted **Nominal Monthly Spot Price** within this thesis for June-2018 is calculated as follows:

= $(67.87 + 74.41 + 73.66) / 3

= $71.83

Similarly; for all the months within the period of study [1988-2018], the crude oil average spot prices (Nominal Prices) were calculated.

2.5.2 Table -1 : Nominal Monthly Spot Prices of Crude Oil in $US [1988-2018] :

- I have gathered the *calculated Nominal Monthly Spot Prices of Crude Oil* **in Table -1**. *See Next* Page, this table summarizes clearly all the calculations of monthly nominal prices for the period under study **[1988-2018]** according to the above mentioned assumption/approach.

- These figures "**Nominal Monthly Spot Prices"**. Are used as my *Data inputs* for all forecasting models presented in this thesis.

- For example to read any value inside **Table-1,** the reader must simply search for the year which he/she is interested in the first column, then horizontally follow the value that represents the month he/she is interested in. ***e.g.*** to search the nominal monthly price for Nov – 2006, then the correct value is **$58.14.** While if the reader is interested in finding the nominal price for April – 2011, then the correct value is **$116.24**.

- Additionally, **Table-1,** provides an additional two interesting values which are:
    - **A.** *The annual average crude oil price* for all years between [1988-2018], relevant data to this info can be found in the most right column of the table. ***e.g.*** The average annual price of crude for year 2017 is **$52.80**
    - **B.** *The 30 –Years monthly average price of crude*, relevant data to this piece of information can be found in the most bottom row. ***e.g.***, the value **$47.70** found in last row, represents the average price of crude for **JUNE** for 30 years between [1988-2018]

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.10	12.18	12.53	14.65	13.12
1989	16.48	16.35	18.03	19.20	18.02	17.63	17.67	16.88	17.67	18.42	18.37	19.35	17.84
1990	20.35	19.60	18.22	16.55	16.58	15.27	17.17	26.40	32.70	34.50	31.08	26.13	22.88
1991	22.58	18.13	18.07	18.47	18.82	17.93	19.05	19.37	20.05	21.47	20.77	17.75	19.37
1992	17.38	17.62	17.45	18.63	19.50	20.83	20.17	19.62	20.15	20.08	18.88	17.93	19.02
1993	17.22	18.17	18.47	18.43	18.17	17.47	16.32	16.48	15.90	16.52	15.20	13.77	16.84
1994	14.13	13.78	13.62	15.08	16.28	17.17	17.88	17.00	16.20	16.47	17.08	15.94	15.89
1995	16.90	17.42	17.35	18.65	18.42	17.36	16.08	16.47	16.82	16.12	16.74	17.87	17.18
1996	17.80	17.70	19.40	20.66	19.06	18.51	19.59	20.44	22.26	23.61	22.39	23.62	20.42
1997	23.23	20.42	19.33	17.88	19.37	17.92	18.33	18.70	18.66	20.04	19.09	17.09	19.17
1998	15.00	14.10	13.12	13.50	14.03	12.48	12.70	12.49	13.80	13.26	11.88	10.41	13.06
1999	11.44	10.75	13.17	15.87	16.06	16.39	18.99	20.27	22.70	21.95	24.16	25.10	18.07
2000	25.31	27.22	27.49	23.47	27.19	29.62	28.18	29.26	32.08	31.40	32.33	25.20	28.23
2001	25.96	27.24	25.02	25.72	27.55	26.97	24.80	25.82	25.21	20.73	18.69	18.52	24.35
2002	19.15	19.98	23.64	25.43	25.67	24.49	25.75	26.78	28.28	27.53	24.54	27.89	24.93
2003	30.75	32.88	30.36	25.56	26.06	27.92	28.59	29.68	26.88	29.01	29.12	29.97	28.90
2004	31.37	31.33	33.67	33.71	37.56	35.54	37.89	42.08	41.60	46.88	42.13	39.04	37.73
2005	42.97	44.82	50.94	50.64	47.83	53.89	56.37	61.89	61.69	58.19	55.04	56.43	53.39
2006	62.46	59.70	60.93	67.97	68.68	68.29	72.45	71.81	62.12	57.91	58.14	60.99	64.29
2007	53.52	57.56	60.60	65.06	65.16	68.19	73.60	70.13	76.76	81.97	91.34	89.52	71.12
2008	90.69	93.39	101.84	108.76	122.63	131.52	132.83	114.57	99.66	72.69	53.97	41.34	96.99
2009	43.86	41.84	46.65	50.28	58.15	69.15	64.67	71.63	68.35	74.08	77.55	74.88	61.76
2010	77.12	74.76	79.30	84.18	75.62	74.73	74.58	75.83	76.12	81.72	84.53	90.01	79.04
2011	92.69	97.91	108.65	116.24	108.07	105.85	107.92	100.49	100.82	99.85	105.41	104.23	104.01
2012	107.07	112.69	117.79	113.67	104.09	90.73	96.75	105.27	106.28	103.41	101.17	101.19	105.01
2013	105.10	107.64	102.52	98.85	99.37	99.74	105.26	108.16	108.76	105.43	102.63	105.48	104.08
2014	102.10	104.83	104.04	104.87	105.71	108.37	105.23	100.05	95.85	86.08	76.99	60.70	96.24
2015	47.11	54.79	52.83	57.54	62.51	61.31	54.34	45.69	46.28	46.96	43.11	36.57	50.75
2016	29.78	31.03	37.34	40.75	45.94	47.69	44.13	44.88	45.04	49.29	45.26	52.62	42.81
2017	53.59	54.35	50.90	52.16	49.89	46.17	47.66	49.94	52.95	54.92	59.93	61.19	52.80
2018	66.23	63.46	64.17	68.79	73.43	71.98	72.67	71.08	75.36	76.73	62.32	53.96	68.35
Monthly Average	43.31	44.05	45.50	46.89	47.51	47.70	48.25	48.31	47.10	46.43	44.92	43.53	

Table-1: Nominal Monthly Crude Oil Spot Prices in $US for [1988-2018]

CHAPTER – 3: Inflation-Adjusted Prices Approach

3.1 Introduction to the inflation-Adjusted Approach

Consumer price indices can be intended to measure the following two objectives, without any conflict between these two objectives.

i. **The rate of price inflation** *"See figure-4"*
ii. **Changes in cost of living:** *that is, changes in the amounts that the households need to spend in order to maintain their standard of living.*

In practice, most CPIs are calculated as weighted averages of the percentage price changes for a specified set, or ''basket'', of consumer products, the weights reflecting their relative importance in household consumption in some period. **(8)**

In the course of contents of this thesis; I have used ***CPI Values*** for the US Dollar for the recent 30 years [1988 – 2018] in United States of America, in order to adjust all monthly prices of crude oil to the current year of 2018 *due to inflation solely, I have used then those Adjusted Spot Prices as an input to different forecasting* models. ***Please see CH-6.***

Table-2, Correlates the Years throughout year 1988 – 2018, to their corresponding CPI's values, according to the US Dollar values, Source is *Bureau of Labor Statistics* of USA.

Table-2: CPI Values [1988-2018] (C)

Year	CPI	Year	CPI	Year	CPI	Year	CPI
1988	118.30	1989	124.00	1990	130.70	1991	136.20
1992	140.30	1993	144.50	1994	148.20	1995	152.40
1996	156.90	1997	160.50	1998	163.00	1999	166.60
2000	172.20	2001	177.10	2002	179.90	2003	184.00
2004	188.90	2005	195.30	2006	201.60	2007	207.30
2008	215.30	2009	214.50	2010	218.10	2011	224.90
2012	229.60	2013	233.00	2014	236.70	2015	237.00
2016	240.00	2017	245.10	2018	252.10		

3.2 Numerical Calculations of Inflation-Adjusted Oil Prices :

Follows is an example that illustrates the methodology, and the formula I have used to calculate the adjusted price of oil for every monthly value of price oil, for the recent 30 years [1988 - 2017] to the current year 2018.

Example-4: Numerical Calculations of Inflation-Adjusted Oil Prices

Assuming the Average price of Crude oil in 1989 was $17.14/bbl, and I am interested to calculate the equivalent price of the same bbl in 2017 "due to inflation", then in order to do so, I will need the following piece of information :

- Average Crude Oil Price $/bbl in 1989 : **$17.84**
- CPI for US Dollar in 2017 :**245.10** - "Value is Taken from **Table-1**"
- CPI for US Dollar in 1989: **124.00** - "Value is Taken from **Table-1**"

Additionally, I will need to use the following formula,

$$\text{Adjusted Price}_{@\ \text{Year}_K} = [\text{CPI}_{@\ \text{Year}_K} / \text{CPI}_{@\ \text{Year}_J}] * \text{Price}_{@\ \text{Year}_J}$$

$$= [245.1/124] * \$17.84$$

$$= \$35.27$$

Similarly, by following this formula I can adjust all prices of crude oil in **$US /bbl** from any month within the Period under study [1988 - 2018] , to the current year 2018, by simply using the **value of CPI_{2018}**, this will allow me to see the influence of inflation rates solely on the crude oil prices nowadays.

3.3 Table-3: 2018 Inflation - Adjusted Monthly Crude Oil Prices in $US for [1988-2018]

- I have gathered the calculated *Inflation-Adjusted Monthly Spot Prices of Crude Oil* in **Table -3.** See Next Page, **Table-3;** Summarizes clearly 2018 Inflation-Adjusted Monthly Crude Oil Prices in $US for the study period [1988-2018] according to the above mentioned calculation in example-4.
- For example to read any value inside **Table-3,** the reader must simply follow the same exact approach for reading **Table-1** above.
- To help the reader understand the meaning of any number in any cell In **Table-3**, let me take an example of the price quoted for March-2004, which reads **$44.93**, this number represents the crude oil price of our benchmark in today's US Dollar value, and in other words the price you would have actually paid at the time.
- Please also note that the nominal spot price of the same benchmark for the same month March-2004 is **$33.67,** *Quoted from* **Table-1,** the reader can also note that the adjusted price is always higher than the nominal one that is for sure due to inflation of US Dollar value, through the years
- In other words, *$33.67 in 2004 is equivalent in purchasing power to $44.93 in 2018*, a difference of $11.26 over the span of 14 years.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.92	25.96	26.70	31.22	**27.95**
1989	33.50	33.24	36.66	39.03	36.64	35.84	35.92	34.32	35.92	37.45	37.35	39.34	**36.27**
1990	39.25	37.81	35.14	31.92	31.98	29.45	33.12	50.92	63.07	66.55	59.95	50.40	**44.13**
1991	41.79	33.56	33.45	34.19	34.83	33.19	35.26	35.85	37.11	39.74	38.44	32.85	**35.86**
1992	31.23	31.66	31.36	33.48	35.04	37.43	36.24	35.25	36.21	36.08	33.92	32.22	**34.18**
1993	30.04	31.70	32.22	32.15	31.70	30.48	28.47	28.75	27.74	28.82	26.52	24.02	**29.39**
1994	24.04	23.44	23.17	25.65	27.69	29.21	30.42	28.92	27.56	28.02	29.05	27.12	**27.02**
1995	27.96	28.82	28.70	30.85	30.47	28.72	26.60	27.24	27.82	26.67	27.69	29.56	**28.42**
1996	28.60	28.44	31.17	33.20	30.62	29.74	31.48	32.84	35.77	37.94	35.98	37.95	**32.81**
1997	36.49	32.07	30.36	28.08	30.42	28.15	28.79	29.37	29.31	31.48	29.98	26.84	**30.11**
1998	23.20	21.81	20.29	20.88	21.70	19.30	19.64	19.32	21.34	20.51	18.37	16.10	**20.21**
1999	17.31	16.27	19.93	24.01	24.30	24.80	28.74	30.67	34.35	33.21	36.56	37.98	**27.34**
2000	37.05	39.85	40.25	34.36	39.81	43.36	41.26	42.84	46.96	45.97	47.33	36.89	**41.33**
2001	36.95	38.78	35.62	36.61	39.22	38.39	35.30	36.75	35.89	29.51	26.61	26.36	**34.67**
2002	26.84	28.00	33.13	35.64	35.97	34.32	36.08	37.53	39.63	38.58	34.39	39.08	**34.93**
2003	42.13	45.05	41.60	35.02	35.71	38.25	39.17	40.66	36.83	39.75	39.90	41.06	**39.59**
2004	41.87	41.81	44.93	44.99	50.13	47.43	50.57	56.16	55.52	62.56	56.23	52.10	**50.36**
2005	55.47	57.86	65.76	65.37	61.74	69.56	72.76	79.89	79.63	75.11	71.05	72.84	**68.92**
2006	78.11	74.65	76.19	85.00	85.88	85.40	90.60	89.80	77.68	72.42	72.70	76.27	**80.39**
2007	65.09	70.00	73.70	79.12	79.24	82.93	89.51	85.29	93.35	99.68	111.08	108.87	**86.49**
2008	106.19	109.35	119.25	127.35	143.59	154.00	155.53	134.15	116.69	85.11	63.19	48.41	**113.57**
2009	51.55	49.17	54.83	59.09	68.34	81.27	76.01	84.19	80.33	87.07	91.14	88.01	**72.58**
2010	89.14	86.41	91.66	97.30	87.41	86.38	86.21	87.65	87.99	94.46	97.71	104.04	**91.36**
2011	103.90	109.75	121.79	130.30	121.14	118.65	120.97	112.64	113.01	111.93	118.16	116.84	**116.59**
2012	117.56	123.73	129.33	124.81	114.29	99.62	106.23	115.59	116.70	113.54	111.08	111.11	**115.30**
2013	113.72	116.46	110.92	106.95	107.52	107.92	113.89	117.03	117.68	114.07	111.04	114.13	**112.61**
2014	108.74	111.65	110.81	111.69	112.59	115.42	112.08	106.56	102.09	91.68	82.00	64.65	**102.50**
2015	50.11	58.28	56.20	61.21	66.49	65.22	57.80	48.60	49.23	49.95	45.86	38.90	**53.99**
2016	31.28	32.59	39.22	42.80	48.26	50.09	46.35	47.14	47.31	51.78	47.54	55.27	**44.97**
2017	55.12	55.90	52.35	53.65	51.31	47.49	49.02	51.37	54.46	56.49	61.64	62.94	**54.31**
2018	66.23	63.46	64.17	68.79	73.43	71.98	72.67	71.08	75.36	76.73	62.32	53.96	**68.35**
Monthly Average	**53.68**	**54.39**	**56.14**	**57.78**	**58.58**	**58.80**	**59.56**	**59.95**	**59.05**	**58.35**	**56.50**	**54.75**	

Table-3: 2018 Inflation- Adjusted Monthly Crude Oil Prices in $US for [1988-2018]

- ***Figure - 6*** below shows a chart that presents **Monthly Average Crude Oil Price** and **Inflation Adjusted Crude Oil Prices** in chart form.
- The **Red line** on the chart below shows oil prices adjusted for inflation in July 2017 dollars.
- The **Black line** indicates the nominal price (in other words the price you would have actually paid for a barrel of oil at the time).
- The **Blue Line** indicates the Average since **1946.**
- The **Green Line** indicates the Average since **1980.**
- The **Brown Line** indicates the Average since **2000.**

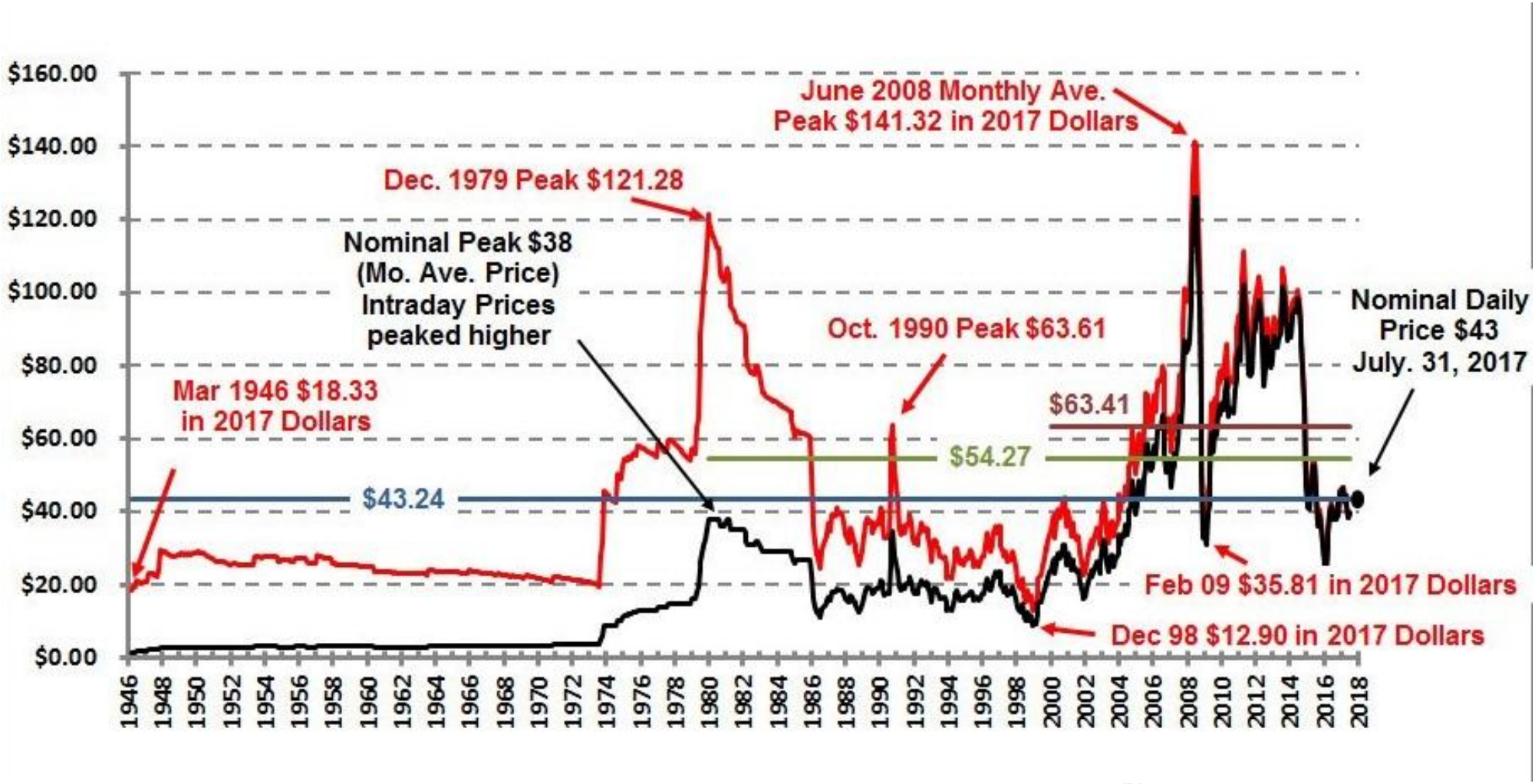


Figure -6: 2018- Adjusted Monthly Crude Oil Prices in $US for [1946-2017] [(D)]

Figure -6 Analysis:

Starting in **1946** the inflation adjusted price of oil was **$18.33** per barrel. After climbing sharply for a couple of years, it stayed relatively steady and in fact steadily declined in inflation adjusted terms until 1973. From there on prices exploded until **1980** when the bubble burst and prices returned to "normal" however during eighties and on, prices were much more volatile from then on, *this is the period of interest throughout my thesis.*

I can observe that the major peaks occurred in **December 1979** at around **$121**, also in, October **1990** at approximately **$66**, and for sure **July 2008** at almost **$154**, please remind that those prices are the inflation-adjusted prices to **2017** according to the chart.

Another very interesting item to note is that the inflation adjusted average price has been increasing with time see **table-4**:

Since Year	Average
1946 - 2017	$43.24
1980 - 2018	$54.27
1990 - 2018	$58.40
2000 -2017	$63.41
2010 - 2018	$84.59

Table - 4:

Adjusted crude oil prices long term Averages in $US for different periods

Table-4 demonstrates clearly that the average for the entire period from **1946** to present is **$43.24** but the average since **1980** is **$54.27** and the average since **1990** is **$58.40**, additionally since **2000** the average is **$63.41**, and finally to since **2010** it reached up to **$84.59**, I might think of this increase as a result of increased extraction costs as it becomes harder and more costly to find and requires much greater technology to get to it.

The absolute peak occurred in **July 2008** with the highest inflation adjusted monthly average crude oil price of **$154.32** / barrel, directly from there we see one of the sharpest drops in history in only six months for the prices to drop to **$48.41** in **Dec of the same year 2008.**

In nominal terms, we see a fall from **$132.83 in June 2008** to **$41.34 in February 2009** but by **June 2009** oil is back to **$69.15 and by April of 2011** it was back to **$116.24**.

The average for the year **2011, 2012** and **2013** was almost stable and oscillating between **$104** and **$105**. *Again,* The first **8 months of 2014** had an average price again close to **$104.40**, but December's sharp drop brought the annual average price down to **$96.60**. The average nominal price for **2015, 2016** & **2017** were **$50.75, $42.81** & **$52.80** respectively, actually the last 3 years showed a semi steady pattern in prices, except for the winter period of 2015-2016, when prices really drop to as low as **$29. 87** demonstrating a drop of **30-35%** less from the annual average.

As we can see from the chart and the corresponding two tables, In the **2008** run-up, the annual average price for all of **2008** was nominally **$96.99** and fell much lower in **2009** to an average of **$61.76**, So on an annual average basis, prices were very close to the peak of **1979** but slightly below, *yet* on *a monthly inflation adjusted basis 2008 prices exceeded 1979 prices but for a shorter duration.*

Also, as we can observe from figure-1, inflation adjusted prices were higher in 2008 than they were in either 2011 or 1980, the only difference that in 1980 the prices stair-stepped down rather than falling sharply as they did in 2008.

Interestingly, prices fell so low by **1998** that by **December** on an inflation-adjusted basis they reached only about **88%** of what they were in **1946.** The inflation adjusted price of a barrel of oil in **1946** was **$18.03** while in December of **1998** it was only **$16.10**.

CHAPTER – 4: Finding, Trends & Analysis "Oil Prices":

4.1 Introduction to Oil Prices:

Oil prices through modern economy, have been one of the most monitored trends during the twenty-first century,, Oil prices suffers and shows seasonality, spikes and they are largely volatile, as a result, in order to give a better understanding of the oil prices, it could be good to illustrate a graph with the oil prices of the first four assumptions used throughout this thesis.

Figure – 7 presents in a clear manner the daily fluctuation of crude oil for 3 different types Benchmark (WTI, Brent & Dubai), for the period range begins from 1988 ends to 2018, According to the assumptions mentioned in **CH-2,** all the prices in the graph are shown in US dollars and are referring to spot prices one month ahead.

Figure- 7: Daily crude oil prices per barrel. "WTI - Dubai - Brent Benchmark". 1988-2018

4.2 Descriptive & Qualitative Graphical Analysis of Oil Prices [1988-2018].

As it can be seen, the oil prices are highly volatile. A peak at the middle of 2008 is observed and then a significant decline causes the prices to reach a level of almost $30 per barrel. However, from this period and up to 2011, oil prices show an increasing trend.

For the purpose of descriptive analysis of the graph, the periods are going to be divided Into 8 periods, the first period will be from 1988 up to 1991, and the final period from 2015 up to 2018, with another 6 periods in between, decided based on significant events that influence the analysis.

4.2.1 Period Range : 1988-1990 :

1988 is the year at which an eight-year war between two major and large producers of oil **"Iraq & Iran"** officially came to an end. The end of this war brought to the world also the end of long period of high prices of crude oil, that lasted between 1980 till 1988, which is the war period between the two countries, the oil price reached a peak of $**120 /bbl** in1980 at the beginning of the war, but in 1988, upon the official declaration of the war end prices of crude oil reached a values close to **$42/bbl.** This is for sure highly related to the **Iraqi-Iranian war** that took place in this period, as both countries are considered major oil producers in the Middle East, and also due to the huge cuts of production and exports that these two countries declared during the war period as well.

Another important event within this period is also connected to Iraq, as in the summer of 1990 the famous **Iraqi Invasion to Kuwait** took place, leading to a new drop in crude oil prices that recorded one of the lowest recorded values reaching close to $15.27/bbl in June-1990, this was also accompanied with cuts of production of oil by Kuwait due to this invasion, which again led the prices to increase at the end of second half of 1990, to a bit more than the double in the span of 4 months.

During 1988 up to the end of 1990, prices of crude oil demonstrate an overall monthly average of $19.32

- The Minimum monthly average oil price was recorded for Oct/1988 with value of $12.18.
- The Maximum Monthly average oil price recorded in Oct/1990 with the value of $34.50
- The range of fluctuation is exactly $26.32 for the entire period on monthly basis.

The following table summarizes the oil prices average fluctuations for the corresponding periods between 1988-1990, it is very obvious that the prices showed a dramatic increasing pattern in the second half of 1990, where average monthly prices of the fourth quarter of 1990 had almost doubled than the second quarter of the same year. Please note that in **Table5**, the symbol **Q** refers to the Quarter of a year.

	Year					
Annual Average ($/bbl)	1988	1989	Q1-1990	Q2-1990	Q3-1990	Q4-1990
	$13.12	$17.84	$19.39	$16.13	$25.42	$30.57

Table – 5: Annual average prices for period between 1988– 1990

4.2.2 Period Range : 1991-End of 1997 :

During 1991 up to the end of 1997, prices of crude oil demonstrate a stable pattern observed, with an overall monthly average of $18.27.

- The Minimum monthly average oil price was recorded for March/1994 with value of $13.62.
- The Maximum Monthly average oil price recorded in Dec/1996 with the value of $23.62
- The range of fluctuation is exactly $10.00 for the entire period on monthly basis.

Yet on Annual Basis, the readings are as follows:

- The Minimum annual average oil price was recorded for 1994 with value of $15.89
- The Maximum annual average oil price recorded in 1996 with the value of $20.42
- The range of fluctuation is exactly $4.53 for the entire period on Annual basis.

	Year						
Annual Average ($/bbl)	1991	1992	1993	1994	1995	1996	1997
	$19.37	$19.02	$16.84	$15.89	$17.18	$20.42	$19.17

Table – 6: Annual average prices for period between 1991 – 1997

Analysis:

This period from 1991 up to the end of 1997, shows one of the most stable periods for the fluctuations of oil prices within the period under study throughout this thesis.

i. Simply by reviewing the most important events that might influence Oil prices within this period we can find out that this period also enjoyed a very stable trend, let us call it dramatic free of any huge events such as, Geopolitical event, or Major changes in OPEC policies, or presence of new Technological advancements, or even major changes in crude oil production quantities. *See chapter 7.*

ii. Additionally the era between 1991 & end of 1997 also can be seen as a recession –free period, which played a major role in keeping oil prices also stable and steady. *See chapter 7.*

iii. Oil world demand for this period grew up normally, again which helps the prices to stabilize. *See chapter 7.*

Period conclusion – [1991-1997]

That if our planet enjoys continuously such trend of stability, the behavior of oil prices fluctuations within this period will be the best for consumers, and for monitoring risks related to investments that are highly influenced by oil prices fluctuations, due to the high stability of oil prices.

4.2.3 Period Range : 2000-End of 2003:

During 2000 up to the end of 2003, a generic clear stability of the oil prices is observed, where the minimum oil price was recorded in Dec /2001 with an average of $18.50 , while the maximum of $32 recorded in Feb/2003,

By following the monthly and annually price oil for this period we can see that the Average annual price of oil for each of the years, in the following table:

	Year			
Annual Average ($/bbl)	2000	2001	2002	2003
	$28.23	$24.35	$24.93	$28.90

Table – 7: Annual average prices for period between 2000 –2003

Although the 9/11 attack have occurred during this period, but we can still notice that the oil prices for 2000 were kept almost steady without any extreme changes, as the crude oil monthly average price of oil in Aug/2000 was recorded to be $29.30, while that of Sep/2000 was recorded to be $32.08 with just a slight increase, therefore we cannot drive a conclusion that states that 9/11 attack has significantly influenced the oil prices at this period.

However for the same period, the US Invasion on Iraq took place on the end of 2003, leading to obvious increase on oil prices for 2004, which reached an average of $37.73, invasion of Iraq was associated with a registered peak value of $46.88. *See next period range please*.

Period conclusion – [2000-2003]

The table clearly states that average annual prices of crude oil were kept very stable, with very reasonable slight changes that have to do solely with the offer and demand factors

4.2.4 Period Range : 2004-2006

During 2004 up to 2006, an increasing trend of the oil prices is observed. According to "Dees et al" the main reasons that can explain the increase of oil prices within this period is highly linked to the availability of crude oil and demand-supply considerations. **(10)**

	Year		
Annual Average ($/bbl)	2004	2005	2006
	$37.73	$53.39	$64.29

Table –8: Annual average prices for period between 2004 –2006

i. More specifically, it is argued that in the United States, the supply of oil during the underlying period faced significant shortcomings due to the steady number of oil refineries which date back to 1981.

ii. Additionally, it is also claimed that a large number of oil refineries in the United States was under maintenance. As a consequence, the market of crude oil faced supply shortages which in turn influenced the global oil prices during the period 2004 up to 2006. **(10)**

4.2.5 Period Range : 2006-2008

During 2006 up to 2008, it is observed that oil prices increased at higher rates and decreased sharply after the financial crisis of 2008. Moreover, from the end of 2006 to 2008, the price of oil saw an unprecedented spike, going from under $64 per barrel in the end of 2006 to almost $140 per barrel in July of 2008.

The following table summarizes the oil prices average fluctuations for the corresponding periods between 2006-2008, it is very obvious that the prices showed a dramatic increasing pattern, followed by again a drastic decay at the last quarter of 2008, Please note that in **Table-9**, the symbol **Q** refers to a quarter of a year.

	Year					
Average ($/bbl)	2006	2007	2008 / Q1	2008 / Q2	2008 / Q3	2008 / Q4
	$64.29	$72.12	$95.31	$120.97	$115.69	$56.00

Table – 9: Average prices for period between 2006 –2008

Follows my analysis and justification to this behavior of oil prices for this period:

i. The drastic increase can be seen as a response to the rapidly increasing demand in economies such as China and India and production cuts by the Organization of Petroleum Exporting Countries **(OPEC)** in the Middle East drove the price of oil to its record heights.

ii. Although, the sharp price decrease can be easily attributed to the financial crisis, the significant price increase remains questionable. Dees et al. in his argument in (2008) argue that the non-linear relationship between oil prices and supply caused the prices to peak.[10]

iii. Other factors may sufficiently explain the increasing peak of the prices such:
- The Insufficient production capacities similar to the previous period.
- Extreme events and expectations concerning the market conditions of the future. Such as the Contango or Backwardation. See chapter-2.

However, By digging more in the history of oil prices and possible scenarios for this bizarre behavior of oil prices during 2008, I found that according to "Talley and Meyer from the Commodity Futures Trading Commission in 2008), they suggest that there are also assertions that the oil price increase in 2008 was the result of speculative investments. They declare that there was strong evidence of speculation in oil markets, which caused the prices to increase.[11] the two journalists, given evidence from Congressional committees in the United States, state that 70% of the trades in futures of the New York Merchantile Exchange (NYMEX) and the Intercontinental Exchange (ICE) have speculative nature. As a consequence, they argue that the main reason for the oil price increases was speculation in the futures market. [12]

Period conclusion – [2006-2008]

As it can be seen, there are no clear answers as to which are the main reasons which led the oil prices to increase rapidly. Given the evidence presented, it could be argued that for the period 2006 up to 2008, shifts in the demand-supply conditions and speculation caused the prices to increase dramatically. The aftermath of this increase was a sharp decline of the prices during the financial crisis

4.2.6 Period Range : 2009-2011

By the end of 2008, the price of oil had bottomed out at $40. The economic recovery that began the following year sent the price of oil back over $100, shortly thereafter; a deep global recession throttled demand for energy and sent oil prices into a precipitous free fall.

For the period from 2009 up to 2011, the general tendency that is observed is that oil prices tend *to increase but in smaller rates* compared to the past. This increase of the oil prices can be attributed to according to **(ExxonMobil, 2010**):

- The expansionary growth of developing economies.
- Geopolitical uncertainties in the Middle East.
- The production quotas of the Organization of Petroleum Producing Countries (OPEC) for the mentioned period.

The following table summarizes the oil prices average fluctuations for the corresponding periods between 2009-2011, it is very obvious that the prices showed a dramatic increasing pattern, followed by again a drastic decay at the last quarter of 2008, Please note that in **Table-10**, the symbol **S** refers to the half of a year.

	Year					
Average ($/bbl)	2009 – S1	2009 – S2	2010 – S1	2010 – S2	2011 / S1	2011/ S2
	$51.66	$71.86	$77.62	$80.47	$104.90	$103.12

Table – 10: Average prices for period between 2009 –2011

Period conclusion – [2009-2011]

As it can be seen, the oil price per barrel for this period started with an average of $51.66/bbl recorded for the first half of 2009, this can be translated as continuity to the huge drop witnessed at the end of 2008.
But starting from the second half of 2009 a noticeable clear increase in oil prices have been observed which continued incrementally & continuously to increase until the end of 2011, where the average crude oil prices almost doubled on semiannual basis from $51 to $103 in the span of 3 years.

4.2.7 Period Range : 2011-2014

The following table summarizes the oil prices average fluctuations for the corresponding periods between 2011-2014, it is very obvious that the prices showed a dramatic increasing pattern, followed by again a drastic decay at the last quarter of 2008, Please note that in **Table-11**, the symbol **S** refers to the half of a year & the symbol **Q** refers to a quarter of a year.

	Year						
Average ($/bbl)	2012-S1	2012-S2	2013-S1	2013-S2	2014-S1	2014-Q3	2014-Q4
	$107.67	$102.35	$102.20	$105.95	$104.99	$100.93	$74.95

Table – 11: Average prices for period between 2012 –2014

As the table shows the prices that for the period from 2011 up to the end of the third quarter of 2014, oil prices have hovered between $100 and $125, , when again it experienced another steep drop in the fourth quarter of 2014. Where the price of oil *reached minima of $60.70 in Dec/2014, which is almost* 44% less than the highest price registered in June/2014 of $108.37

Numerous Interesting factors contributed to the ***end of 2014 drop*** in oil prices are briefed within the upcoming bullets: **(13)**

- Economies such as China, whose rapid growth and expansion created an unquenchable thirst for oil in the first decade of the new millennium, began to slow after 2010, since China is the world's largest country by population, so China's lower oil demand had significant price ramifications.
- Other large emerging economies such as Russia, India and Brazil experienced similar economic trajectories in the early 21st century – rapid growth during the first decade, followed by much slower growth after 2010
- Spurred by the negative effect of high oil prices on their economies, countries such as the U.S. and Canada increased their efforts to produce oil. In the U.S., private companies began extracting oil from shale formations in North Dakota using a process known as fracking.
- Meanwhile, Canada went to work extracting from Alberta's oil sands, which is seen as the world's third-largest crude oil reserve.

- Saudi Arabia's actions also contributed to falling 2014 oil prices. Faced with a decision between:

A. Letting prices continue to drop or ceding market share by cutting production in an effort to send prices upward again, the Middle Eastern country finally kept its production stable, deciding that low oil prices offered more of a long-term benefit than giving up market share.

B. Because Saudi Arabia produces oil so cheaply and holds the largest oil reserves in the world, it can withstand low oil prices for a long time without any threat to its economy.

Period conclusion – [2012-2014]

1. **The same countries that pushed up the price of oil in 2008 with their ravenous demand helped bring oil prices down in 2014 by demanding much less of it**
2. **As a result of this local production mentioned in Point iii, the two North American countries were able to cut their oil imports sharply, which put further downward pressure on world prices.**
3. **In contrast, extraction methods such as fracking are more expensive and therefore not profitable if oil prices fall too low. By supporting low oil prices, Saudi Arabia hopes that countries such as the U.S. and Canada will be forced to abandon their more costly production methods due to lack of profitability.**

4.2.8 Period Range : 2015 – 2018:

The following table summarizes the oil prices average fluctuations for the corresponding periods between 2015-2018, this table shows that except for year 2016, we can assume that the prices showed a stable and constant pattern per year, Please note that in **Table-12**, the symbol **S** refers to the half of a year

		Year						
Average ($/bbl)	2015-S1	2015-S2	2016-S1	2016-S2	2017-S1	2017-S2	2018-S1	2018-S2
	$56.01	$45.49	$38.76	$46.87	$51.17	$54.43	$68.01	$68.68

Table – 12: Average prices for period between 2015 –2018

As table-12 shows, and also by watching the monthly prices in Table-1 and figure-7, a noticeable drop in oil prices can be observed between Dec/2015 and April/2016, as prices averaged in these 4 months a value of $33.68, a considerably low value if compared with the average annual prices of year 2015.

this drop can be explained by 2 major reasons, Seasonality of Oil prices usually go lower in winter, Please see CH-7, but mainly also due to the appearance of the Niger Delta Avengers who appeared at the beginning of 2016, which lead to huge drop in crude oil prices to reach low values such as $29.78 in Jan/2016. Afterwards, prices started to recover starting from may/2016 coming back to its average values before the presence of the Niger Delta Avengers.

Another noticeable observation is that starting from Sep/2017, crude prices tended to increase almost continuously until Nov/2018 where average monthly price of crude drop to a value of $62.32/bbl, then prices dropped once again in Dec/2018 recording a lower value of $53.96/bbl, it is important to mention that the prices of crude in Oct/2018 registered a value of $76.73/bbl meaning that the drop 29.67% in less than a span of 2 months.

During 2015 up to the end of 2018, prices of crude oil demonstrate an overall average of $53.68

- The Minimum monthly average oil price was recorded for Jan/2015 with value of $29.78.
- The Maximum Monthly average oil price recorded in Oct/2018 with the value of $76.73

Yet on Annual Basis, the readings are as follows:

- The Minimum annual average oil price was recorded for 2018 with value of $68.35
- The Maximum annual average oil price recorded in 2018 with the value of $42.81
- The range of fluctuation is exactly $25.54 for the entire period on Annual basis.

CHAPTER – 5: Forecasting

5.1 Introduction to Forecasting:

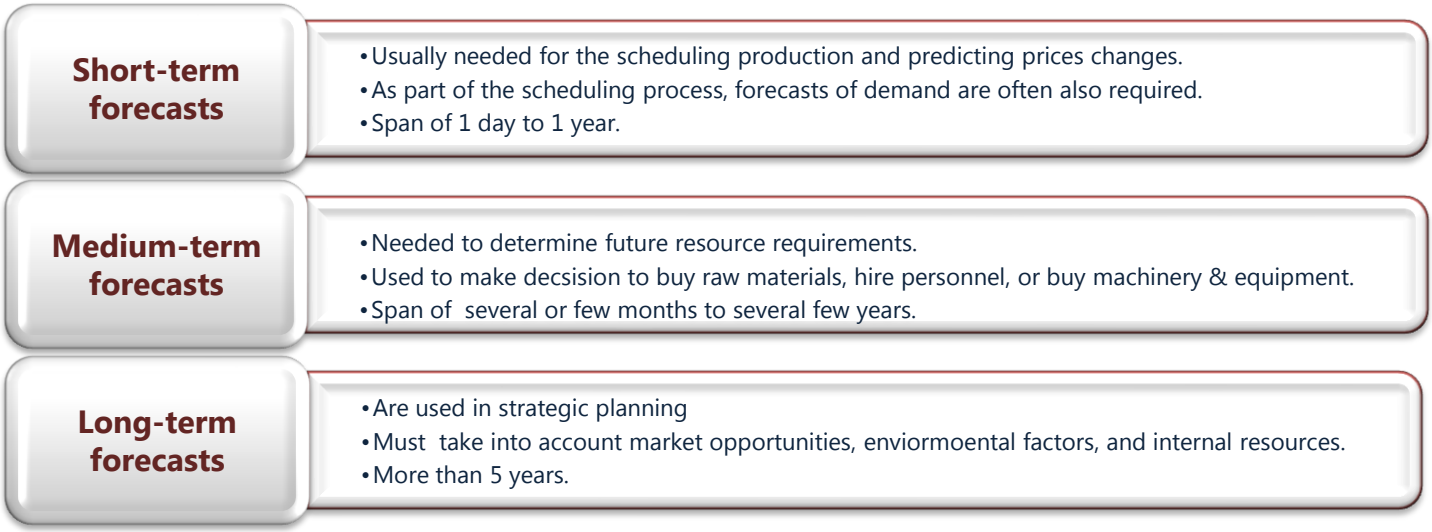
In literature, Forecasting is seen as predicting the future as accurately as possible, given all of the information available, including historical data and knowledge of any future events that might impact the forecasts.[14]

Forecasting according to expert opinions can also be seen as predicting the future, but it is not an exact science, instead it consists of a set of statistical tools and techniques that are supported by human judgment and intuition, Prod Paul Saffo in an article published by Harvard Business Review adds also that the goal of forecasting is not to predict the future but also to tell you what you need to know to take meaningful action in the present. [15]

Business forecasting generally attempts to predict future customer demand for goods or services, also it is a common statistical task in business, where it helps to inform decisions about the scheduling of production, and provides a guide to long-term strategic planning. While the Macroeconomic forecasting attempts to predict future behavior of the economy and identify business cycle turning points. [14]

Types of Forecasting in relation to time are strictly 3 types, and are demonstrated clearly in **figure-8**:

Figure -8: Type of forecasting with relation to time span.



5.2 Forecasting Applications in Oil Industry:

In practice forecasting has a wide variety of applications, but the most important within oil industry are related to:

i. **Economics:** This kind of forecast is targeting the major economic variables, such as inflation & oil prices.
ii. **Finance & Risk Management:** Aims to forecast returns from investments in the oil industry by forecasting the possible amounts of productions.
iii. **Industrial Process Control:** forecasts of the quality characteristics of the produced oil /gas.

In this Thesis, I am using the Economic aspect or Application of Forecasting in the oil industry.

5.3 Types of forecasting methods:

5.3.1 Qualitative methods:

These types of forecasting methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations. In other words they are based mainly on judgment, opinion, past experience and best guesses.[16]

Figure-9 Provides four of the most famous qualitative approaches of forecasting and brief explanation of each.

Figure -9: Qualitative Forecasting Approaches.

5.3.2 Quantitative methods:

These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations; **Figure-10** provides the two famous qualitative approaches of forecasting and brief explanation of each. [16]

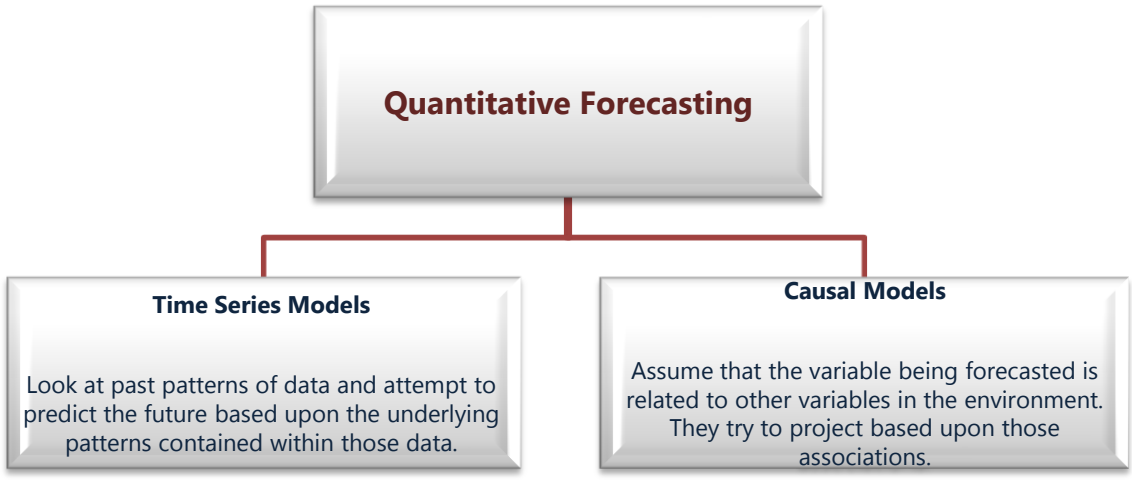


Figure -10: Quantitative Forecasting Approaches.

5.3.3 Benchmarking :Qualitative Methods vs. Quantitative Methods.

These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations; **Figure-11** provides a detailed comparison between both types of forecasting on the basis of 4 factors.

Figure -11: Quantitative vs. Forecasting comparison.

5.4 Time Series Forecasting Methods.

A time series is defined as a series of observations on a particular variable collected over a period of time *(usually at equally spaced intervals).*

According to this definition, this means that the Input data throughout the context of my thesis which represent **[Nominal Monthly Spot Prices** in **$US/BBL.**] "*See Assumption 5*", for the study period between **[1988 -2018]** can be treated as a time series.

This means that the collected data under study can be seen and treated as a time series, thus, the use of Quantitative methods and utilizing a time series forecasting model is also valid, the following **Figure-12** will provide some examples of the most common time series model used in forecasting, and a brief about each one .

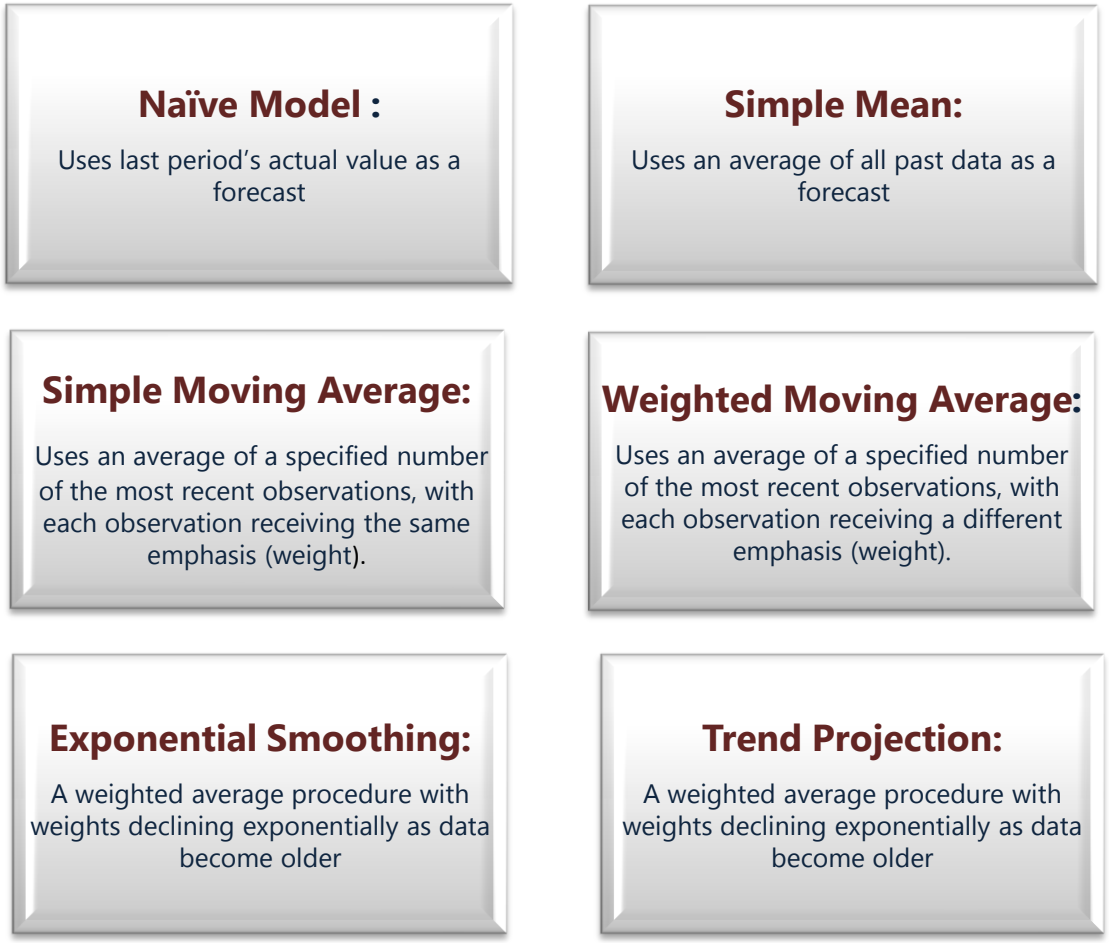


Figure - 12: Time Series Models.

Throughout the context of this thesis, I have decided with my supervisor to use both the simple moving average I and the exponential smoothing methods as my forecasting models, and then compare between the two methods, follows a brief illustration of each.

5.4.1 SIMPLE MOVING AVERAGE METHOD:

Let us assume that:

- The current Nominal Spot Price is P_t,
- The price for the next period is P_{t+1}
- The forecast for current Price is F_t
- The forecast for the next period is F_{t+1}

Then the forecast of the price for next period **(t+1)** will equal the average of *a specified number* of the most recent observations, with each observation receiving the same emphasis, in other hands equally weighted.

In the following illustration, I will demonstrate an example to show how simple moving average works, also how I applied it to my Input Data in this thesis.

The below table offers information of **Nominal Monthly Spot Prices** of Crude Oil for the period between Sep-1988 & Aug-1989, for this example I assume that a **3-month** simple moving average is being used.

I will also assume that:

- In the absence of data at startup, I made a guess for the forecast of Sep to equal $13.00.
- Then, after Sep elapsed, I made a forecast for Oct using a naïve method to equal the actual price of Sep.
- Again I did the same thing for Nov forecast using naïve method to equal the actual price of Oct.
- The Forecast for Months Dec through August, were made using the 3-simple moving average model, that's because beyond Nov, I have sufficient data to let the 3-month simple moving average forecasts unfold throughout the months.

Month	Period (t)	Actual Price (Pt)	Forecast (Ft)	Notes
Sep - 1988	1	13.10	13.00	**This forecast F_1 can be found by a guess at the beginning.**
Oct - 1988	2	12.18	13.10	**This forecast F_2 can be found using the naïve method.**
Nov - 1988	3	12.53	12.18	**This forecast F_3 can be found using the naïve method.**
Dec - 1988	4	14.65	12.60	**From this point forward, these forecasts were made on a month by month basis using a 3-month moving average approach $F_4 = [P_1 + P_2 + P_3] / 3$ $F_4 = [13.10 + 12.18 + 12.53] / 3$ $= 12.60$**
Jan -1989	5	16.48	13.12	**Similarly, $F_5 = [P_2 + P_3 + P_4] / 3$ $=12.18+12.53+14.65$ $=13.12$**
Feb - 1989	6	16.35	14.55	
Mar - 1989	7	18.03	15.83	
Apr - 1989	8	19.20	16.95	
May - 1989	9	18.02	17.86	
Jun - 1989	10	17.63	18.42	
Jul - 1989	11	17.67	18.28	
Aug - 1989	12	16.88	17.77	

Table- 13: Moving Average Method Calculations Sample

Throughout the context of this thesis, I have used the simple moving average model for **3, 4, 6 & 12** months period using the same mathematics shown above, for forecasting the **Monthly Nominal Spot Prices**, and for the **Inflation – Adjusted Spot Prices** as well, resulting in 8 different models of forecast, to forecast all crude oil prices for the study period between [1988 -2018].

5.4.2 EXPONENTIAL SMOOTHING METHOD:

Let as assume that:

- $\mathbf{P_t}$: is the current nominal spot price.
- $\mathbf{P_{t-1}}$: is the price for the previous period.
- $\mathbf{F_t}$: is the forecast for current period is
- $\mathbf{F_{t-1}}$: is the forecast for the previous period is
- α is a smoothing coefficient whose value is between 0 and 1
- **(1- α)** is called the damping factor.

Then the forecast of the price for current period **(t)** will be calculated as follows:

Current forecast = Last period's forecast + α x [Last period's actual Price – Last period's forecast]

$$F_t = F_{t-1} + \alpha \times (P_{t-1} - F_{t-1})$$

$$F_t = \alpha \times P_{t-1} + (1-\alpha) \times F_{t-1}$$

The exponential smoothing method only requires that you dig up two pieces of data to apply it (the most recent actual price and the most recent forecast).

An attractive feature of this method is that forecasts made with this model will include a portion of every piece of historical demand. Furthermore, there will be different weights placed on these historical demand values, with older data receiving lower weights.

In the following illustration, I will demonstrate an example to show how Exponential Smoothing works, also how I applied it to my Input Data in this thesis.

The below table offers information of **Nominal Monthly Spot Prices** of Crude Oil for the period between Sep-1988 & Aug-1989, for this example I assume that the damping factor is 0.9, meaning that α=0.1.
I will also assume that:

- In the absence of data at startup, I made a guess for the forecast of Sep to equal $13.00.
- Then, for each subsequent month (beginning with Oct) I made a forecast using the exponential smoothing model. After the forecast was made, I have to wait to see what demand unfolded during October; I then made a forecast for the subsequent month, and so on right through to the forecast till the last period I am interested in

Month	Period (t)	Actual Price (Pt)	Forecast (Ft)	Notes
Sep - 1988	1	13.10	13.00	**This forecast F_1 can be found by a guess at the beginning.**
Oct - 1988	2	12.18	13.01	**From this point forward, these forecasts were made on a month by month basis using exponential smoothing with α=.1** **F_2= [P_1 x α] + [F_1 x 1-α]** **F_2 = [13.10 x 0.1] + [13.00 x 0.9]** **= 13.01**
Nov - 1988	3	12.53	12.93	**Similarly,** **F_3= [P_2 x α] + [F_2 x 1-α]** **F_2 = [12.08 x 0.1] + [13.01x 0.9]** **= 12.93**
Dec - 1988	4	14.65	12.89	
Jan -1989	5	16.48	13.06	
Feb - 1989	6	16.35	13.41	
Mar - 1989	7	18.03	13.70	
Apr - 1989	8	19.20	14.13	
May - 1989	9	18.02	14.64	
Jun - 1989	10	17.63	14.98	
Jul - 1989	11	17.67	15.24	
Aug - 1989	12	16.88	15.49	

Table- 14: Exponential Smoothing Method Calculations Sample

Throughout the context of this thesis, I have used the exponential smoothing model using the same mathematics shown above , with values of α = 0.1, 0.2, 0.3, & 0.4, for forecasting the **Monthly Nominal Spot Prices**, and for the **Inflation – Adjusted Spot Prices** as well, resulting in an additional 8 different models of forecast for the study period between [1988 -2018].

CHAPTER – 6: Forecasting Numerical Results:

6.1 Oil-Prices Forecasting Methodology:

This forecasting task involved five basic steps.

⊤ Step 1: Problem definition.

In this thesis, my objective is to set up the light on the problem of forecasting oil prices using numerical models on short term basis, such as the time series methods

Please see CH-4 for more details on time series methods.

⊤ Step 2: Gathering information.

In this thesis, the initial gathered statistical data are the Monthly average spot prices of 3 different types of Crude oil including WTI, Brent and Dubai Crude in $/bbl.

Then I took the average monthly spot price of a benchmark consists of Brent, Dubai and West Texas Intermediate (WTI), equally weighted to represent what is called the Nominal Monthly Average Spot Price for a study period of 30 years ranging from [1988-2018] on monthly basis, as occasionally, old data will be less useful due to structural changes in the system being forecast.

Please "See Assumption-5" for the detailed calculations of the Nominal Monthly Average Spot Prices of Crude Oil.

⊤ Step 3: Preliminary (exploratory) analysis.

Then I have defined a new approach, which is the "*Inflation-Adjusted Spot Prices*", where I used the consumer price indices for US Dollar for the study period [1988-2018] to adjust all nominal spot prices to the year 2018 so I can see how the prices grow solely due to inflation, and then I performed the same forecasting models that I used to forecast the nominal spot prices on the newly calculated "*inflation-adjusted spot prices*".

Please see CH-3 for more details and related calculations.

⊤ Step 4: Choosing and fitting models.

The two methods suggested for forecasting and have been agreed upon with my supervisor throughout my thesis are:

i. Simple Moving Average.
ii. Exponential Smoothing.

Please see CH-4 for more details on these 2 methods.

⊤ Step 5: Using and evaluating a forecasting model.

Once a model has been selected and its parameters estimated, the model is used to make forecasts. The performance of the model can only be properly evaluated after the data for the forecast period have become available. A number of methods have been developed to help in assessing the accuracy of forecasts numerically; I used the 3 types of Errors to compare between the output forecast models:

- Mean Absolute Deviation **(MAD)**
- Mean Square Error **(MSE)**
- Mean Average Percentage Error **(MAPE).**

6.2 Numerical Methodology:

For Better understanding of the work methodology followed throughout this thesis to come up with the forecasting models, please see Figures 13 and 14.

Figure- 13 represents the methodology used in order to come up with the forecasting models of the nominal Spot Prices.

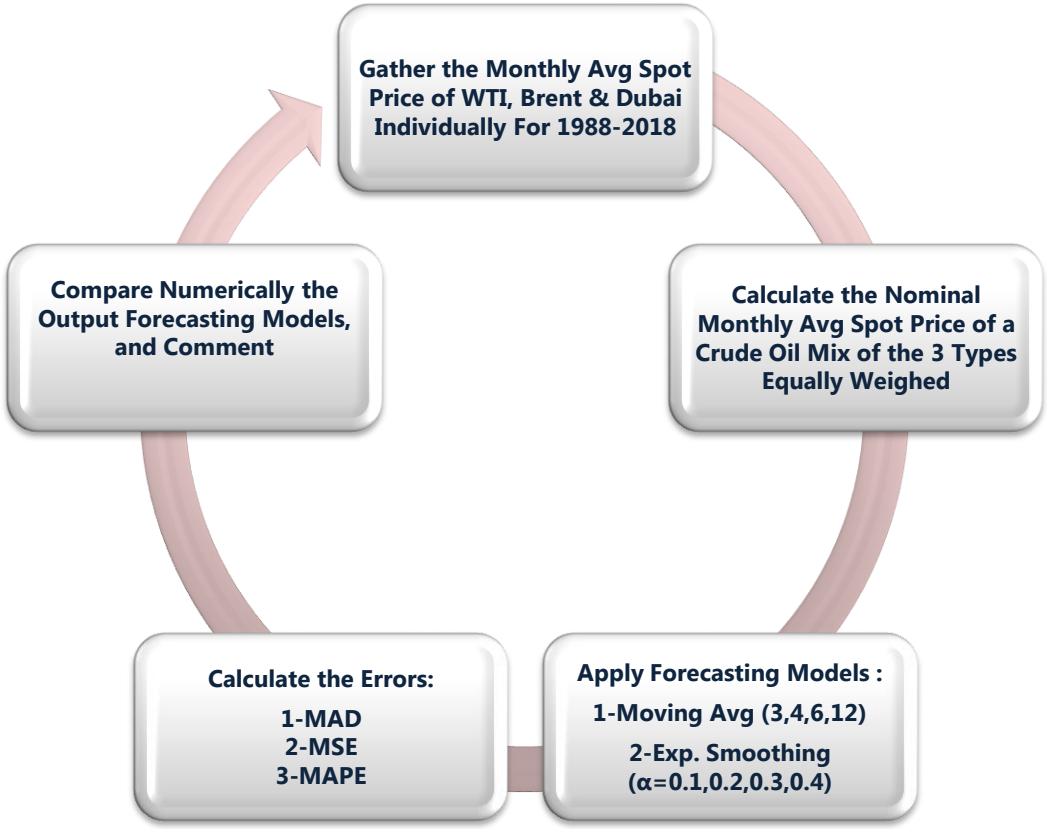


Figure – 13: Flow Chart / Nominal Average Monthly Spot Prices Forecasting Methodology

Figure-14 represents the methodology used in order to come up with the forecasting models of the inflation-adjusted prices.

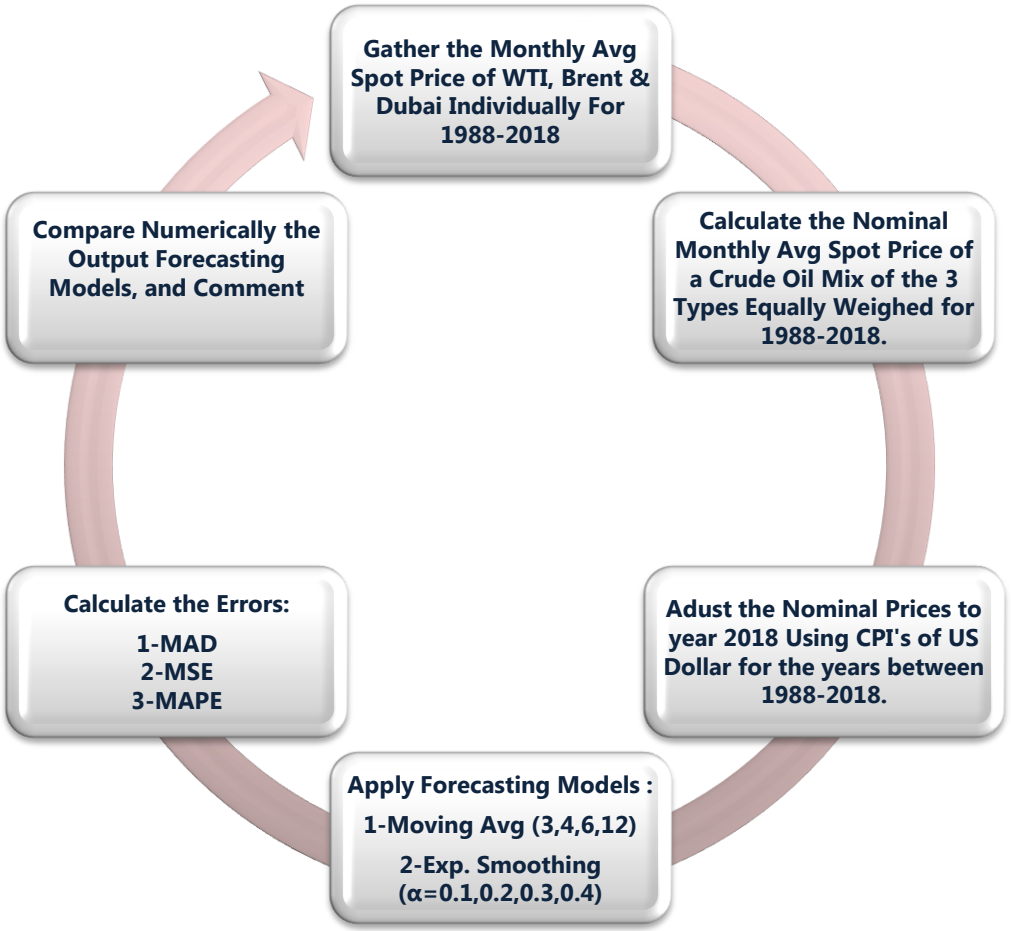
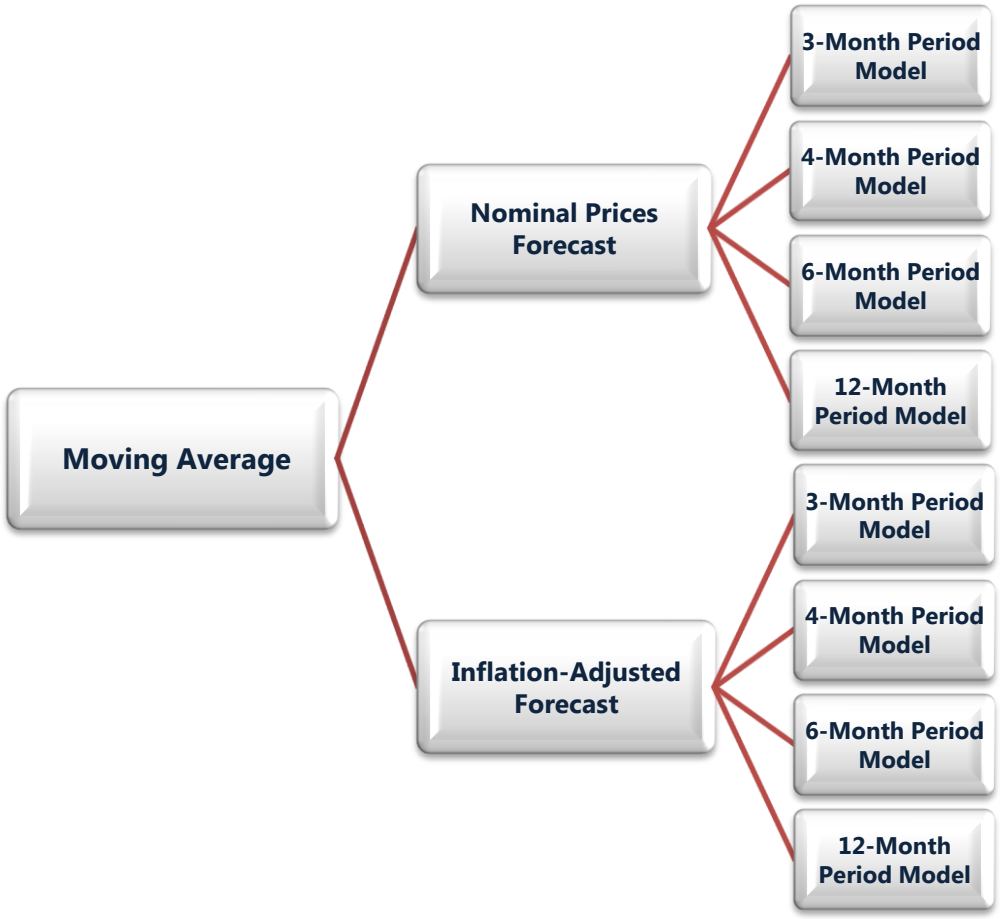


Figure – 14: Flow Chart / Inflation-Adjusted Average Monthly Spot Prices Forecasting Methodology

6.3 Numerical Forecasting Output Models:

For Better understanding of the forecasting output models investigated throughout this thesis, please see Figures 15 and 16.

Figure-15 clearly shows the forecasting output models for the simple moving average method applied on both the nominal prices & the adjusted ones using different periods "3-months, 4-months, 6-months & 12-months.



Figure–15: Flow Chart –Moving Average Forecasting Output Models

Figure-16clearly shows the forecasting output models for the exponential smoothing method applied on both the nominal prices & the adjusted ones using different values of alpha "α": "α=0.1, α=0.2, α=0.3 & α=0.4".

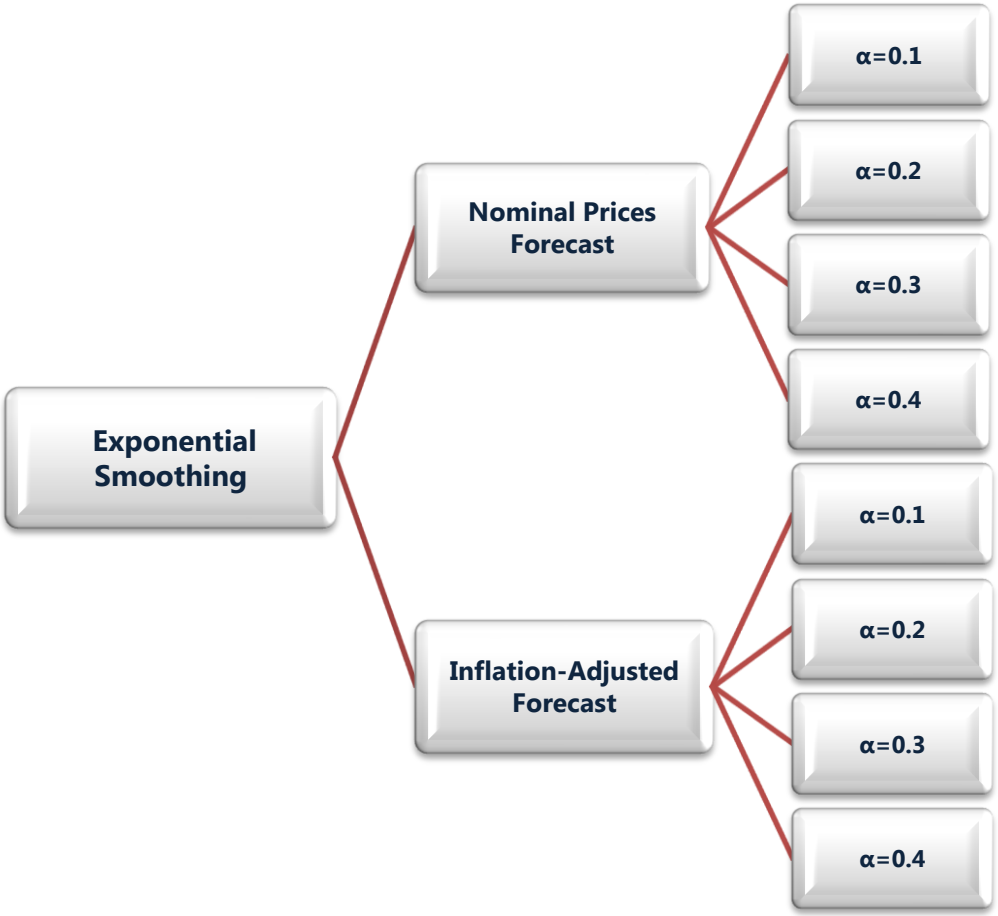


Figure – 16: Flow Chart –Exponential Smoothing Forecasting Output Models

6.4 Errors Calculations for Time Series:

6.4.1 Mean Absolute Deviation (MAD) :

Both the Mean Absolute Deviation **(MAD)** and the Mean Absolute Error **(MAE)** refer to the same method for measuring forecast error. **(17)**

- The error is said to be the difference between the attribute which is to be estimated and the estimator.
- MAD is most useful when linked to revenue, prices or some other independent measure of value.
- MAD can reveal which high-value forecasts are causing higher error rates.
- MAD takes the absolute value of forecast errors and averages them over the entirety of the forecast time periods.
- Taking an absolute value of a number disregards whether the number is negative or positive and, in this case, avoids the positives and negatives canceling each other out.

MAD is obtained by using the following **Error formula-1**:

$$\frac{1}{N}\sum_{k=1}^{N}| F_k - A_k$$

Error Formula-1

Where:

A_k : is the actual data in period **k** F_k: is the forecast for period **k** **N**: is the number of forecast periods.

Example 5: Mean Absolute Deviation (MAD) Calculations

The following tables provides a sample real data, for oil prices and their forecast using to the 3-Moving Average Method, for the period between Dec-2009 & Nov-2009, Number of forecasting periods **(N)** is **12**, and all prices are quoted in $/BBL. I will use the provided data inside this table in order to show how MAD is calculated.

N	Period	Actual Price A_k	Forecasted Price F_k	Error A_k-F_k	|Error| $\|A_k-F_k\|$
1	12/2009	74.88	73.33	1.55	1.55
2	01/2010	77.12	75.50	1.62	1.62
3	02/2010	74.76	76.52	-1.76	1.76
4	03/2010	79.30	75.59	3.71	3.71
5	04/2010	84.18	77.06	7.12	7.12
6	05/2010	75.62	79.41	-3.79	3.79
7	06/2010	74.73	79.70	-4.97	4.97
8	07/2010	74.58	78.18	-3.60	3.60
9	08/2010	75.83	74.98	0.85	0.85
10	09/2010	76.12	75.05	1.07	1.07
11	10/2010	81.72	75.51	6.21	6.21
12	11/2010	84.53	77.89	6.64	6.64
TOTAL					42.90
MAD					3.57

Applying Error formula-1 , for this Sample Data, MAD is found to be 42.90 / 12 = 3.57

Similarly, all **MAD** values for the 16 forecasting output models were found using the same approach.

6.4.2 Mean Squared Error (MSE) :

The mean squared error, abbreviated as **MSE**, is quite important for relaying the concepts of precision, bias and accuracy during the statistical estimation [17]

- The mean squared error may be called a risk function which corresponds to the expected value of the loss of squared error.
- The unit of MSE is the same as the unit of measurement for the quantity which is being estimated.
- When the value of MSE is zero, it means that there is perfect accuracy found by the estimator, this condition is ideal and usually not practically possible.
- The values of MSE could be used for making comparisons between two or more statistical models. It can be measured how well illustrated a given data set.

MSE is defined as the average of squares of the "errors", and is obtained by using the following **Error formula-2**

$$\frac{1}{N}\sum_{k=1}^{N}|F_k - A_k|^2$$

Error Formula-2

Where:

N: is the number of forecast periods. $\mathbf{F_k}$: is the forecast for period **k** $\mathbf{A_k}$: is the actual data in period **k**

Example 6: Mean Squared Error Calculations

The following tables provides a sample real data, for oil prices and their forecast using to the 3-Moving Average Method, for the period between Dec-2009 & Nov-2009, Number of forecasting periods **(N)** is **12**, and all prices are quoted in $/BBL. I will use the provided data inside this table in order to show how MAD is calculated.

N	Period	Actual Price A_k	Forecasted Price F_k	Error A_k-F_k	|Error| $\|A_k-F_k\|$	|%Error| $\|A_k-F_k\| / A_k$
1	12/2009	74.88	73.33	1.55	1.55	2.41
2	01/2010	77.12	75.50	1.62	1.62	2.61
3	02/2010	74.76	76.52	-1.76	1.76	3.09
4	03/2010	79.30	75.59	3.71	3.71	13.79
5	04/2010	84.18	77.06	7.12	7.12	50.69
6	05/2010	75.62	79.41	-3.79	3.79	14.39
7	06/2010	74.73	79.70	-4.97	4.97	24.70
8	07/2010	74.58	78.18	-3.60	3.60	12.94
9	08/2010	75.83	74.98	0.85	0.85	0.73
10	09/2010	76.12	75.05	1.07	1.07	1.15
11	10/2010	81.72	75.51	6.21	6.21	38.56
12	11/2010	84.53	77.89	6.64	6.64	44.09
TOTAL						209.16
MSE						17.43

Applying Error formula-2, for this Sample Data, MSE is found to be 209.16 / 12 = 17.43

Similarly, all **MSE** values for the 16 forecasting output models were found using the same approach.

6.4.3 Mean Absolute Percent Error (MAPE) :

Mean Absolute Percent Error **(MAPE)** is the most common measure of forecast error.

- MAPE functions best when there are no extremes to the data (including zeros). "Which is for sure the case in our data, as prices of crude oil can never reach zero, which make it efficient and effective to use the MAPE.
- With zeros or near-zeros, MAPE can give a distorted picture of error. The error on a near-zero item can be infinitely high, causing a distortion to the overall error rate when it is averaged in.
- MAPE is the average absolute percent error for "each time period/forecast minus actual" divided by actual. **(18)**

MAPE is obtained by using the following **formula-3**:

$$\frac{1}{N}\sum_{k=1}^{N}\frac{|F_k - A_k|}{A_k}$$

Error Formula-3

Where:

N: is the number of forecast periods. **F_k**: is the forecast for period **k** **A_k** : is the actual data in period **k**

Example 7: Mean Absolute Percent Error Calculations

I will use the previous tables which provides a sample real data, for oil prices and their forecast using to the 3-Moving Average Method, for the period between Dec-2009 & Nov-2009, Number of forecasting periods **(N)** is **12**, and all prices are quoted in $/BBL. I will use the provided data inside this table in order to show how MAPE is calculated.

N	Period	Actual Price A_k	Forecasted Price F_k	Error A_k-F_k	|Error| $\|A_k-F_k\|$	|%Error| $\|A_k-F_k\| / A_k$
1	12/2009	74.88	73.33	1.55	1.55	2.07%
2	01/2010	77.12	75.50	1.62	1.62	2.10%
3	02/2010	74.76	76.52	-1.76	1.76	2.35%
4	03/2010	79.30	75.59	3.71	3.71	4.68%
5	04/2010	84.18	77.06	7.12	7.12	8.46%
6	05/2010	75.62	79.41	-3.79	3.79	5.02%
7	06/2010	74.73	79.70	-4.97	4.97	6.65%
8	07/2010	74.58	78.18	-3.60	3.60	4.82%
9	08/2010	75.83	74.98	0.85	0.85	1.13%
10	09/2010	76.12	75.05	1.07	1.07	1.41%
11	10/2010	81.72	75.51	6.21	6.21	7.60%
12	11/2010	84.53	77.89	6.64	6.64	7.86%
TOTAL						54.14%
MAPE						4.51%

Applying Error formula-3 , for this Sample Data, MAPE is found to be 54.14% / 12 = 4.51%

Similarly, all **MAPE** values for the 16 forecasting output models were found using the same approach.

6.5 Oil-Prices Forecasting Results:

As shown in figures 8 & 9, a total of 16 different forecasting models were generated throughout this thesis, those models were generated by using the moving average at different periods, and exponential smoothing methods with different alpha values, when applied separately on both the nominal oil prices and the inflation-adjusted oil prices.

Next I will provide the numerical results of these 16 models, each evaluated for accuracy using 3 different types of Errors:

- Mean Absolute Deviation **(MAD)**
- Mean Square Error **(MSE)**
- Mean Absolute Percent Error **(MAPE).**

Results are summarized throughout **table-15** till **table-30;** each table is labeled and clearly titled to demonstrate which model it represents, additionally each table as well presents the corresponding Errors to that specific model.
All data were processed using Microsoft Office Excel, and according to the assumptions of this thesis, all prices are quoted in $/BBL and approximated to decimal places.

Forecasted Values were calculated using the appropriate formulas for Moving Average Methods of a time series, and also Exponential Smoothing Method of a time series, using the same approach explained previously in Sections, 4.4.1 & 4.4.2 of this thesis.

Errors were calculated using the appropriate formulas for MAD, MSE & MAPE of a time series using the same approach explained previously in Section 6.4.1, 6.4.2 and 6.4.3 of this thesis.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.10	12.18	12.60	12.72
1989	13.12	14.55	15.83	16.95	17.86	18.42	18.28	17.77	17.39	17.41	17.66	18.15	16.95
1990	18.71	19.36	19.77	19.39	18.12	17.12	16.13	16.34	19.61	25.42	31.20	32.76	21.16
1991	30.57	26.60	22.28	19.59	18.22	18.45	18.41	18.60	18.78	19.49	20.30	20.76	21.00
1992	20.01	19.34	18.38	17.55	17.77	18.30	19.10	19.78	20.03	20.19	20.01	19.68	19.18
1993	18.96	18.01	17.77	17.95	18.36	18.36	18.02	17.32	16.76	16.23	16.30	15.87	17.49
1994	15.16	14.37	13.89	13.84	14.16	14.99	16.18	17.11	17.35	17.03	16.56	16.58	15.60
1995	16.50	16.64	16.75	17.22	17.81	18.14	18.14	17.29	16.64	16.46	16.47	16.56	17.05
1996	16.91	17.47	17.79	18.30	19.25	19.71	19.41	19.05	19.51	20.76	22.10	22.75	19.42
1997	23.21	23.08	22.42	20.99	19.21	18.86	18.39	18.54	18.32	18.56	19.13	19.26	20.00
1998	18.74	17.06	15.40	14.07	13.57	13.55	13.34	13.07	12.56	13.00	13.18	12.98	14.21
1999	11.85	11.24	10.87	11.79	13.26	15.03	16.11	17.15	18.55	20.65	21.64	22.94	15.92
2000	23.74	24.86	25.88	26.67	26.06	26.05	26.76	28.33	29.02	29.84	30.91	31.94	27.50
2001	29.64	27.83	26.13	26.07	25.99	26.10	26.75	26.44	25.86	25.28	23.92	21.54	25.96
2002	19.31	18.79	19.22	20.92	23.02	24.91	25.20	25.30	25.67	26.94	27.53	26.78	23.63
2003	26.65	27.73	30.51	31.33	29.60	27.33	26.51	27.52	28.73	28.38	28.52	28.34	28.43
2004	29.37	30.15	30.89	32.12	32.90	34.98	35.60	37.00	38.50	40.52	43.52	43.54	35.76
2005	42.68	41.38	42.28	46.24	48.80	49.80	50.79	52.70	57.38	59.98	60.59	58.31	50.91
2006	56.55	57.98	59.53	61.03	62.87	65.86	68.31	69.81	70.85	68.79	63.95	59.39	63.74
2007	59.01	57.55	57.36	57.23	61.07	63.61	66.14	68.98	70.64	73.50	76.29	83.36	66.23
2008	87.61	90.52	91.20	95.31	101.33	111.08	120.97	128.99	126.31	115.69	95.64	75.44	103.34
2009	56.00	46.39	42.35	44.12	46.26	51.69	59.19	63.99	68.48	68.22	71.35	73.33	57.61
2010	75.50	76.52	75.59	77.06	79.41	79.70	78.18	74.98	75.05	75.51	77.89	80.79	77.18
2011	85.42	89.08	93.54	99.75	107.60	110.99	110.05	107.28	104.75	103.08	100.39	102.03	101.16
2012	103.16	105.57	108.00	112.52	114.72	111.85	102.83	97.19	97.58	102.77	104.99	103.62	105.40
2013	101.92	102.49	104.64	105.09	103.00	100.25	99.32	101.46	104.39	107.39	107.45	105.61	103.58
2014	104.51	103.40	104.14	103.66	104.58	104.87	106.32	106.44	104.55	100.38	93.99	86.31	101.93
2015	74.59	61.60	54.20	51.58	55.05	57.63	60.45	59.39	53.78	48.77	46.31	45.45	55.73
2016	42.21	36.49	32.46	32.72	36.37	41.34	44.79	45.92	45.57	44.68	46.40	46.53	41.29
2017	49.06	50.49	53.52	52.95	52.47	50.98	49.41	47.91	47.92	50.18	52.60	55.93	51.12
2018	58.68	62.45	63.63	64.62	65.47	68.80	71.40	72.69	71.91	73.04	74.39	71.47	68.21
Montly Avg	44.31	43.63	43.54	44.29	45.47	46.62	47.35	47.81	46.95	47.14	46.88	46.15	

Table - 15:
3-Month Moving Average Model / Nominal Prices Forecast

Mean Error	0.27
MAD	4.05
MSE	45.73
MAPE	9.14%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.10	12.18	12.53	12.70
1989	13.12	13.96	15.00	16.38	17.52	17.90	18.22	18.13	17.55	17.46	17.66	17.84	16.73
1990	18.45	19.12	19.42	19.38	18.68	17.74	16.66	16.39	18.86	22.89	27.69	31.17	20.54
1991	31.10	28.57	24.48	21.23	19.31	18.37	18.32	18.57	18.79	19.10	19.99	20.42	21.52
1992	20.01	19.34	18.38	17.55	17.77	18.30	19.10	19.78	20.03	20.19	20.01	19.68	19.18
1993	19.26	18.53	18.05	17.95	18.07	18.31	18.14	17.60	17.11	16.54	16.31	16.03	17.66
1994	15.35	14.91	14.22	13.83	14.15	14.69	15.54	16.60	17.08	17.06	16.89	16.69	15.58
1995	16.42	16.60	16.84	16.90	17.58	17.96	17.95	17.63	17.08	16.68	16.37	16.54	17.05
1996	16.89	17.13	17.53	18.19	18.89	19.21	19.41	19.46	19.40	20.20	21.48	22.18	19.16
1997	22.97	23.21	22.42	21.65	20.22	19.25	18.63	18.38	18.58	18.40	18.93	19.12	20.15
1998	18.72	17.81	16.32	14.83	13.93	13.69	13.28	13.18	12.93	12.87	13.06	12.86	14.46
1999	12.34	11.75	11.12	11.44	12.81	13.96	15.37	16.83	17.93	19.59	20.98	22.27	15.53
2000	23.48	24.13	25.45	26.28	25.87	26.34	26.94	27.12	28.56	29.79	30.23	31.27	27.12
2001	30.25	28.72	27.68	25.86	25.99	26.38	26.32	26.26	26.29	25.70	24.14	22.61	26.35
2002	20.79	19.27	19.09	20.32	22.05	23.68	24.81	25.34	25.67	26.33	27.09	26.78	23.43
2003	27.06	27.68	29.02	30.47	29.89	28.72	27.48	27.03	28.06	28.27	28.54	28.67	28.41
2004	28.75	29.87	30.45	31.59	32.52	34.07	35.12	36.18	38.27	39.28	42.11	43.17	35.11
2005	42.41	42.76	42.24	44.44	47.34	48.56	50.83	52.18	55.00	58.46	59.54	59.20	50.25
2006	57.84	58.03	58.41	59.88	62.77	64.32	66.47	69.35	70.31	68.67	66.07	62.50	63.72
2007	59.79	57.64	57.55	58.17	59.19	62.10	64.75	68.00	69.27	72.17	75.62	80.05	65.36
2008	84.90	88.38	91.24	93.86	98.67	106.66	116.19	123.94	125.39	119.65	104.94	85.22	103.25
2009	66.92	52.97	45.25	43.42	45.66	49.23	56.06	60.56	65.90	68.45	69.68	72.90	58.08
2010	73.72	75.91	76.08	76.52	78.84	78.47	78.46	77.28	75.19	75.32	77.06	79.55	76.86
2011	83.10	87.24	91.29	97.32	103.87	107.72	109.70	109.52	105.58	103.77	102.27	101.64	100.25
2012	102.58	104.14	107.35	110.45	112.81	112.06	106.57	101.31	99.21	99.76	102.93	104.03	105.27
2013	103.01	102.72	103.78	104.11	103.53	102.10	100.12	100.81	103.13	105.48	106.90	106.25	103.49
2014	105.58	103.91	103.76	104.11	103.96	104.86	105.75	106.05	104.84	102.38	96.80	89.74	102.64
2015	79.91	67.72	59.90	53.86	53.07	56.92	58.55	58.93	55.96	51.91	48.32	45.51	57.54
2016	43.23	39.11	35.12	33.68	34.73	38.77	42.93	44.63	45.66	45.44	45.84	46.12	41.27
2017	48.05	50.19	51.46	52.87	52.75	51.83	49.78	48.97	48.42	49.18	51.37	54.44	50.77
2018	57.25	60.57	62.70	63.76	65.66	67.46	69.59	71.72	72.29	72.77	73.96	71.73	67.46
Montly Avg	44.77	44.06	43.72	44.01	44.94	45.99	46.90	47.59	46.82	46.99	46.93	46.41	

Table - 16:
4-Month Moving Average Model / Nominal Prices Forecast

Mean Error	-0.35
MAD	4.59
MSE	59.88
MAPE	10.39%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.10	12.18	12.53	12.70
1989	14.65	16.48	14.22	15.04	16.21	17.12	17.62	17.82	17.91	17.85	17.72	17.77	16.70
1990	18.06	18.51	18.96	19.05	18.74	18.44	17.76	17.23	18.37	20.78	23.77	26.19	19.65
1991	28.00	28.90	27.52	25.08	22.41	20.37	19.00	18.41	18.62	18.95	19.45	19.77	22.21
1992	19.74	19.47	19.17	18.74	18.27	18.06	18.57	19.03	19.37	19.82	20.06	19.96	19.19
1993	19.47	18.98	18.74	18.46	18.18	18.07	17.99	17.84	17.56	17.13	16.81	16.32	17.96
1994	15.70	15.33	14.88	14.50	14.26	14.44	15.01	15.64	16.17	16.60	16.83	16.97	15.53
1995	16.76	16.60	16.67	16.86	17.22	17.45	17.68	17.55	17.39	17.30	16.88	16.60	17.08
1996	16.68	16.97	17.18	17.61	18.36	18.75	18.86	19.15	19.61	20.09	20.58	21.13	18.75
1997	21.99	22.59	22.59	22.10	21.15	20.64	19.69	18.88	18.59	18.48	18.84	18.79	20.36
1998	18.65	18.10	17.33	16.41	15.32	14.47	13.71	13.32	13.05	13.17	13.13	12.77	14.95
1999	12.42	12.21	11.92	11.82	12.25	12.95	13.95	15.21	16.79	18.38	19.39	20.74	14.84
2000	22.20	23.25	24.41	25.21	25.46	25.96	26.72	27.20	27.54	28.30	29.62	30.48	26.36
2001	29.74	29.37	29.04	27.86	26.91	26.12	26.41	26.22	25.98	26.01	25.18	23.70	26.88
2002	22.30	21.35	20.38	20.12	20.90	22.07	23.06	24.16	25.29	26.07	26.42	26.23	23.19
2003	26.80	27.63	28.65	28.99	28.66	28.92	28.92	28.56	28.03	27.45	28.02	28.53	28.26
2004	28.88	29.34	29.61	30.75	31.53	32.94	33.86	34.95	36.74	38.06	40.26	41.02	33.99
2005	41.60	42.45	42.91	44.46	45.09	46.04	48.52	50.75	53.59	55.39	56.64	57.85	48.77
2006	58.27	59.28	58.92	58.79	60.42	62.70	64.67	66.34	68.36	68.55	66.88	65.12	63.19
2007	63.90	60.75	58.37	58.12	59.31	60.48	61.68	65.03	67.12	69.82	72.64	77.00	64.52
2008	80.55	83.40	87.28	91.46	95.92	101.14	108.14	115.16	118.69	118.33	112.32	100.87	101.11
2009	85.84	71.02	58.89	50.06	46.32	47.02	51.66	55.12	60.09	63.71	67.67	70.91	60.69
2010	71.86	73.94	74.46	76.28	77.97	77.64	77.62	77.20	77.37	76.84	76.43	77.92	76.29
2011	80.47	83.48	87.16	92.59	98.34	102.26	104.90	107.44	107.87	106.57	103.83	103.39	98.19
2012	103.12	102.98	105.01	107.84	110.14	109.92	107.67	105.95	104.72	102.80	101.09	100.60	105.15
2013	102.35	103.74	104.13	103.51	102.75	102.45	102.20	102.23	102.32	103.36	104.45	105.00	103.21
2014	105.95	105.43	104.87	104.09	103.99	104.51	104.99	105.51	104.71	103.35	100.22	95.43	103.59
2015	87.48	77.80	70.25	63.08	58.33	55.91	56.02	57.22	55.70	54.61	52.85	49.62	61.57
2016	45.49	41.40	38.96	37.47	36.43	36.90	38.76	41.15	43.46	44.74	46.16	46.05	41.41
2017	46.87	48.45	50.03	51.00	51.48	52.25	51.18	50.19	49.45	49.80	50.26	51.93	50.24
2018	54.43	57.53	59.78	61.65	63.96	66.21	68.01	69.08	70.35	72.22	73.54	71.69	65.70
Montly Avg	45.34	44.89	44.41	44.30	44.54	45.07	45.83	46.65	46.25	46.70	46.78	46.54	

Table - 17:
6-Month Moving Average Model / Nominal Prices Forecast

Mean Error	0.50
MAD	5.42
MSE	86.36
MAPE	12.35%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.10	12.18	12.53	12.70
1989	14.65	16.48	14.22	15.04	16.21	17.12	17.62	17.82	17.91	17.85	17.72	17.77	16.70
1990	18.06	18.51	18.96	19.05	18.74	18.44	17.76	17.23	18.37	20.78	23.77	26.19	19.65
1991	28.00	28.90	27.52	25.08	22.41	20.37	19.00	18.41	18.62	18.95	19.45	19.77	22.21
1992	19.74	19.47	19.17	18.74	18.27	18.06	18.57	19.03	19.37	19.82	20.06	19.96	19.19
1993	19.47	18.98	18.74	18.46	18.18	18.07	17.99	17.84	17.56	17.13	16.81	16.32	17.96
1994	15.70	15.33	14.88	14.50	14.26	14.44	15.01	15.64	16.17	16.60	16.83	16.97	15.53
1995	16.76	16.60	16.67	16.86	17.22	17.45	17.68	17.55	17.39	17.30	16.88	16.60	17.08
1996	16.68	16.97	17.18	17.61	18.36	18.75	18.86	19.15	19.61	20.09	20.58	21.13	18.75
1997	21.99	22.59	22.59	22.10	21.15	20.64	19.69	18.88	18.59	18.48	18.84	18.79	20.36
1998	18.65	18.10	17.33	16.41	15.32	14.47	13.71	13.32	13.05	13.17	13.13	12.77	14.95
1999	12.42	12.21	11.92	11.82	12.25	12.95	13.95	15.21	16.79	18.38	19.39	20.74	14.84
2000	22.20	23.25	24.41	25.21	25.46	25.96	26.72	27.20	27.54	28.30	29.62	30.48	26.36
2001	29.74	29.37	29.04	27.86	26.91	26.12	26.41	26.22	25.98	26.01	25.18	23.70	26.88
2002	22.30	21.35	20.38	20.12	20.90	22.07	23.06	24.16	25.29	26.07	26.42	26.23	23.19
2003	26.80	27.63	28.65	28.99	28.66	28.92	28.92	28.56	28.03	27.45	28.02	28.53	28.26
2004	28.88	29.34	29.61	30.75	31.53	32.94	33.86	34.95	36.74	38.06	40.26	41.02	33.99
2005	41.60	42.45	42.91	44.46	45.09	46.04	48.52	50.75	53.59	55.39	56.64	57.85	48.77
2006	58.27	59.28	58.92	58.79	60.42	62.70	64.67	66.34	68.36	68.55	66.88	65.12	63.19
2007	63.90	60.75	58.37	58.12	59.31	60.48	61.68	65.03	67.12	69.82	72.64	77.00	64.52
2008	80.55	83.40	87.28	91.46	95.92	101.14	108.14	115.16	118.69	118.33	112.32	100.87	101.11
2009	85.84	71.02	58.89	50.06	46.32	47.02	51.66	55.12	60.09	63.71	67.67	70.91	60.69
2010	71.86	73.94	74.46	76.28	77.97	77.64	77.62	77.20	77.37	76.84	76.43	77.92	76.29
2011	80.47	83.48	87.16	92.59	98.34	102.26	104.90	107.44	107.87	106.57	103.83	103.39	98.19
2012	103.12	102.98	105.01	107.84	110.14	109.92	107.67	105.95	104.72	102.80	101.09	100.60	105.15
2013	102.35	103.74	104.13	103.51	102.75	102.45	102.20	102.23	102.32	103.36	104.45	105.00	103.21
2014	105.95	105.43	104.87	104.09	103.99	104.51	104.99	105.51	104.71	103.35	100.22	95.43	103.59
2015	87.48	77.80	70.25	63.08	58.33	55.91	56.02	57.22	55.70	54.61	52.85	49.62	61.57
2016	45.49	41.40	38.96	37.47	36.43	36.90	38.76	41.15	43.46	44.74	46.16	46.05	41.41
2017	46.87	48.45	50.03	51.00	51.48	52.25	51.18	50.19	49.45	49.80	50.26	51.93	50.24
2018	54.43	57.53	59.78	61.65	63.96	66.21	68.01	69.08	70.35	66.93	68.75	68.95	60.62
Montly Avg	45.34	44.89	44.41	44.30	44.54	45.07	45.83	46.65	46.25	44.99	45.14	45.28	

Table - 18:
12-Month Moving Average Model / Nominal Prices Forecast

Mean Error	0.94
MAD	7.18
MSE	139.91
MAPE	16.00%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.01	12.93	12.89	12.96
1989	13.06	13.41	13.70	14.13	14.64	14.98	15.24	15.49	15.62	15.83	16.09	16.32	14.88
1990	16.62	16.99	17.25	17.35	17.27	17.20	17.01	17.02	17.96	19.44	20.94	21.96	18.08
1991	22.37	22.39	21.97	21.58	21.27	21.02	20.71	20.55	20.43	20.39	20.50	20.53	21.14
1992	20.25	19.96	19.73	19.50	19.41	19.42	19.56	19.62	19.62	19.68	19.72	19.63	19.68
1993	19.46	19.24	19.13	19.07	19.00	18.92	18.77	18.53	18.32	18.08	17.92	17.65	18.67
1994	17.26	16.95	16.63	16.33	16.21	16.21	16.31	16.47	16.52	16.49	16.49	16.55	16.53
1995	16.49	16.53	16.62	16.69	16.89	17.04	17.07	16.97	16.92	16.91	16.83	16.82	16.81
1996	16.93	17.02	17.08	17.32	17.65	17.79	17.86	18.04	18.28	18.67	19.17	19.49	17.94
1997	19.90	20.24	20.25	20.16	19.93	19.88	19.68	19.55	19.46	19.38	19.45	19.41	19.77
1998	19.18	18.76	18.30	17.78	17.35	17.02	16.56	16.18	15.81	15.61	15.37	15.02	16.91
1999	14.56	14.25	13.90	13.83	14.03	14.23	14.45	14.90	15.44	16.17	16.74	17.49	15.00
2000	18.25	18.95	19.78	20.55	20.84	21.48	22.29	22.88	23.52	24.38	25.08	25.80	21.98
2001	25.74	25.76	25.91	25.82	25.81	25.99	26.08	25.96	25.94	25.87	25.36	24.69	25.74
2002	24.07	23.58	23.22	23.26	23.48	23.70	23.78	23.97	24.25	24.66	24.94	24.90	23.99
2003	25.20	25.76	26.47	26.86	26.73	26.66	26.79	26.97	27.24	27.20	27.38	27.56	26.73
2004	27.80	28.16	28.47	28.99	29.46	30.27	30.80	31.51	32.57	33.47	34.81	35.54	30.99
2005	35.89	36.60	37.42	38.77	39.96	40.75	42.06	43.49	45.33	46.97	48.09	48.79	42.01
2006	49.55	50.84	51.73	52.65	54.18	55.63	56.90	58.45	59.79	60.02	59.81	59.64	55.76
2007	59.78	59.15	58.99	59.15	59.74	60.29	61.08	62.33	63.11	64.47	66.22	68.73	61.92
2008	70.81	72.80	74.86	77.56	80.68	84.87	89.54	93.87	95.94	96.31	93.95	89.95	85.09
2009	85.09	80.97	77.05	74.01	71.64	70.29	70.18	69.63	69.83	69.68	70.12	70.86	73.28
2010	71.26	71.85	72.14	72.86	73.99	74.15	74.21	74.25	74.41	74.58	75.29	76.21	73.77
2011	77.59	79.10	80.98	83.75	87.00	89.11	90.78	92.50	93.29	94.05	94.63	95.71	88.21
2012	96.56	97.61	99.12	100.98	102.25	102.44	101.27	100.81	101.26	101.76	101.93	101.85	100.65
2013	101.79	102.12	102.67	102.65	102.27	101.98	101.76	102.11	102.71	103.32	103.53	103.44	102.53
2014	103.64	103.49	103.62	103.67	103.79	103.98	104.42	104.50	104.05	103.23	101.52	99.07	103.25
2015	95.23	90.42	86.85	83.45	80.86	79.03	77.25	74.96	72.04	69.46	67.21	64.80	78.46
2016	61.98	58.76	55.98	54.12	52.78	52.10	51.66	50.91	50.30	49.78	49.73	49.28	53.11
2017	49.61	50.01	50.45	50.49	50.66	50.58	50.14	49.89	49.90	50.20	50.67	51.60	50.35
2018	52.56	53.93	54.88	55.81	57.11	58.74	60.06	61.32	62.30	63.61	64.92	64.66	59.16
Montly Avg	44.28	44.19	44.17	44.30	44.56	44.86	45.14	45.45	44.68	44.92	45.08	45.06	

Table - 19:
α = 0.1
Exponential Smoothing Model
Nominal Prices Forecast

Mean Error	1.39
MAD	7.20
MSE	135.03
MAPE	16.12%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.02	12.85	12.79	12.91
1989	13.16	13.82	14.33	15.07	15.90	16.32	16.58	16.80	16.82	16.99	17.27	17.49	15.88
1990	17.86	18.36	18.61	18.53	18.13	17.82	17.31	17.28	19.11	21.83	24.36	25.70	19.58
1991	25.79	25.15	23.74	22.61	21.78	21.19	20.54	20.24	20.07	20.06	20.34	20.43	21.83
1992	19.89	19.39	19.04	18.72	18.70	18.86	19.25	19.44	19.47	19.61	19.70	19.54	19.30
1993	19.22	18.82	18.69	18.64	18.60	18.52	18.31	17.91	17.62	17.28	17.13	16.74	18.12
1994	16.15	15.74	15.35	15.00	15.02	15.27	15.65	16.10	16.28	16.26	16.30	16.46	15.80
1995	16.36	16.46	16.66	16.79	17.17	17.42	17.41	17.14	17.01	16.97	16.80	16.79	16.91
1996	17.00	17.16	17.27	17.70	18.29	18.44	18.46	18.68	19.03	19.68	20.47	20.85	18.59
1997	21.40	21.77	21.50	21.07	20.43	20.22	19.76	19.47	19.32	19.19	19.36	19.30	20.23
1998	18.86	18.09	17.29	16.46	15.87	15.50	14.89	14.46	14.06	14.01	13.86	13.46	15.57
1999	12.85	12.57	12.21	12.40	13.09	13.69	14.23	15.18	16.20	17.50	18.39	19.54	14.82
2000	20.65	21.59	22.71	23.67	23.63	24.34	25.40	25.95	26.61	27.71	28.45	29.22	24.99
2001	28.42	27.93	27.79	27.24	26.93	27.06	27.04	26.59	26.44	26.19	25.10	23.82	26.71
2002	22.76	22.04	21.63	22.03	22.71	23.30	23.54	23.98	24.54	25.29	25.74	25.50	23.59
2003	25.98	26.93	28.12	28.57	27.97	27.59	27.65	27.84	28.21	27.94	28.16	28.35	27.77
2004	28.67	29.21	29.64	30.44	31.10	32.39	33.02	33.99	35.61	36.81	38.82	39.48	33.27
2005	39.40	40.11	41.05	43.03	44.55	45.21	46.94	48.83	51.44	53.49	54.43	54.55	46.92
2006	54.93	56.43	57.09	57.86	59.88	61.64	62.97	64.87	66.25	65.43	63.92	62.77	61.17
2007	62.41	60.63	60.02	60.13	61.12	61.93	63.18	65.26	66.24	68.34	71.07	75.12	64.62
2008	78.00	80.54	83.11	86.86	91.24	97.52	104.32	110.02	110.93	108.68	101.48	91.98	95.39
2009	81.85	74.25	67.77	63.55	60.89	60.34	62.11	62.62	64.42	65.21	66.98	69.09	66.59
2010	70.25	71.63	72.25	73.66	75.77	75.74	75.54	75.34	75.44	75.58	76.81	78.35	74.70
2011	80.68	83.08	86.05	90.57	95.70	98.18	99.71	101.35	101.18	101.11	100.86	101.77	95.02
2012	102.26	103.22	105.12	107.65	108.85	107.90	104.47	102.92	103.39	103.97	103.86	103.32	104.74
2013	102.89	103.34	104.20	103.86	102.86	102.16	101.68	102.39	103.55	104.59	104.76	104.33	103.38
2014	104.56	104.07	104.22	104.19	104.32	104.60	105.35	105.33	104.27	102.59	99.29	94.83	103.13
2015	88.00	79.82	74.82	70.42	67.84	66.78	65.68	63.41	59.87	57.15	55.11	52.71	66.80
2016	49.48	45.54	42.64	41.58	41.41	42.32	43.39	43.54	43.81	44.05	45.10	45.13	44.00
2017	46.63	48.02	49.29	49.61	50.12	50.07	49.29	48.97	49.16	49.92	50.92	52.72	49.56
2018	54.42	56.78	58.11	59.33	61.22	63.66	65.32	66.79	67.65	69.19	70.70	69.02	63.52
Montly Avg	44.69	44.42	44.34	44.57	45.04	45.53	45.97	46.42	45.71	45.99	46.08	45.84	

Table - 20:
α = 0.2
Exponential Smoothing Model
Nominal Prices Forecast

Mean Error	0.73
MAD	5.46
MSE	82.07
MAPE	12.44%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.03	12.78	12.70	12.88
1989	13.29	14.24	14.88	15.82	16.84	17.19	17.32	17.43	17.26	17.38	17.70	17.90	16.44
1990	18.33	18.94	19.14	18.86	18.17	17.69	16.97	17.03	19.84	23.70	26.94	28.18	20.31
1991	27.57	26.07	23.69	22.00	20.94	20.31	19.59	19.43	19.41	19.60	20.16	20.35	21.59
1992	19.57	18.91	18.52	18.20	18.33	18.68	19.33	19.58	19.59	19.76	19.86	19.56	19.16
1993	19.07	18.52	18.41	18.43	18.43	18.35	18.09	17.56	17.23	16.83	16.74	16.28	17.83
1994	15.53	15.11	14.71	14.38	14.59	15.10	15.72	16.37	16.56	16.45	16.46	16.64	15.63
1995	16.43	16.57	16.83	16.98	17.48	17.76	17.64	17.17	16.96	16.92	16.68	16.70	17.01
1996	17.05	17.27	17.40	18.00	18.80	18.88	18.77	19.01	19.44	20.29	21.28	21.62	18.98
1997	22.22	22.52	21.89	21.12	20.15	19.92	19.32	19.02	18.92	18.85	19.20	19.17	20.19
1998	18.55	17.48	16.47	15.46	14.87	14.62	13.98	13.60	13.26	13.42	13.38	12.93	14.83
1999	12.17	11.95	11.59	12.07	13.21	14.06	14.76	16.03	17.30	18.92	19.83	21.13	15.25
2000	22.32	23.22	24.42	25.34	24.78	25.50	26.74	27.17	27.80	29.08	29.78	30.54	26.39
2001	28.94	28.05	27.80	26.97	26.59	26.88	26.91	26.28	26.14	25.86	24.32	22.63	26.45
2002	21.40	20.72	20.50	21.44	22.64	23.55	23.83	24.41	25.12	26.07	26.51	25.92	23.51
2003	26.51	27.78	29.31	29.63	28.41	27.70	27.77	28.01	28.51	28.02	28.32	28.56	28.21
2004	28.98	29.70	30.19	31.23	31.98	33.65	34.22	35.32	37.35	38.62	41.10	41.41	34.48
2005	40.70	41.38	42.41	44.97	46.67	47.02	49.08	51.27	54.45	56.62	57.09	56.48	49.01
2006	56.46	58.26	58.69	59.36	61.95	63.97	65.26	67.42	68.74	66.75	64.10	62.31	62.77
2007	61.91	59.40	58.85	59.37	61.08	62.30	64.07	66.93	67.89	70.55	73.98	79.19	65.46
2008	82.29	84.81	87.38	91.72	96.83	104.57	112.66	118.71	117.47	112.12	100.29	86.40	99.60
2009	72.88	64.17	57.47	54.23	53.04	54.57	58.95	60.66	63.95	65.27	67.91	70.81	61.99
2010	72.03	73.56	73.92	75.53	78.13	77.37	76.58	75.98	75.94	75.99	77.71	79.76	76.04
2011	82.83	85.79	89.43	95.19	101.51	103.48	104.19	105.31	103.86	102.95	102.02	103.04	98.30
2012	103.39	104.50	106.96	110.21	111.24	109.10	103.59	101.54	102.66	103.74	103.64	102.90	105.29
2013	102.39	103.20	104.53	103.93	102.41	101.49	100.97	102.26	104.03	105.45	105.44	104.60	103.39
2014	104.86	104.03	104.27	104.20	104.40	104.80	105.87	105.68	103.99	101.55	96.91	90.93	102.62
2015	81.86	71.44	66.44	62.36	60.91	61.39	61.37	59.26	55.19	52.52	50.85	48.53	61.01
2016	44.94	40.39	37.58	37.51	38.48	40.72	42.81	43.21	43.71	44.11	45.66	45.54	42.06
2017	47.67	49.44	50.91	50.91	51.29	50.87	49.46	48.92	49.22	50.34	51.72	54.18	50.41
2018	56.28	59.27	60.52	61.62	63.77	66.67	68.26	69.58	70.03	71.63	73.16	69.91	65.89
Montly Avg	44.61	44.22	44.17	44.57	45.26	45.94	46.47	47.00	46.28	46.53	46.50	46.02	

Table - 21:
α = 0.3
Exponential Smoothing Model
Nominal Prices Forecast

Mean Error	0.48
MAD	4.59
MSE	59.40
MAPE	10.48%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									13.00	13.04	12.70	12.63	12.84
1989	13.44	14.65	15.33	16.41	17.53	17.72	17.69	17.68	17.36	17.48	17.86	18.06	16.77
1990	18.58	19.29	19.41	18.94	17.98	17.42	16.56	16.80	20.64	25.47	29.08	29.88	20.84
1991	28.38	26.06	22.89	20.96	19.96	19.51	18.88	18.95	19.12	19.49	20.28	20.48	21.25
1992	19.39	18.58	18.20	17.90	18.19	18.71	19.56	19.80	19.73	19.90	19.97	19.53	19.12
1993	18.89	18.22	18.20	18.31	18.36	18.28	17.96	17.30	16.97	16.54	16.53	16.00	17.63
1994	15.11	14.72	14.34	14.05	14.46	15.19	15.98	16.74	16.84	16.59	16.54	16.76	15.61
1995	16.43	16.62	16.94	17.10	17.72	18.00	17.74	17.08	16.84	16.83	16.55	16.62	17.04
1996	17.12	17.39	17.52	18.27	19.23	19.16	18.90	19.18	19.68	20.71	21.87	22.08	19.26
1997	22.70	22.91	21.91	20.88	19.68	19.56	18.90	18.67	18.68	18.67	19.22	19.17	20.08
1998	18.34	17.00	15.84	14.75	14.25	14.16	13.49	13.17	12.90	13.26	13.26	12.71	14.43
1999	11.79	11.65	11.29	12.04	13.57	14.57	15.30	16.77	18.17	19.98	20.77	22.13	15.67
2000	23.32	24.11	25.36	26.21	25.11	25.94	27.41	27.72	28.34	29.83	30.46	31.21	27.09
2001	28.80	27.67	27.50	26.51	26.19	26.73	26.83	26.02	25.94	25.65	23.68	21.68	26.10
2002	20.42	19.91	19.94	21.42	23.02	24.08	24.25	24.85	25.62	26.68	27.02	26.03	23.60
2003	26.77	28.36	30.17	30.25	28.37	27.45	27.64	28.02	28.68	27.96	28.38	28.68	28.39
2004	29.19	30.06	30.57	31.81	32.57	34.57	34.96	36.13	38.51	39.75	42.60	42.41	35.26
2005	41.06	41.83	43.02	46.19	47.97	47.91	50.30	52.73	56.39	58.51	58.38	57.05	50.11
2006	56.80	59.06	59.32	59.96	63.17	65.37	66.54	68.90	70.07	66.89	63.30	61.23	63.38
2007	61.14	58.09	57.88	58.97	61.40	62.91	65.02	68.45	69.12	72.18	76.09	82.19	66.12
2008	85.12	87.35	89.77	94.60	100.26	109.21	118.13	124.01	120.24	112.01	96.28	79.36	101.36
2009	64.15	56.03	50.36	48.87	49.44	52.92	59.41	61.52	65.56	66.68	69.64	72.80	59.78
2010	73.63	75.03	74.92	76.67	79.68	78.05	76.72	75.87	75.85	75.96	78.26	80.77	76.78
2011	84.47	87.76	91.82	98.55	105.63	106.60	106.30	106.95	104.37	102.95	101.71	103.19	100.02
2012	103.61	104.99	108.07	111.96	112.64	109.22	101.83	99.80	101.99	103.70	103.59	102.62	105.33
2013	102.05	103.27	105.02	104.02	101.95	100.92	100.45	102.37	104.69	106.32	105.96	104.63	103.47
2014	104.97	103.82	104.23	104.15	104.44	104.95	106.32	105.88	103.55	100.47	94.71	87.62	102.09
2015	76.85	64.96	60.89	57.67	57.62	59.57	60.27	57.90	53.01	50.32	48.98	46.63	57.89
2016	42.61	37.48	34.90	35.87	37.82	41.07	43.72	43.88	44.28	44.59	46.47	45.98	41.56
2017	48.64	50.62	52.11	51.63	51.84	51.06	49.10	48.53	49.09	50.64	52.35	55.38	50.92
2018	57.70	61.11	62.05	62.90	65.26	68.53	69.91	71.01	71.04	72.77	74.35	69.54	67.18
Montly Avg	44.38	43.95	43.99	44.59	45.51	46.31	46.87	47.42	46.65	46.83	46.67	45.97	

Table - 22:
α = 0.4
Exponential Smoothing Model
Nominal Prices Forecast

Mean Error	0.35
MAD	4.03
MSE	46.10
MAPE	9.15%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.92	25.96	26.86	27.13
1989	27.96	30.48	32.65	34.47	36.31	37.44	37.17	36.13	35.36	35.39	35.90	36.91	34.68
1990	38.05	38.65	38.80	37.40	34.96	33.02	31.12	31.52	37.83	49.04	60.18	63.19	41.14
1991	58.96	50.71	41.92	36.27	33.73	34.16	34.07	34.43	34.77	36.08	37.57	38.43	39.26
1992	37.01	34.18	31.91	31.42	32.16	33.29	35.31	36.24	36.31	35.90	35.85	35.40	34.58
1993	34.07	32.06	31.32	31.32	32.03	32.03	31.44	30.22	29.23	28.32	28.44	27.69	30.68
1994	26.45	24.86	23.83	23.55	24.09	25.50	27.52	29.11	29.51	28.96	28.16	28.21	26.65
1995	28.06	28.04	27.96	28.49	29.46	30.01	30.01	28.60	27.52	27.22	27.24	27.39	28.33
1996	27.97	28.62	28.87	29.40	30.94	31.66	31.19	30.61	31.35	33.36	35.51	36.56	31.34
1997	37.29	36.80	35.50	32.97	30.17	29.62	28.89	29.12	28.77	29.16	30.05	30.26	31.55
1998	29.44	26.68	23.95	21.77	20.99	20.96	20.63	20.21	19.42	20.10	20.39	20.08	22.05
1999	18.33	17.26	16.56	17.84	20.07	22.75	24.37	25.95	28.07	31.25	32.75	34.71	24.16
2000	35.92	37.20	38.30	39.05	38.15	38.14	39.18	41.47	42.49	43.69	45.26	46.76	40.47
2001	43.40	40.39	37.54	37.12	37.00	37.15	38.07	37.64	36.82	35.98	34.05	30.67	37.15
2002	27.49	26.60	27.07	29.32	32.25	34.91	35.31	35.46	35.98	37.75	38.58	37.53	33.19
2003	37.35	38.53	42.09	42.93	40.56	37.44	36.33	37.71	39.36	38.89	39.08	38.82	39.09
2004	40.24	40.94	41.58	42.87	43.91	46.68	47.52	49.37	51.39	54.08	58.08	58.10	47.90
2005	56.96	54.60	55.14	59.69	62.99	64.29	65.56	68.02	74.07	77.43	78.21	75.26	66.02
2006	73.00	74.00	75.20	76.32	78.61	82.36	85.43	87.29	88.60	86.03	79.97	74.27	80.09
2007	73.80	71.35	70.45	69.59	74.27	77.35	80.43	83.89	85.91	89.38	92.77	101.37	80.88
2008	106.54	108.71	108.14	111.60	118.65	130.06	141.65	151.04	147.90	135.46	111.99	88.33	121.67
2009	65.57	54.38	49.71	51.85	54.37	60.75	69.57	75.21	80.49	80.17	83.86	86.18	67.68
2010	88.74	89.43	87.85	89.07	91.79	92.12	90.36	86.66	86.75	87.28	90.03	93.38	89.46
2011	98.74	101.88	105.90	111.81	120.61	124.41	123.36	120.25	117.42	115.54	112.53	114.37	113.90
2012	115.64	117.52	119.38	123.54	125.96	122.81	112.91	106.71	107.15	112.84	115.27	113.77	116.13
2013	111.91	111.97	113.76	113.70	111.45	108.46	107.46	109.77	112.94	116.20	116.26	114.26	112.35
2014	113.08	111.30	111.51	110.40	111.38	111.70	113.23	113.36	111.35	106.91	100.11	91.92	108.85
2015	79.44	65.59	57.68	54.86	58.56	61.30	64.31	63.17	57.21	51.88	49.26	48.35	59.30
2016	44.90	38.68	34.26	34.37	38.21	43.43	47.05	48.24	47.86	46.94	48.74	48.88	43.46
2017	51.53	52.65	55.43	54.46	53.97	52.44	50.82	49.27	49.29	51.62	54.11	57.53	52.76
2018	60.36	63.60	64.21	64.62	65.47	68.80	71.40	72.69	71.91	73.04	74.39	71.47	68.50
Montly Avg	56.27	54.92	54.28	54.74	56.10	57.50	58.39	58.98	58.41	58.83	58.73	57.97	

Table - 23:
3-Month Moving Average Model / Inflation-adjusted Prices Forecast

Mean Error	0.19
MAD	4.95
MSE	64.03
MAPE	9.02%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.92	25.96	26.70	27.10
1989	27.95	29.35	31.17	33.66	35.61	36.39	37.04	36.86	35.68	35.50	35.90	36.26	34.28
1990	37.52	38.35	38.44	37.89	36.03	34.21	32.12	31.62	36.37	44.14	53.41	60.12	40.02
1991	59.99	54.67	46.43	39.80	35.75	34.01	33.91	34.37	34.78	35.35	36.99	37.79	40.32
1992	37.04	35.57	33.55	31.77	31.93	32.88	34.32	35.55	35.99	36.28	35.95	35.37	34.68
1993	34.61	33.07	31.97	31.55	31.53	31.94	31.64	30.70	29.85	28.86	28.45	27.96	31.01
1994	26.78	25.85	24.50	23.67	24.07	24.99	26.43	28.24	29.06	29.02	28.73	28.39	26.64
1995	27.94	28.04	28.24	28.15	29.08	29.71	29.68	29.16	28.26	27.60	27.08	27.36	28.36
1996	27.94	28.13	28.57	29.44	30.35	30.86	31.18	31.26	31.17	32.46	34.51	35.63	30.96
1997	36.91	37.09	35.62	34.22	31.75	30.24	29.25	28.86	29.18	28.91	29.74	30.04	31.82
1998	29.40	27.88	25.46	23.04	21.54	21.17	20.54	20.38	19.99	19.90	20.20	19.89	22.45
1999	19.08	18.07	17.01	17.40	19.38	21.13	23.26	25.46	27.13	29.64	31.74	33.70	23.58
2000	35.53	36.20	37.86	38.78	37.88	38.57	39.44	39.70	41.82	43.61	44.26	45.78	39.95
2001	44.29	41.79	39.99	37.06	36.99	37.56	37.46	37.38	37.42	36.58	34.36	32.19	37.76
2002	29.59	27.33	26.95	28.58	30.90	33.18	34.76	35.50	35.98	36.89	37.96	37.53	32.93
2003	37.92	38.55	40.16	41.96	40.95	39.34	37.64	37.04	38.45	38.73	39.10	39.28	39.09
2004	39.38	40.64	41.16	42.42	43.40	45.47	46.87	48.28	51.07	52.42	56.20	57.62	47.08
2005	56.60	56.59	55.41	57.79	61.11	62.68	65.61	67.36	70.99	75.46	76.85	76.42	65.24
2006	74.66	74.28	74.16	75.45	78.49	80.43	83.12	86.72	87.92	85.87	82.62	78.15	80.16
2007	74.77	71.62	71.01	71.26	71.98	75.51	78.75	82.70	84.24	87.77	91.96	97.35	79.91
2008	103.24	106.46	108.87	110.91	115.54	124.88	136.05	145.12	146.82	140.10	122.87	99.79	121.72
2009	78.35	62.07	53.08	50.99	53.66	57.86	65.88	71.18	77.45	80.45	81.90	85.68	68.21
2010	86.64	88.84	88.68	88.81	91.13	90.70	90.69	89.32	86.91	87.06	89.08	91.95	89.15
2011	96.05	100.03	103.85	109.87	116.44	120.75	122.97	122.77	118.35	116.32	114.64	113.94	113.00
2012	114.98	116.12	119.07	121.87	123.86	123.04	117.01	111.24	108.93	109.53	113.01	114.23	116.08
2013	113.11	112.36	113.09	113.05	112.01	110.46	108.33	109.07	111.59	114.13	115.67	114.95	112.32
2014	114.23	112.00	111.39	111.33	110.72	111.68	112.63	112.94	111.66	109.04	103.10	95.58	109.69
2015	85.10	72.11	63.76	57.31	56.45	60.54	62.28	62.68	59.53	55.21	51.40	48.41	61.23
2016	45.98	41.50	37.16	35.50	36.48	40.72	45.09	46.88	47.96	47.73	48.15	48.44	43.47
2017	50.48	52.43	53.46	54.66	54.26	53.31	51.20	50.37	49.80	50.58	52.83	55.99	52.45
2018	58.88	61.82	63.57	64.20	65.66	67.46	69.59	71.72	72.29	72.77	73.96	71.37	67.78
Montly Avg	56.83	55.63	54.79	54.75	55.50	56.72	57.83	58.68	58.21	58.57	58.66	58.19	

Table - 24:
4-Month Moving Average Model / Inflation-adjusted Prices Forecast

Mean Error	0.24
MAD	5.63
MSE	84.22
MAPE	10.32%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.92	25.96	26.70	27.10
1989	31.22	33.24	29.76	31.21	33.39	35.05	35.82	36.22	36.40	36.28	36.02	36.13	34.23
1990	36.72	37.27	37.85	37.72	36.80	35.91	34.26	33.24	35.42	40.08	45.85	50.51	38.47
1991	54.00	55.45	52.55	47.62	42.22	38.04	35.17	34.08	34.46	35.07	36.00	36.60	41.77
1992	36.54	35.87	35.17	34.21	33.17	32.60	33.36	34.20	34.80	35.61	36.04	35.86	34.79
1993	34.99	33.95	33.36	32.70	32.04	31.67	31.38	31.12	30.63	29.88	29.33	28.46	31.63
1994	27.39	26.65	25.76	25.00	24.47	24.67	25.53	26.60	27.51	28.24	28.63	28.86	26.61
1995	28.51	28.10	28.09	28.28	28.75	28.98	29.25	29.03	28.76	28.62	27.92	27.46	28.48
1996	27.60	27.93	28.13	28.69	29.78	30.27	30.30	30.77	31.51	32.27	33.06	33.96	30.36
1997	35.32	36.16	36.03	35.13	33.49	32.56	30.93	29.65	29.20	29.02	29.59	29.51	32.22
1998	29.30	28.36	27.10	25.60	23.83	22.45	21.20	20.60	20.19	20.36	20.30	19.75	23.25
1999	19.21	18.83	18.32	18.08	18.67	19.65	21.10	23.01	25.41	27.81	29.35	31.39	22.57
2000	33.59	34.97	36.50	37.48	37.67	38.22	39.11	39.81	40.31	41.43	43.37	44.62	38.92
2001	43.54	42.82	42.15	40.26	38.70	37.34	37.59	37.32	36.98	37.03	35.84	33.74	38.61
2002	31.74	30.33	28.87	28.41	29.43	30.99	32.31	33.86	35.44	36.53	37.02	36.75	32.64
2003	37.55	38.56	39.81	40.14	39.54	39.76	39.63	39.13	38.40	37.61	38.40	39.09	38.97
2004	39.56	40.01	40.20	41.55	42.43	44.13	45.19	46.64	49.03	50.80	53.73	54.74	45.67
2005	55.52	56.34	56.62	58.33	58.80	59.71	62.62	65.51	69.18	71.49	73.12	74.67	63.49
2006	75.21	76.11	75.23	74.66	76.31	78.78	80.87	82.95	85.48	85.73	83.63	81.43	79.70
2007	79.91	75.66	72.36	71.69	72.81	73.90	75.01	79.08	81.63	84.90	88.33	93.64	79.08
2008	97.96	100.74	104.75	109.07	113.68	119.10	126.62	134.85	138.98	138.55	131.51	118.12	119.49
2009	100.52	83.19	69.02	58.71	54.37	55.23	60.71	64.79	70.62	74.87	79.53	83.33	71.24
2010	84.46	86.65	87.02	88.91	90.61	89.99	89.72	89.23	89.44	88.82	88.35	90.07	88.60
2011	93.01	95.96	99.64	105.28	111.25	115.15	117.59	120.43	120.92	119.45	116.39	115.89	110.91
2012	115.59	115.02	116.87	119.59	121.74	121.09	118.22	116.34	114.98	112.87	110.99	110.46	116.15
2013	112.37	113.62	113.77	112.81	111.71	111.11	110.58	110.61	110.70	111.83	113.02	113.60	112.14
2014	114.64	113.78	112.89	111.74	111.34	111.60	111.82	112.37	111.52	110.07	106.74	101.64	110.85
2015	93.18	82.85	74.80	67.15	62.07	59.49	59.58	60.87	59.25	58.09	56.22	52.78	65.53
2016	48.39	43.97	41.30	39.63	38.44	38.84	40.71	43.22	45.65	46.99	48.49	48.37	43.67
2017	49.23	50.69	52.15	52.99	53.31	53.94	52.64	51.62	50.87	51.22	51.69	53.41	51.98
2018	55.99	58.85	60.87	62.49	64.54	66.50	68.01	69.08	70.35	72.22	73.54	71.69	66.18
Montly Avg	57.43	56.73	55.90	55.50	55.51	55.89	56.56	57.54	57.48	58.12	58.32	58.17	

Table - 25: 6-Month Moving Average Model / Inflation-adjusted Prices Forecast

Mean Error	0.34
MAD	6.64
MSE	119.32
MAPE	12.30%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.92	25.96	26.70	27.10
1989	31.22	33.50	33.24	36.66	39.03	36.64	35.84	35.92	33.08	33.75	34.70	35.59	34.93
1990	36.27	36.75	37.13	37.00	36.41	36.02	35.49	35.25	36.64	38.90	41.33	43.21	37.53
1991	44.13	44.34	43.99	43.85	44.04	44.27	44.58	44.76	43.51	41.34	39.11	37.32	42.94
1992	35.86	34.98	34.82	34.64	34.58	34.60	34.95	35.04	34.99	34.91	34.61	34.23	34.85
1993	34.18	34.08	34.08	34.15	34.04	33.76	33.19	32.54	32.00	31.29	30.69	30.07	32.84
1994	29.39	28.88	28.20	27.44	26.90	26.57	26.46	26.62	26.64	26.62	26.55	26.77	27.25
1995	27.02	27.35	27.80	28.26	28.69	28.92	28.88	28.56	28.42	28.45	28.33	28.22	28.24
1996	28.42	28.48	28.45	28.65	28.85	28.86	28.95	29.35	29.82	30.48	31.42	32.11	29.49
1997	32.81	33.47	33.77	33.70	33.28	33.26	33.13	32.90	32.61	32.08	31.54	31.04	32.80
1998	30.11	29.01	28.15	27.31	26.71	25.98	25.25	24.48	23.65	22.98	22.07	21.10	25.57
1999	20.21	19.71	19.25	19.22	19.48	19.70	20.16	20.92	21.86	22.95	24.01	25.52	21.08
2000	27.34	28.99	30.96	32.65	33.51	34.80	36.35	37.39	38.41	39.46	40.52	41.42	35.15
2001	41.33	41.32	41.23	40.84	41.03	40.98	40.57	40.07	39.57	38.64	37.27	35.54	39.87
2002	34.67	33.82	32.92	32.72	32.64	32.37	32.03	32.09	32.16	32.47	33.22	33.87	32.91
2003	34.93	36.21	37.63	38.33	38.28	38.26	38.59	38.84	39.11	38.87	38.97	39.43	38.12
2004	39.59	39.57	39.30	39.58	40.41	41.61	42.38	43.33	44.62	46.18	48.08	49.44	42.84
2005	50.36	51.49	52.83	54.56	56.26	57.23	59.07	60.92	62.90	64.91	65.96	67.19	58.64
2006	68.92	70.81	72.21	73.08	74.71	76.72	78.04	79.53	80.36	80.19	79.97	80.11	76.22
2007	80.39	79.31	78.92	78.71	78.22	77.67	77.46	77.37	76.99	78.30	80.57	83.77	78.97
2008	86.49	89.91	93.19	96.99	101.01	106.37	112.29	117.79	121.87	123.81	122.60	118.61	107.58
2009	113.57	109.02	104.00	98.63	92.94	86.67	80.61	73.99	69.82	66.79	66.95	69.28	86.02
2010	72.58	75.72	78.82	81.89	85.07	86.66	87.09	87.94	88.23	88.86	89.48	90.03	84.36
2011	91.36	92.59	94.54	97.05	99.80	102.61	105.30	108.20	110.28	112.36	113.82	115.52	103.62
2012	116.59	117.73	118.89	119.52	119.06	118.49	116.91	115.68	115.93	116.23	116.37	115.78	117.27
2013	115.30	114.98	114.37	112.84	111.35	110.79	111.48	112.12	112.24	112.32	112.36	112.36	112.71
2014	112.61	112.20	111.79	111.78	112.18	112.60	113.23	113.08	112.20	110.91	109.04	106.62	111.52
2015	102.50	97.61	93.16	88.61	84.40	80.56	76.38	71.86	67.03	62.62	59.14	56.13	78.33
2016	53.99	52.42	50.28	48.86	47.33	45.81	44.55	43.60	43.47	43.31	43.47	43.61	46.72
2017	44.97	46.96	48.90	49.99	50.90	51.15	50.94	51.16	51.51	52.11	52.50	53.67	50.40
2018	54.31	55.24	55.87	56.85	58.11	59.96	62.00	63.97	65.61	67.35	69.04	69.10	61.45
Montly Avg	56.38	56.55	56.62	56.81	56.97	57.00	57.07	57.18	56.24	56.37	56.44	56.56	

Table - 26:
12-Month Moving Average Model / Inflation-adjusted Prices Forecast

Mean Error	0.62
MAD	8.63
MSE	184.99
MAPE	15.91%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.81	27.63	27.53	27.69
1989	27.90	28.46	28.94	29.71	30.64	31.24	31.70	32.13	32.34	32.70	33.18	33.59	31.05
1990	34.17	34.68	34.99	35.01	34.70	34.43	33.93	33.85	35.55	38.31	41.13	43.01	36.15
1991	43.75	43.56	42.56	41.64	40.90	40.29	39.58	39.15	38.82	38.65	38.76	38.73	40.53
1992	38.14	37.45	36.87	36.32	36.03	35.93	36.08	36.10	36.02	36.03	36.04	35.83	36.40
1993	35.47	34.92	34.60	34.36	34.14	33.90	33.56	33.05	32.62	32.13	31.80	31.27	33.49
1994	30.55	29.90	29.25	28.64	28.34	28.28	28.37	28.58	28.61	28.50	28.46	28.52	28.83
1995	28.38	28.33	28.38	28.41	28.66	28.84	28.83	28.60	28.47	28.40	28.23	28.18	28.48
1996	28.31	28.34	28.35	28.63	29.09	29.24	29.29	29.51	29.84	30.44	31.19	31.67	29.49
1997	32.29	32.71	32.65	32.42	31.99	31.83	31.46	31.20	31.01	30.84	30.91	30.81	31.68
1998	30.42	29.70	28.91	28.05	27.33	26.77	26.02	25.38	24.78	24.43	24.04	23.47	26.61
1999	22.74	22.19	21.60	21.43	21.69	21.95	22.24	22.89	23.67	24.73	25.58	26.68	23.12
2000	27.81	28.73	29.85	30.89	31.23	32.09	33.22	34.02	34.90	36.11	37.10	38.12	32.84
2001	38.00	37.89	37.98	37.74	37.63	37.79	37.85	37.59	37.51	37.35	36.56	35.57	37.46
2002	34.65	33.87	33.28	33.26	33.50	33.75	33.81	34.03	34.38	34.91	35.27	35.19	34.16
2003	35.58	36.23	37.11	37.56	37.31	37.15	37.26	37.45	37.77	37.68	37.88	38.08	37.25
2004	38.38	38.73	39.04	39.63	40.16	41.16	41.79	42.67	44.01	45.17	46.91	47.84	42.12
2005	48.26	48.98	49.87	51.46	52.85	53.74	55.32	57.07	59.35	61.38	62.75	63.58	55.38
2006	64.51	65.87	66.75	67.69	69.42	71.07	72.50	74.31	75.86	76.04	75.68	75.38	71.26
2007	75.47	74.43	73.99	73.96	74.48	74.95	75.75	77.12	77.94	79.48	81.50	84.46	76.96
2008	86.90	88.83	90.88	93.72	97.08	101.73	106.96	111.82	114.05	114.31	111.39	106.57	102.02
2009	100.76	95.84	91.17	87.54	84.69	83.06	82.88	82.19	82.39	82.18	82.67	83.52	86.57
2010	83.97	84.49	84.68	85.38	86.57	86.65	86.63	86.58	86.69	86.82	87.58	88.60	86.22
2011	90.14	91.52	93.34	96.19	99.60	101.75	103.44	105.19	105.94	106.65	107.17	108.27	100.77
2012	109.13	109.97	111.35	113.15	114.31	114.31	112.84	112.18	112.52	112.94	113.00	112.81	112.38
2013	112.64	112.75	113.12	112.90	112.30	111.82	111.43	111.68	112.21	112.76	112.89	112.71	112.43
2014	112.85	112.44	112.36	112.20	112.15	112.20	112.52	112.47	111.88	110.90	108.98	106.28	111.44
2015	102.12	96.92	93.05	89.37	86.55	84.55	82.61	80.13	76.98	74.20	71.78	69.19	83.95
2016	66.16	62.67	59.66	57.62	56.14	55.35	54.82	53.98	53.29	52.70	52.60	52.10	56.42
2017	52.41	52.69	53.01	52.94	53.01	52.84	52.31	51.98	51.92	52.17	52.60	53.51	52.62
2018	54.45	55.63	56.41	57.19	58.35	59.86	61.07	62.23	63.11	64.34	65.58	65.25	60.29
Montly Avg	56.21	55.96	55.80	55.83	56.03	56.28	56.54	56.84	56.20	56.49	56.67	56.66	

Table - 27:
α = 0.1
Exponential Smoothing Model / Inflation-adjusted Prices Forecast

Mean Error	1.00
MAD	8.60
MSE	175.96
MAPE	16.01%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.82	27.45	27.30	27.59
1989	28.08	29.17	29.98	31.32	32.86	33.62	34.06	34.43	34.41	34.71	35.26	35.68	32.80
1990	36.41	36.98	37.14	36.74	35.78	35.02	33.91	33.75	37.18	42.36	47.20	49.75	38.52
1991	49.88	48.26	45.32	42.95	41.19	39.92	38.58	37.91	37.50	37.42	37.89	38.00	41.24
1992	36.97	35.82	34.99	34.26	34.11	34.29	34.92	35.18	35.20	35.40	35.54	35.21	35.16
1993	34.61	33.70	33.30	33.08	32.90	32.66	32.22	31.47	30.93	30.29	30.00	29.30	32.04
1994	28.25	27.40	26.61	25.92	25.87	26.23	26.83	27.55	27.82	27.77	27.82	28.06	27.18
1995	27.87	27.89	28.08	28.20	28.73	29.08	29.01	28.53	28.27	28.18	27.88	27.84	28.30
1996	28.18	28.27	28.30	28.88	29.74	29.92	29.88	30.20	30.73	31.74	32.98	33.58	30.20
1997	34.45	34.86	34.30	33.51	32.43	32.03	31.25	30.76	30.48	30.25	30.49	30.39	32.10
1998	29.68	28.39	27.07	25.71	24.75	24.14	23.17	22.46	21.84	21.74	21.49	20.87	24.28
1999	19.91	19.39	18.77	19.00	20.00	20.86	21.65	23.07	24.59	26.54	27.88	29.61	22.61
2000	31.29	32.44	33.92	35.19	35.02	35.98	37.46	38.22	39.14	40.70	41.76	42.87	37.00
2001	41.68	40.73	40.34	39.40	38.84	38.91	38.81	38.11	37.84	37.45	35.86	34.01	38.50
2002	32.48	31.35	30.68	31.17	32.06	32.84	33.14	33.73	34.49	35.52	36.13	35.78	33.28
2003	36.44	37.58	39.07	39.58	38.67	38.07	38.11	38.32	38.79	38.40	38.67	38.91	38.38
2004	39.34	39.85	40.24	41.18	41.94	43.58	44.35	45.59	47.71	49.27	51.93	52.79	44.81
2005	52.65	53.21	54.14	56.46	58.25	58.94	61.07	63.41	66.70	69.29	70.45	70.57	61.26
2006	71.03	72.44	72.88	73.55	75.84	77.85	79.36	81.60	83.24	82.13	80.19	78.69	77.40
2007	78.21	75.58	74.47	74.31	75.27	76.07	77.44	79.85	80.94	83.42	86.67	91.55	79.48
2008	95.02	97.25	99.67	103.59	108.34	115.39	123.11	129.60	130.51	127.74	119.22	108.01	113.12
2009	96.09	87.18	79.58	74.63	71.52	70.89	72.96	73.57	75.70	76.62	78.71	81.20	78.22
2010	82.56	83.88	84.38	85.84	88.13	87.99	87.67	87.37	87.43	87.54	88.92	90.68	86.87
2011	93.35	95.46	98.32	103.01	108.47	111.01	112.53	114.22	113.91	113.73	113.37	114.33	107.64
2012	114.83	115.37	117.05	119.50	120.56	119.31	115.37	113.54	113.95	114.50	114.31	113.66	116.00
2013	113.15	113.27	113.91	113.31	112.04	111.13	110.49	111.17	112.34	113.41	113.54	113.04	112.57
2014	113.26	112.36	112.21	111.93	111.89	112.03	112.70	112.58	111.38	109.52	105.95	101.16	110.58
2015	93.86	85.11	79.74	75.03	72.27	71.11	69.93	67.51	63.73	60.83	58.65	56.09	71.16
2016	52.65	48.38	45.22	44.02	43.78	44.67	45.76	45.88	46.13	46.37	47.45	47.47	46.48
2017	49.03	50.25	51.38	51.57	51.99	51.85	50.98	50.59	50.74	51.49	52.49	54.32	51.39
2018	56.04	58.08	59.16	60.16	61.89	64.19	65.75	67.13	67.92	69.41	70.87	69.16	64.15
Montly Avg	56.58	56.00	55.67	55.77	56.17	56.65	57.08	57.58	57.08	57.47	57.65	57.42	

Table - 28:
α = 0.2
Exponential Smoothing Model / Inflation-adjusted Prices Forecast

Mean Error	0.53
MAD	6.63
MSE	110.57
MAPE	12.36%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.83	27.27	27.10	27.50
1989	28.34	29.89	30.89	32.62	34.55	35.17	35.37	35.54	35.17	35.40	36.01	36.41	33.78
1990	37.29	37.88	37.86	37.04	35.51	34.45	32.95	33.00	38.38	45.79	52.01	54.39	39.71
1991	53.20	49.78	44.91	41.47	39.29	37.95	36.52	36.14	36.06	36.37	37.38	37.70	40.56
1992	36.25	34.74	33.82	33.08	33.20	33.75	34.85	35.27	35.27	35.55	35.71	35.17	34.72
1993	34.29	33.01	32.62	32.50	32.40	32.19	31.67	30.71	30.13	29.41	29.23	28.42	31.38
1994	27.10	26.18	25.36	24.70	24.99	25.80	26.82	27.90	28.21	28.01	28.01	28.33	26.78
1995	27.96	27.96	28.22	28.36	29.11	29.52	29.28	28.47	28.11	28.02	27.61	27.64	28.35
1996	28.21	28.33	28.36	29.21	30.40	30.47	30.25	30.62	31.29	32.63	34.22	34.75	30.73
1997	35.71	35.94	34.78	33.46	31.84	31.42	30.44	29.94	29.77	29.63	30.19	30.13	31.94
1998	29.14	27.36	25.69	24.07	23.11	22.69	21.67	21.06	20.54	20.78	20.70	20.00	23.07
1999	18.83	18.38	17.74	18.40	20.08	21.35	22.38	24.29	26.20	28.65	30.02	31.98	23.19
2000	33.78	34.76	36.29	37.48	36.54	37.52	39.27	39.87	40.76	42.62	43.63	44.74	38.94
2001	42.38	40.75	40.16	38.80	38.14	38.46	38.44	37.50	37.28	36.86	34.65	32.24	37.97
2002	30.48	29.38	28.97	30.22	31.84	33.08	33.45	34.24	35.23	36.55	37.16	36.33	33.08
2003	37.15	38.65	40.57	40.88	39.12	38.10	38.14	38.45	39.12	38.43	38.82	39.15	38.88
2004	39.72	40.36	40.80	42.04	42.92	45.08	45.79	47.22	49.90	51.59	54.88	55.28	46.30
2005	54.33	54.67	55.63	58.66	60.68	61.00	63.57	66.33	70.39	73.17	73.75	72.94	63.76
2006	72.91	74.47	74.52	75.03	78.02	80.38	81.88	84.50	86.09	83.57	80.22	77.97	79.13
2007	77.46	73.75	72.62	72.94	74.80	76.13	78.17	81.57	82.68	85.88	90.02	96.34	80.20
2008	100.10	101.93	104.15	108.68	114.28	123.07	132.35	139.31	137.76	131.44	117.54	101.24	117.65
2009	85.39	75.24	67.42	63.64	62.28	64.10	69.25	71.28	75.15	76.70	79.81	83.21	72.79
2010	84.65	86.00	86.12	87.78	90.64	89.67	88.68	87.94	87.85	87.89	89.86	92.22	88.28
2011	95.76	98.20	101.67	107.71	114.48	116.48	117.13	118.28	116.59	115.52	114.44	115.56	110.99
2012	115.94	116.43	118.62	121.83	122.73	120.20	114.02	111.69	112.86	114.01	113.87	113.03	116.27
2013	112.46	112.83	113.92	113.02	111.20	110.10	109.44	110.78	112.65	114.16	114.13	113.21	112.32
2014	113.48	112.06	111.94	111.60	111.63	111.92	112.97	112.70	110.86	108.23	103.26	96.88	109.79
2015	87.21	76.08	70.74	66.38	64.83	65.33	65.29	63.05	58.71	55.87	54.09	51.62	64.93
2016	47.81	42.85	39.77	39.61	40.57	42.87	45.04	45.43	45.95	46.36	47.98	47.85	44.34
2017	50.08	51.59	52.88	52.72	53.00	52.50	50.99	50.40	50.69	51.82	53.22	55.75	52.14
2018	57.90	60.40	61.32	62.17	64.16	66.94	68.45	69.72	70.13	71.70	73.21	69.94	66.34
Montly Avg	56.51	55.66	55.28	55.54	56.21	56.92	57.49	58.11	57.66	58.08	58.16	57.66	

Table - 29:
α = 0.3
Exponential Smoothing Model / Inflation-adjusted Prices Forecast

Mean Error	0.34
MAD	5.61
MSE	81.58
MAPE	10.38%

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly Average
1988									27.80	27.85	27.09	26.93	27.42
1989	28.65	30.59	31.65	33.65	35.81	36.14	36.02	35.98	35.32	35.56	36.32	36.73	34.37
1990	37.77	38.36	38.14	36.94	34.93	33.75	32.03	32.47	39.85	49.14	56.10	57.64	40.59
1991	54.74	49.56	43.16	39.28	37.24	36.28	35.04	35.13	35.42	36.10	37.55	37.91	39.78
1992	35.89	34.02	33.08	32.39	32.82	33.71	35.20	35.62	35.47	35.77	35.89	35.10	34.58
1993	33.95	32.39	32.11	32.16	32.16	31.97	31.38	30.21	29.63	28.87	28.85	27.92	30.97
1994	26.36	25.43	24.63	24.05	24.69	25.89	27.22	28.50	28.67	28.22	28.14	28.51	26.69
1995	27.95	27.95	28.30	28.46	29.42	29.84	29.39	28.27	27.86	27.85	27.37	27.50	28.35
1996	28.32	28.44	28.44	29.53	31.00	30.85	30.41	30.83	31.64	33.29	35.15	35.48	31.11
1997	36.47	36.48	34.72	32.97	31.02	30.78	29.73	29.35	29.36	29.34	30.20	30.11	31.71
1998	28.80	26.56	24.66	22.91	22.10	21.94	20.88	20.39	19.96	20.51	20.51	19.66	22.41
1999	18.23	17.86	17.23	18.31	20.59	22.07	23.17	25.39	27.51	30.24	31.43	33.48	23.79
2000	35.28	35.99	37.53	38.62	36.92	38.07	40.19	40.62	41.50	43.69	44.60	45.69	39.89
2001	42.17	40.09	39.56	37.98	37.43	38.15	38.25	37.07	36.94	36.52	33.72	30.87	37.40
2002	29.07	28.18	28.10	30.11	32.32	33.78	34.00	34.83	35.91	37.40	37.87	36.48	33.17
2003	37.52	39.36	41.64	41.62	38.98	37.67	37.90	38.41	39.31	38.32	38.89	39.29	39.08
2004	40.00	40.75	41.17	42.68	43.60	46.21	46.70	48.25	51.41	53.05	56.86	56.61	47.27
2005	54.80	55.07	56.18	60.01	62.15	61.99	65.02	68.12	72.83	75.55	75.37	73.64	65.06
2006	73.32	75.24	75.00	75.48	79.29	81.93	83.31	86.23	87.66	83.67	79.17	76.58	79.74
2007	76.46	71.91	71.14	72.17	74.95	76.67	79.17	83.30	84.10	87.80	92.55	99.96	80.85
2008	103.52	104.59	106.50	111.60	117.90	128.17	138.50	145.32	140.85	131.19	112.76	92.93	119.49
2009	75.12	65.69	59.09	57.38	58.07	62.18	69.81	72.29	77.05	78.36	81.84	85.56	70.20
2010	86.54	87.58	87.11	88.93	92.28	90.33	88.75	87.73	87.70	87.81	90.47	93.37	89.05
2011	97.64	100.14	103.99	111.11	118.78	119.73	119.30	119.97	117.04	115.43	114.03	115.68	112.73
2012	116.14	116.71	119.52	123.44	123.99	120.11	111.91	109.64	112.02	113.89	113.75	112.68	116.15
2013	112.05	112.72	114.22	112.90	110.52	109.32	108.76	110.81	113.30	115.05	114.66	113.21	112.29
2014	113.58	111.64	111.65	111.31	111.46	111.91	113.32	112.82	110.32	107.02	100.89	93.33	109.10
2015	81.86	69.16	64.81	61.36	61.30	63.38	64.11	61.59	56.39	53.53	52.10	49.60	61.60
2016	45.32	39.70	36.86	37.81	39.81	43.19	45.95	46.11	46.52	46.84	48.81	48.30	43.77
2017	51.09	52.70	53.98	53.33	53.46	52.60	50.56	49.94	50.51	52.09	53.85	56.97	52.59
2018	59.36	62.11	62.65	63.26	65.47	68.65	69.98	71.06	71.07	72.78	74.36	69.55	67.52
Montly Avg	56.27	55.23	54.89	55.39	56.35	57.24	57.87	58.54	58.09	58.47	58.42	57.65	

Table - 30:
α = 0.4
Exponential Smoothing Model / Inflation-adjusted Prices Forecast

Mean Error	0.24
MAD	4.94
MSE	64.14
MAPE	9.08%

6.6 Numerical Forecasting Results Summary:

6.6.1 Nominal Prices Forecast

Error Type	Moving Average				Exponential Smoothing			
	3-Month	4-Month	6-Month	12-Month	α=0.1	α=0.2	α=0.3	α=0.4
MAD	4.05	4.59	5.42	7.18	7.20	5.46	4.59	4.03
MSE	45.73	59.88	86.36	139.91	135.03	82.07	59.40	46.10
MAPE	9.14%	10.39%	12.35%	16.00%	16.12%	12.44%	10.48%	9.15%

Table – 31: Nominal Price Faorecasting Results Summary

6.6.2 Inflation-Adjusted Prices Forecast:

Error Type	Moving Average				Exponential Smoothing			
	3-Month	4-Month	6-Month	12-Month	α=0.1	α=0.2	α=0.3	α=0.4
MAD	4.95	5.63	6.64	8.63	8.60	6.63	5.61	4.94
MSE	64.03	84.22	119.32	184.99	175.96	110.57	81.58	64.14
MAPE	9.02%	10.32%	12.30%	15.91%	16.01%	12.36%	10.38%	9.08%

Table – 32: Inflation-Adjusted Faorecasting Results Summary

6.6.3 Observations

6.6.3.1 Observation : Moving Average Models:

i. Moving Average Method leads to *Increasing Error Values* of all three types of errors -under study- as the period of forecasting increases.

ii. By utilizing Moving Average Method; **MAD, MSE & MAPE** they all show tendency to increase as the period of forecasting increases.

iii. The *accuracy of Moving Average Forecasting Models decreases* for forecasting the oil prices on short term basis, by including larger number of older data.

iv. For having more accurate and precise short-term basis forecasting models of oil prices, fewer number of previous data shall be included to forecast the upcoming price.

v. Newer Data / Recent Data regarding oil Prices plays more significant role in predicting the oil price for the next period.

6.6.3.2 Observations: - Exponential Smoothing Models:

i. Exponential Smoothing Method leads to *decreasing Error Values* of all three types of errors -under study- as the value of Alpha (**α**) increases.

ii. By utilizing Moving Average Method; **MAD, MSE & MAPE** they all show tendency to decrease as the value of Alpha (**α**) increases.

iii. For having more accurate and precise short-term basis forecasting models of oil prices (older data shall be given less weight to forecast the upcoming price this can be done by using higher values of Alpha (**α**).

iv. Exponential Smoothing assigns exponentially decreasing weights as the observation get older, In other words, recent observations are given relatively more weight in forecasting than the older observations.

6.6.3.3 Observations: - Inflation- Adjusted Prices:

i. Applying Moving Average Method on Inflation-Adjusted Prices of crude oil showed the same behavior when applied on Nominal Spot Prices, Both forecasting output models, demonstrated similar pattern of results, and the above mentioned observations in Section 6.6.3.1 apply here too.

ii. Applying Exponential Smoothing Method on Inflation-Adjusted Prices of crude oil showed the exact same behavior when applied on Nominal Spot Prices, Both forecasting output models, demonstrated similar pattern of results, and the above mentioned observations in Section 6.6.3.2 apply here too.

iii. Using the Inflation-Adjusted Prices Approach is useful to monitor, evaluate and trace the changes of Oil Prices solely due to inflation without taking into consideration any other external effects.

iv. Calculating the Inflation-Adjusted Prices of crude oil is a time consuming process and needs the collection of large number of data, their corresponding forecasting models though did not show a significant difference in terms of forecasting accuracy than those models generated by the Nominal spot prices, therefore *I don't recommend* using this approach unless the researcher or the forecaster needs to assess the influence of inflation on crude oil prices, or really cares for slight differences of forecasting accuracy.

6.6.3.4 Observations: - Best Models / Numerically:

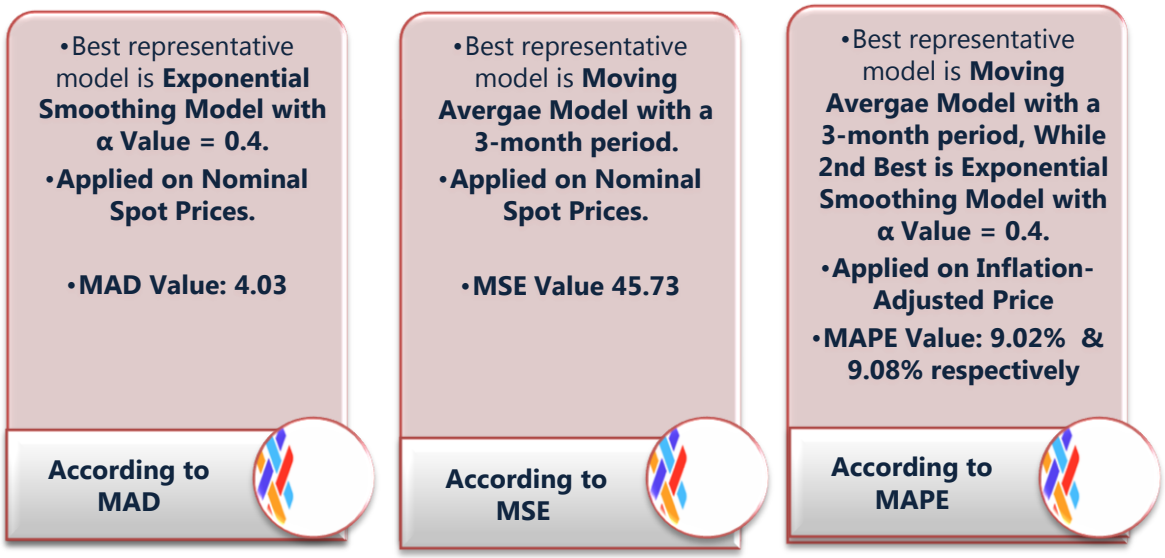


Figure – 16 : Best Forecasting Models / Numerically

i. According to the numerical analysis solely, the best model of forecasting using the Moving Average Method is found to be the **3-Month Moving Average Model**. This is compliant to all observations mentioned above

ii. According to the numerical analysis solely, the best model of forecasting using the Exponential smoothing is found to be the **exponential smoothing model with Alpha (α) = 0.4** . This is compliant to all observations mentioned above

CHAPTER – 7: Variables of Crude Oil:

Oil prices are underpinned by supply/demand fundamentals but can also be greatly impacted by market sentiment, global currencies and availability of money flow in financial markets as well, This Chapter will enlighten upon the importance of Supply and Demand on oil prices, and how it can be a major error when neglecting the demand and supply trends globally on oil prices forecasting.

7.1 Variable I - Supply :

Supply can be seen as arguably the more complex half of the supply/demand curve and ***the only variable producers can directly control.***

Oil prices are influenced by several factors, some of which are temporary in nature (such as weather events), causing a short-term boost in oil prices. Other variables such as technological shifts and adjustments in capital spending can have a more prolonged effect.

7.1.1 Oil Supplier Types:

According to the Oil Sand experts, There are three types of oil suppliers in the world, I prepared **Figure-18** to distinguish between these types and conduct a simplified benchmark among them to create for the reader a better understanding of oil supplier types:

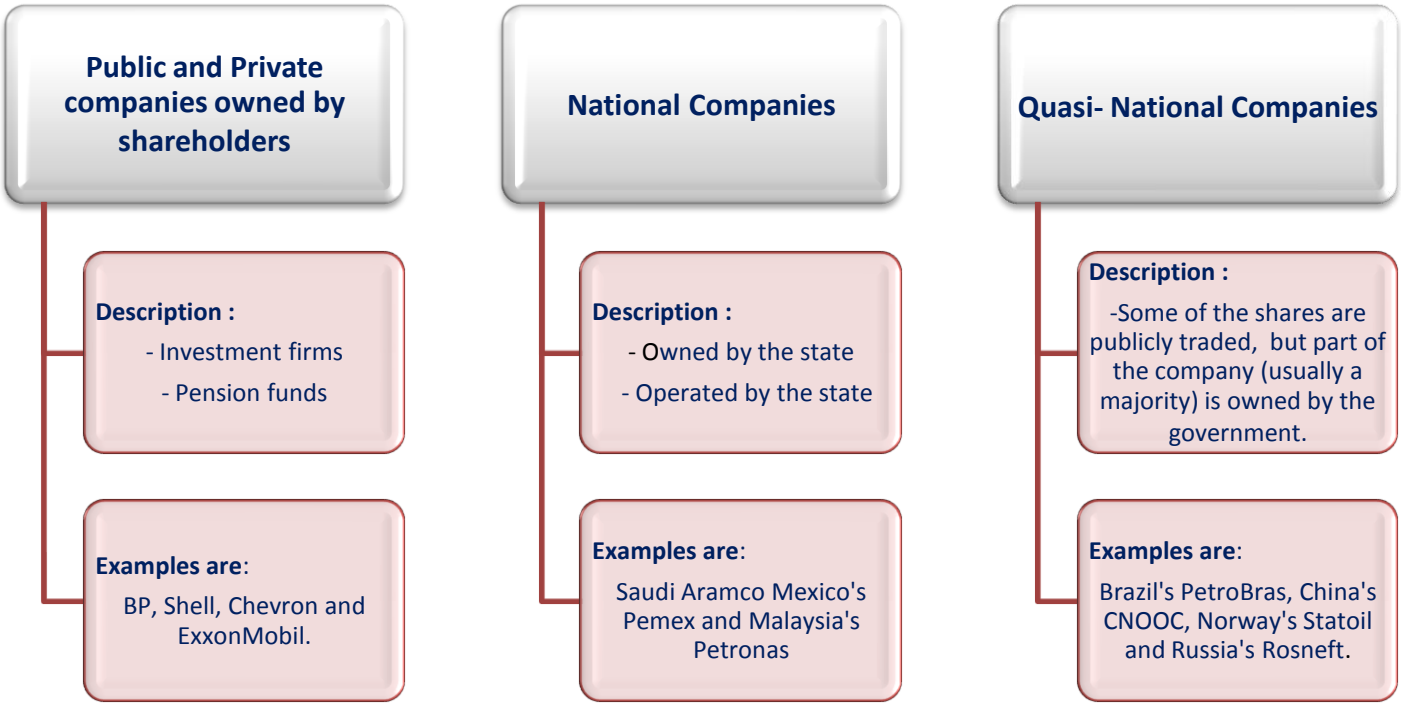


Figure – 18: Simplified Benchmark Between Oil SupplierTypes

But in order to clarify the very important differences between national and public/private producers, I have also prepared **Figure-19** which illustrates those differences:

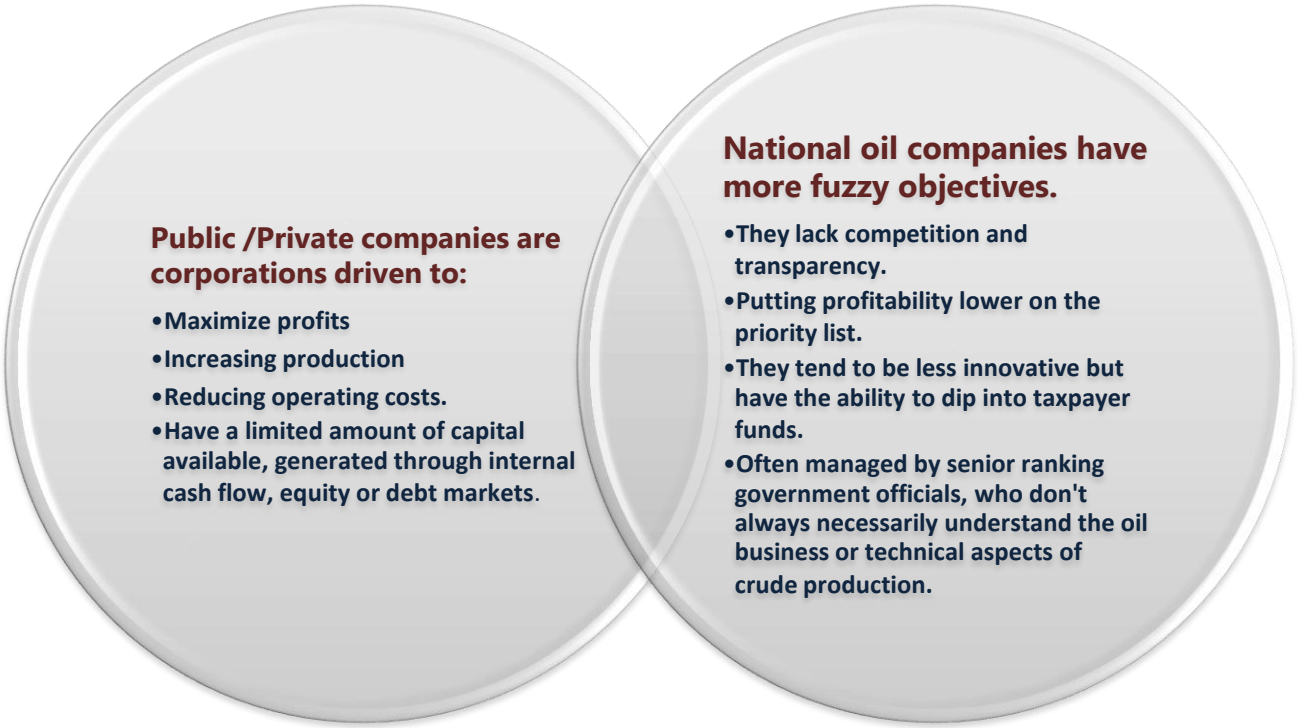


Figure – 19: Comparisopm between Public/Private oil companies and National oil companies in terms of objectives.

7.1.2 Oil Supply Shifts :

Before introducing the major four categories of supply shifts that affect energy markets, let me introduce an economic definition of what a supply shift is.

A shift in Supply occurs when the position of a supply curve will change following a change in one or more of the *underlying determinants* of supply. A general example is if a change in costs, such as a change in labour or raw material costs, will shift the position of the supply curve.

A- Rising costs

- If costs rise, less can be produced at any given price, and the supply curve will shift to the left [(8)], *see the following graph.*

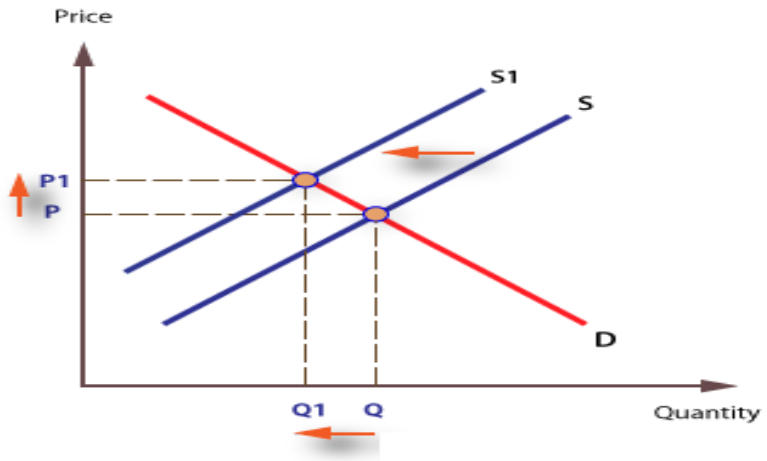


Figure – 20: Shift in Supply curve to the left due to rising cost.

B- Falling costs

- If costs fall, more can be produced, and the supply curve will shift to the right [8]. See the following graph.

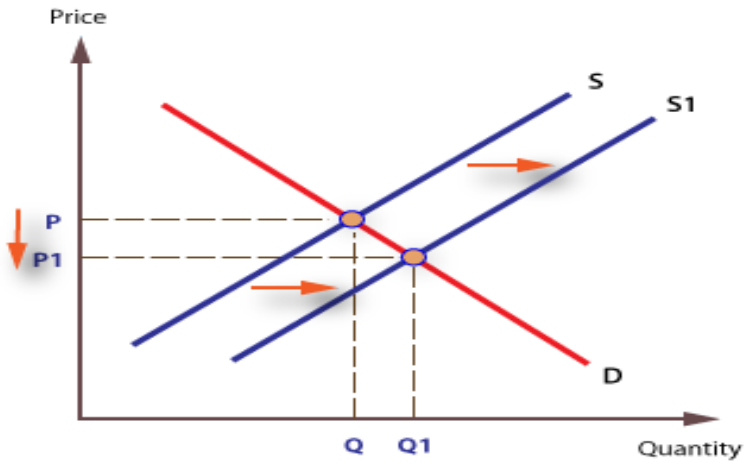


Figure – 21 Shift in Supply curve to the right due to falling cost.

Therefore, any change in an underlying determinant of supply, such as a change in the availability of factors, or changes in weather, taxes, and subsidies, will shift the supply curve to the left or right.

7.1.3 Categories of Oil Supply Shift:

So, throughout my research, my observation and investigation in the literature, I found out that there are **four** categories of supply shifts that affect energy markets, I have prepare the following **figure-22** illustrating the first major factors, those are the ones that throughout my research I found that they are strongly effecting Crude Oil Supply, leading to huge effect on oil prices on the short term, *the fourth factor is considered to be a lagging factor and it is the capital investment.*[18] *See section 7.1.3.4*

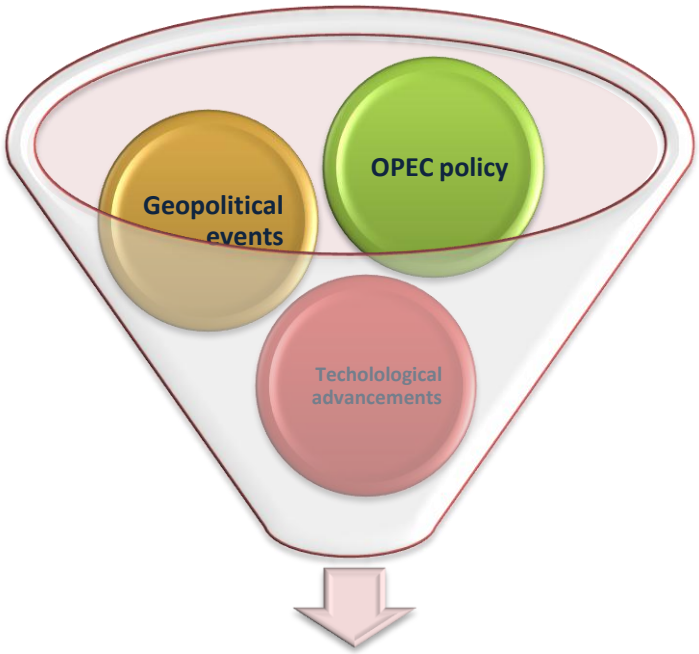


Figure – 22 Oil Supply Shift Categories

7.1.3.1. Geopolitical events: war, strife and conflict

Geopolitical events, such as war, sanctions or global conflicts, can affect supply or stability of supply. Although oil output may not be directly affected, oil markets can be jolted if supply is perceived to be at risk. This is especially true for conflicts among Middle-Eastern nations, which still represent one-third of the world's oil output.

Although conflicts can cause oil prices to rise, meaningful declines in oil prices can also lead to political upheaval. Oil production still accounts for a big chunk of government revenues in places like Venezuela, Russia, the Middle-East and parts of Africa.

When oil prices are low, the economy contracts sharply, government handouts get reduced and *military spending is often curtailed*. This can sometimes fuel anti-government sentiment, initiating cycles of civil unrest. This was evident during the Arab spring uprising, collapse of Venezuela's economy and the rise of terrorist activity in Nigeria.

Figure-23 summarizes the major political events that are thought to influence oil market and oil prices for the recent 40 years, starting from **1976 till today.**

By visual inspection, we can observe that for the period between 1980 till 1988. ***The oil prices suffered a major continuous drop in prices***, going down form $120/bbl to as low as little bit over $20 , this is for sure highly related to the ***Iraqi-Iranian war*** that took place in this period, which are both considered major oil producers in the middle east and for sure in the region.

Additionally, we can also observe two peaks in 1990 & 1991, where both represents the ***invasion of Kuwait by Iraq***, and the ***starting date of Gulf War***, since Gulf region is considered a huge producer of oil globally, prices peaked in this period, until they again settled down and went down to normal prices in the following period.

Other clearly observed peaks can also been seen:

- **Directly upon US invasion to Iraq in 2003.**
- **Following the start of the Arab spring in 2010.**
- **The beginning of the Venezuelan Crisis in 2012.**
- **The 2nd Libyan war in 2014.**

One of the major drops or minimal values of Oil prices was witnessed in 2016, when the prices of oil dropped to approximately as low as $31/bbl which is the ***date of birth of the Niger Delta Avengers*****,** averaging $42/bbl in 2016.

I have provided explanation of oil prices changes for different periods of time throughout CH-6 of this thesis, linking them to many reasons including the political ones, please see ch-6 for more details.

Figure – 23: Major Political Events in relation to oil prices oscillation between 1976-2017.

7.1.3.2. OPEC - A Swing producer

The Organization of Petroleum Exporting Countries (OPEC) accounts for about 40% of the world's oil production, largely from state-owned oil fields.

OPEC was founded in the early 1960s with the goal of coordinating its members' petroleum policies and stabilizing oil markets. As state producers, OPEC members are not directly accountable to shareholders, allowing them to throttle output and control the supply side of the curve. Today, this OPEC has a total of 15 Member Countries. **(19)**

There have been several coordinated OPEC production cuts over the past few decades, each intended to limit supply while demand is temporarily low, such as in the case of global recessions or excessive production. OPEC quotas are generally successful in boosting oil prices, at least in the short term. However, OPEC's ability to shift the supply curve in the long run is debatable. **(19)**

Figure-24 summarizes the major OPEC Policy changes in production that are thought to influence oil market and oil prices for the recent 40 years, starting from **1976 till today.**

- The Boxes in **Red Color** represents Positive changes in Production by OPEC.
- The Boxes in **Green Color** represents Positive changes in Production by OPEC.
- Where numbers represent the increase/decrease in production by Millions Barrels per day.

It is noticeable, with the start of ***Iranian- Iraqi war in 1980***, both countries which are both are founder members of OPEC have conducted major cuts in production / exports of oil, while in ***1988, almost at the end of this war***, both countries Iran & Iraq have raised production, and this is certainly linked to the fact that upon ending the war, both countries were trying to come back into the market with larger amounts of Crude than the war period.

Additionally we can also observe that in 1986, Saudi Arabia has also increased its production, this can be thought of as a reason to compensate for the deficiencies of production caused by both Iran & Iraq at that period due to the continuous war between them at that period.

Other major changes in production can be tracked by **Figure-24**, occurred in 1990, upon the invasion of Iraq to Kuwait; this led to huge cuts of production by Kuwait.

Other observations contain:

- The value of changes in OPEC Production can varied between 1.5 – 4.2 Millions of barrels.
- Those changes in OPEC production rates are highly linked to crude oil fluctuation in prices globally, so when prices tend to go down, OPEC Members push to lower their productions rates, on the contrary when prices go up we can witness an increase in crude production by OPEC members, it is important to notice here that this is not a rule of thumb, but it can be true most of the time.
- The oscillation in OPEC Production rates, are also highly linked to Political reasons, since oil is a strong and is considered as an efficient tool used to achieve political pressure on other countries, and gain political support for global decisions such as initiating wars, or gain votes on political events.
- The largest change in OPEC policy for production has been witnessed in 2008, when crude oil witnessed a steep, rapid and huge drop in prices from above $150/bbl to almost $40/bbl in a span of a year or even less, as due to the repetitive and continuous drop in crude prices, OPEC has kept reducing its production of oil to a **negative value -4.2 Million barrels per day in 2008/2009.**
- While the largest positive change in OPEC policy for oil production has been witnessed in 2000, Where 3 major changed occurred in that year alone resulting in **a positive value of 3.7 Million barrels per day,** that happened directly after crude oil prices reached an extremely low prices less than $15/bbl in 1999, then they started to recover again reaching to up to $33/bbl at the end of 2000.
- Similar Positive change occurred also in 2003/2004, with the same **positive value of 3.7 Million barrels per day**, helping the prices to increase from less than $30/bbl to double in Mid of 2005.

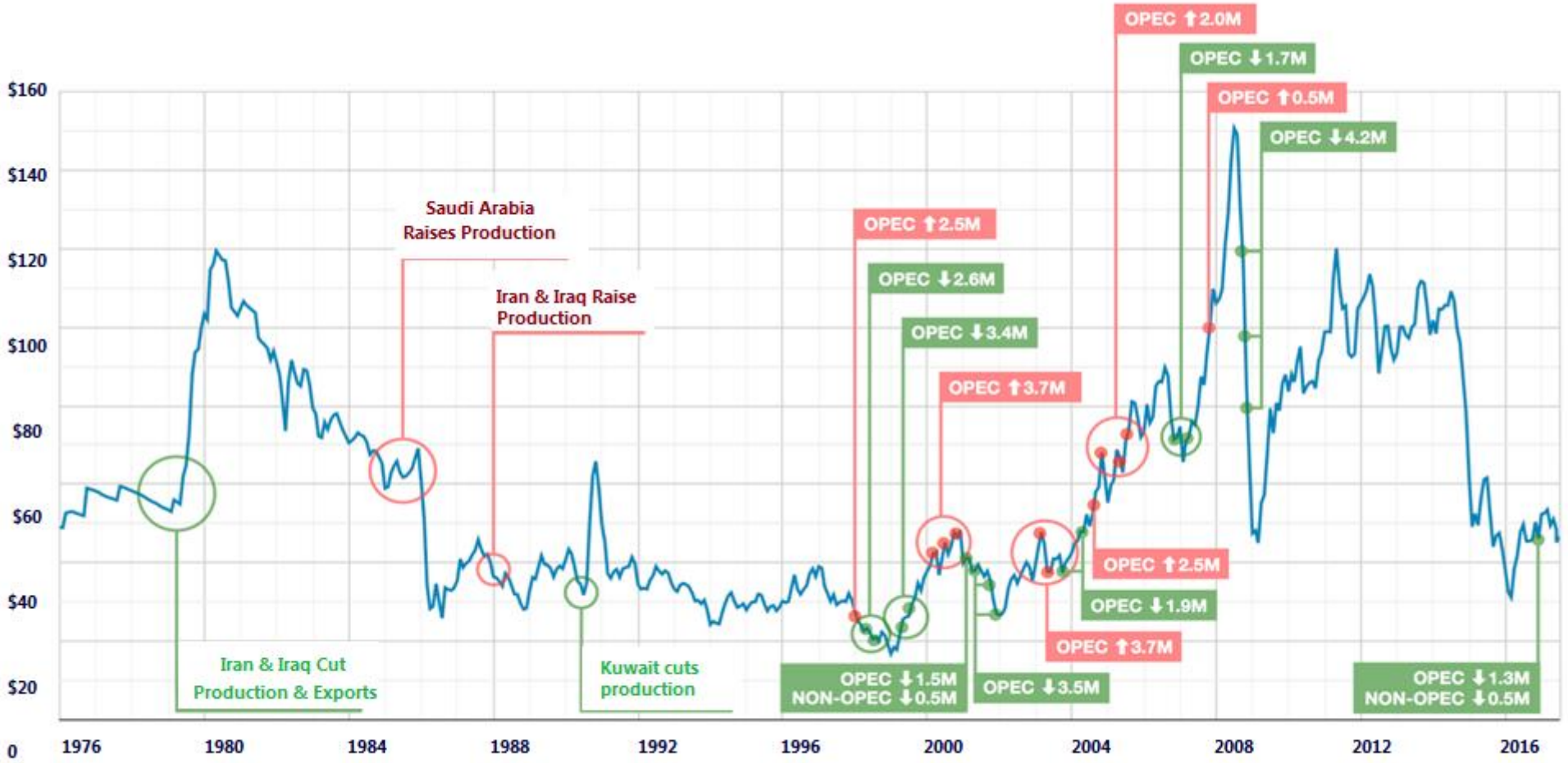


Figure-24: Crude Oil Prices Chart Shwoing Major Changes in OPEC Members Production between 1976-2017.

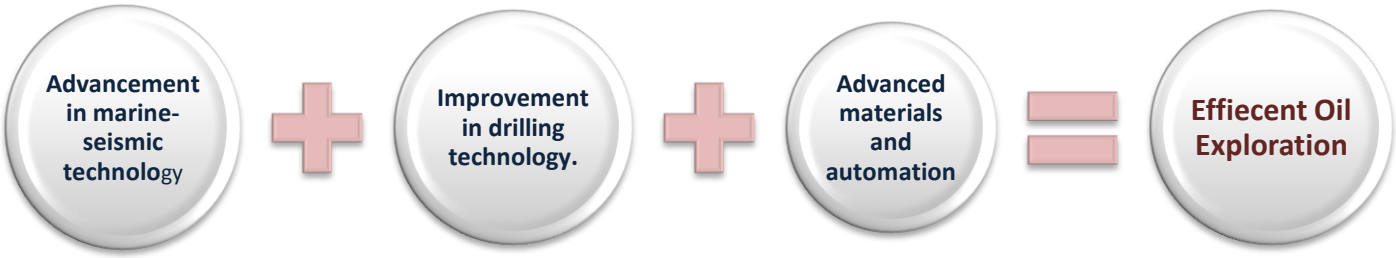
7.1.3.3. TECHNOLOGICAL SHIFTS AND INNOVATION:

Step-changes in technology can have a profound effect on supply and certainty of supply. This has been an evident in recent decades, ***making it difficult to forecast future oil production.***

Less than 10 years ago, forecasters were convinced the world was running out of oil. Then ***The Peak Oil Theory*** combined with rapid economic growth in emerging markets caused oil prices to spike to all-time highs

Exploring for oil is no longer a shot in the dark due to:

- Advancements in marine-seismic technology; which enable explorers to pinpoint with much greater certainty where the oil deposits lie.
- Improvements in drilling technology.
- Advanced materials and automation has made ultra-deepwater exploration at depths greater than 1,500 meters not only technically feasible, but rather common.



7.1.3.3.1 New Technological Innovations & Shifts:

- Perhaps the greatest example of a technology shift is the unlocking of production from **unconventional shale deposits**. The US shale boom took oil markets by surprise, now accounting for over 5 million bbl/day of production. More importantly, the technology now exists for exploiting oil from massive unconventional shale reserves around the world.

- **Horizontal drilling technology combined with fracking** now allows operators to cover up to 3,000 meters of rock, versus a previous norm of a few hundred meters, greatly reducing the number of wells that need to be drilled. **(20)**

- **Advancements in seismic imaging** allows drillers to adjust to where the oil deposit lies, greatly improving productivity per well.

7.1.3.3.2 Outcomes of New Technological Innovations & Shifts :

- As producers learn to do more with less, breakeven prices come down, allowing for supply expansion despite unfavorable economic conditions.
- Technological Innovations can have great positive influence on the oil industry and tend to increase oil supply, presence of technologies that help increasing wells' productivity, or enhancing oil exploration or those facilitating drilling processes, will help to increase the oil supply to the globe at cheaper prices and long lasting periods.
- Yet, the presence of new innovation shifts, such as Shales, may impact negatively the oil industry by losing capital investment, thus reducing the demands on oil coming from traditional sources, but this can only happen if those new shifts are cheaper, easier to produce and are available in huge quantities that can hugely impact the oil market.
- in my opinion, technological innovation will be always in the favor of oil industry, and oil industry is still capable to beat any potential competitions.

7.1.3.4. CAPITAL INVESTMENT: A LAGGING INDICATOR

Capital investment can have a profound effect on **future oil supply**. *However*, there is a considerable time lag between when the capital is deployed and when first oil is produced.

When oil prices suddenly goes down, production doesn't stop instantly. Large projects of billions of dollars take years to construct and eventually initiates production, regardless of the price of crude.

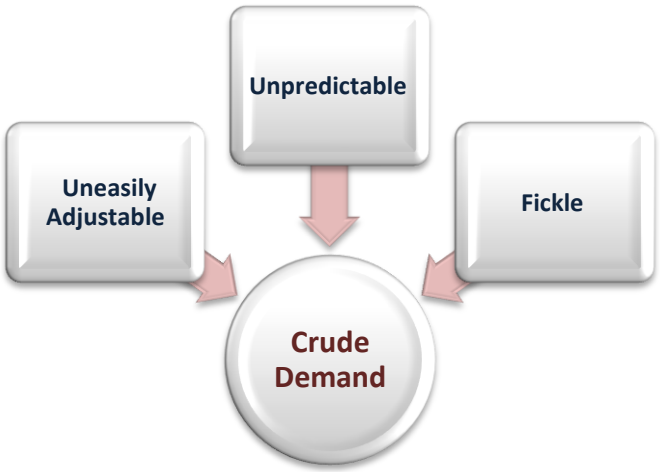
That's why production often keeps growing as oil prices initially begin to fall. On the contrary, when prices recover, it can take a long time for production to recover, even if more capital is deployed. This is especially true for massive deepwater drilling platforms.

More importantly, capital investment is a function of cash flow and therefore follows the oil price **(not vice versa)**.

A good example is onshore producers, as quickly switching production off when prices fall and restarting operation when prices recover. The effect is clearly evident in US crude production, where the number of oil rigs in service lags the price of West Texas Intermediate **WTI** by about 4 to 5 months.

7.2 Variable II - Demand :

While the supply side of the **Supply-Demand Equation** is relatively easy to measure and control, crude demand is fickle, unpredictable and far more difficult to adjust. [18]



Oil still accounts for one-third of the world's energy demand, making it very susceptible to global economic trends. About two-thirds of world's crude is used for transportation of people and goods - planes, trains, ships and automobiles - which can also be greatly affected by advancements in technology. See **Figure 25/A**

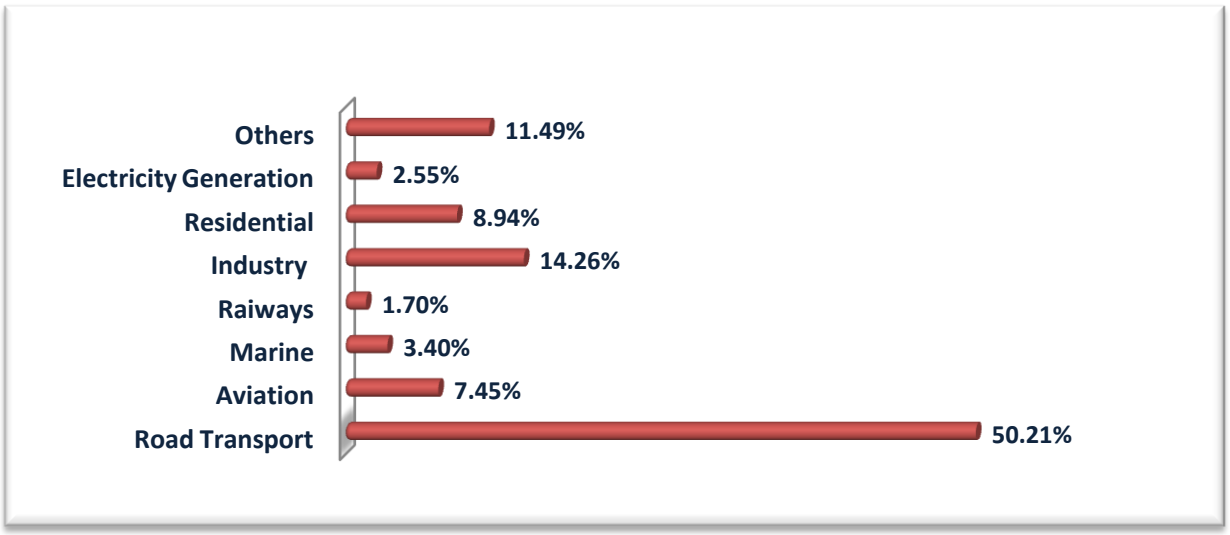


Figure – 25/A: Distribution of oil demand worldwide in 2016 by sector [E]

Figure-25/A *represents the distribution of oil demand worldwide by sector in 2016, data source is OPEC, published in Nov 2017, by the 2017 world oil outlook, Figure-25/A is prepared by me and have been calculated based on total numbers, which were represented in million barrels per day.*

This statistic shows the distribution of oil demand worldwide as of 2016, broken down by sector. In 2016, approximately half of the global demand for oil was attributable to the road transportation sector. Thus, this is the sector with the world's largest demand for oil, but when taking all transportation sectors into account including Aviation, Railways, Marines and automobiles, and then this **Transportation Sector** will account for more than **62.70%** of the global demand of oil.

- **Global Demand of Crude Oil:**

∓ Figure-25/B represents the distribution of oil demand worldwide by sector in 2016, data source is OPEC, published in Nov 2017, by the 2017 world oil outlook, Figure-25/B is prepared by me and have been calculated based on total numbers, which were represented in million barrels per day.

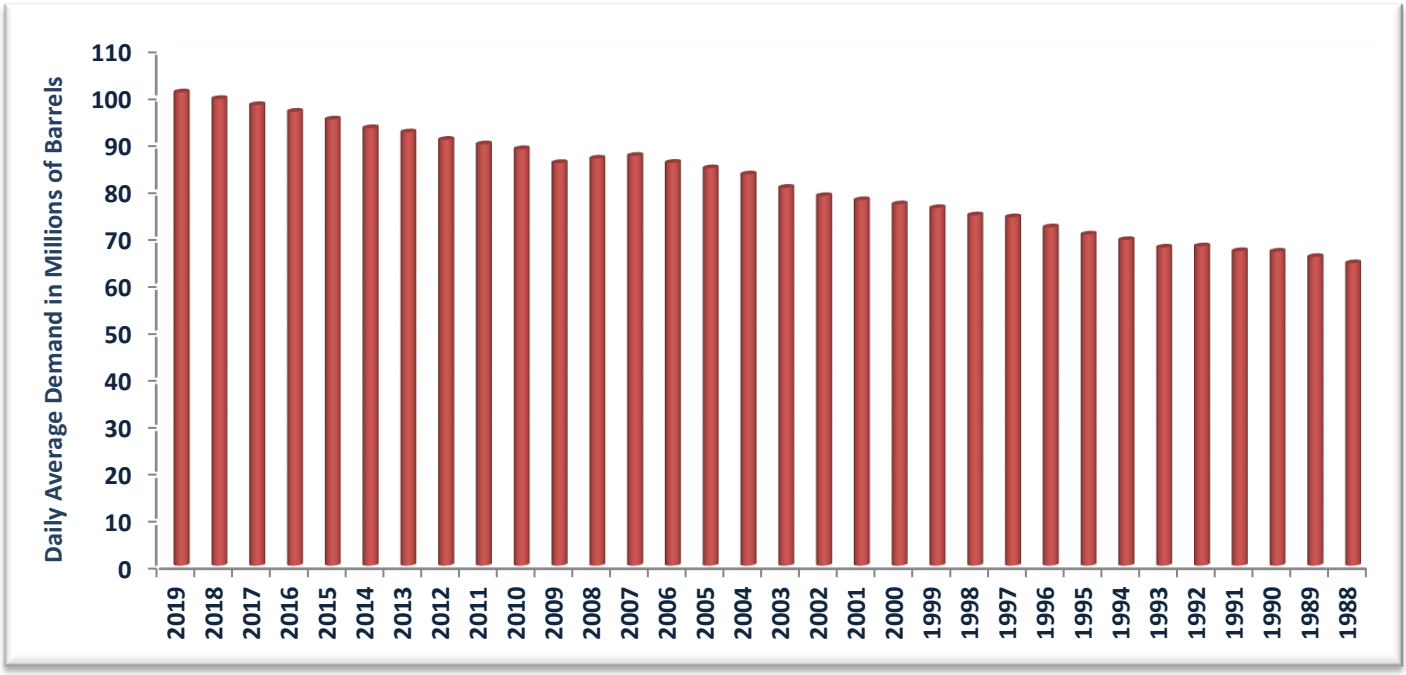


Figure – 25/B: Daily Average Demand of Crude Oil Globally in Millions of Barrels between [1988 – 2019] **(F)**

- **Observations on Figure 25/B:**

∓ The last registered value is **99.2 Millions** this value reflects the number of barrels of crude oil consumed globally in 2018."In another word" the daily demand of crude oil globally. Figures of 2018 are correct till June-2018.

∓ The Chart also offers a projected value for the expected global daily demand of crude oil in 2019, which is expected to reach an average of 100.6 Million barrels/day.

∓ The change percentage for the daily global consumption of Crude oil between 2018 & 2017 is equal to 1.32%.

∓ The Generic trend of the daily global demand of crude oil is continuously increasing, except for the two consecutive years 2008 & 2009.

∓ In 2008 global daily demand rates witnessed a drop of almost 0.6 million bbl/day lower than those of 2007, also In 2009 global daily demand rates witnessed an additional drop to become **1 million barrels/day** less than those of 2008. This can be explained by the known economic recession occurred at the end of 2008 and continued in 2009, which affected demand rates on crude oil and cause them to drop down.

7.2.1 Categories of Oil Demand Shifting factors:

When examining oil demand in recent history, I have found that there are four major categories of events that can shift the demand side of the curve [18]:

i. **Economic cycles and recessions.**
ii. **Global GDP growth and emerging markets.**
iii. **Gasoline consumption and automotive trends.**
iv. **Seasonality.**

7.2.1.1 Economic Cycles and Recessions: [21]

All commodities, including energy, tend to follow periodic cycles of expansion and contraction:

- As the economy expands, demand for energy increases, causing prices to rise.
- As prices rise, producers will try to increase output, expanding the supply.
- Rising oil prices touches all corners of the economy, sparking inflation.
- Consumers then start to feel the pinch in their wallets, sometimes causing a change in spending patterns and eventually leading to economic contraction.
- Since demand is elastic, oil consumption starts to drop-off, creating an oversupply in the market. And that eventually causes the oil price to drop.

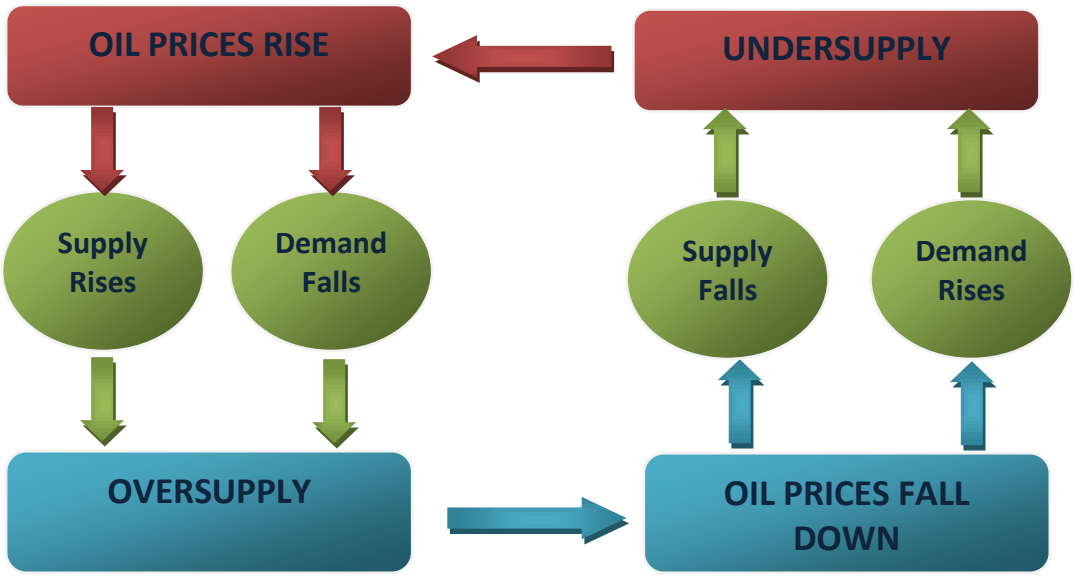


Figure – 26 Oil Prices Rise/Fall Cycle.

Prolonged weakness in oil prices eventually incentivizes producers to cut back on output, shrinking the supply. Then the cycle begins again.

7.2.1.1.1. Oil peaks Vs Economic Recessions?

Spikes in oil prices have long been an indication of upcoming recessions. In fact, since 1946, **9 out of 10** major oil price spikes have ended in recession, where the oil price continues to fall during periods of economic contraction.

By having an analytical eye on **Figure-27,** which demonstrates different recessions, registered in the period between 1976 till today, we can observe some facts, but before analyzing the graph, let me ask a valid question here, ***what is An Oil Price Peak?***

Peak of Oil Price:

I can simply explain an oil price peak as the point when the prices of oil noticeably rises up gradually or suddenly for short period of time, but goes back to decline again close to their average value before the rise, thus when representing them graphically on a diagram of Price vs. Time, those increases in prices will form a shape of a peak of a mountain.

Therefore, by coming back again to **Figure-27,** we can observe the following:

- *Five economic recessions took place in the last 40 years globally*, two of which were registered in 1980's, one in the beginning of 1990's and another two witnessed since 2000.
- The figure also shows that *4 out of these 5 recessions were either accompanied with a peak in oil prices.*
- *The first recession occurred in 1980 following a peak in oil prices* averaging almost $120/bbl, which is considered as a very high price for oil at that period.
- *The third recession was the only recession witnessed in 1990's century, and took place between mid 1990 & 1991*, in parallel to the invasion of Kuwait by Iraq, was also accompanied again by a peak in oil prices reaching an average value close to $67/bbl.
- *The fourth recession took place in 2001 for short period of time*, and again this was accompanied with not a very clear peak of oil prices reaching an average of $43/bbl
- *The last recession is the one of the longest in modern history, and it was recorded in 2008*, and almost lasted more than a year and a half, has recorded the highest records of oil prices ever, when they reached an average values over $150/bbl.
- Finally, we can also observe *that the second recession occurred in 1980, is the only recession which did not accompany a peak in oil prices*, in fact, it occurred in a period where prices of oil were witnessing a continuous drop in prices, and we can even notice a valley in the middle of the recession, *this recession is thought to be the only recession registered in the past 70 years that did not accompany or follow a peak in oil prices.*

Conclusion of Figure 27- Analysis.

1. This analysis and this graph imply that economist can predict upcoming recession, by simply and clearly watching the trend of oil prices fluctuations.
2. Another major conclusion is that oil prices are not the kind of variables that can be only forecasted numerically using numerical methods, but they have to be accompanied with a clear vision and a professional economic opinion to help/correct those numerical forecasting methods to give more accurate forecasts, since they are very viable to economic & political events.

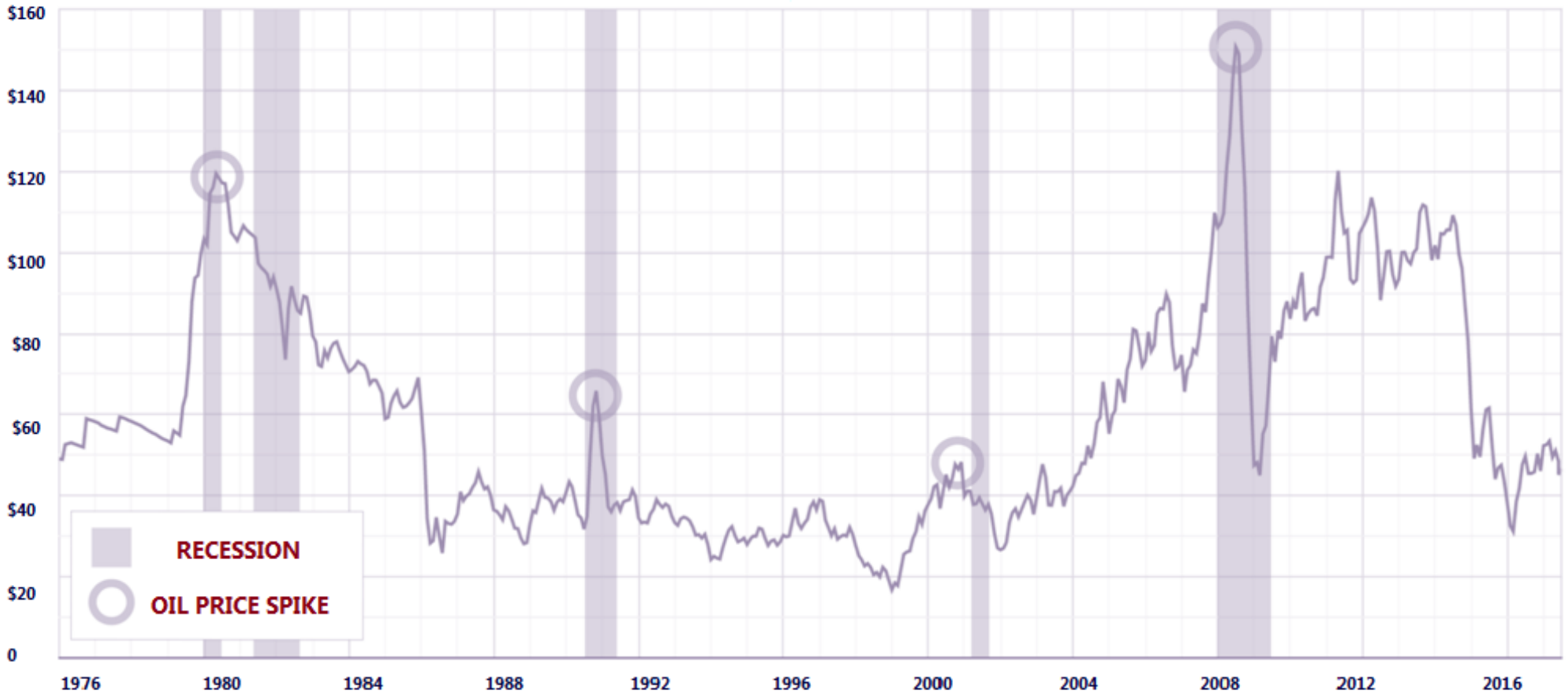


Figure – 27: Major Economic Recessions in relation to oil prices peak in the last 40 years between 1976-2017.

7.2.1.2 GLOBAL GDP GROWTH AND EMERGING MARKETS:

To understand the impact of Gross World Product **"GWP"**, also named as Global GDP on the World demand of crude oil, I need first to clarify its meaning, which is economically agreed to be defined *as the combined gross national product of all the countries in the world.*[8]

While Gross National product, also known as "**GDP",** *is the accumulated value of all finished goods and services produced in a country, often measured annually*. [8]

In this section; I will present two interesting figures that help in better and deeper understanding the relationship between the GWP Growth with Oil Prices, **Figure-28 & Figure-29**

Figure-28 represents the Gross World product "GWP" from 1990 to 2017, with projections up until 2022. In 2017, global GDP amounted to about 80.05 trillion U.S. dollars, while **Figure-29** correlates the global oil demand to the GWP Growth for the period between 1980 & 2016.

Data source for figure-28 is IMF, published very recently in Oct 2018, by the world Economic outlook database. Figure-28 is prepared by me and the figures were rounded for a better comprehension of the statistic. All numbers representing GWP were represented in Billions US Dollars.

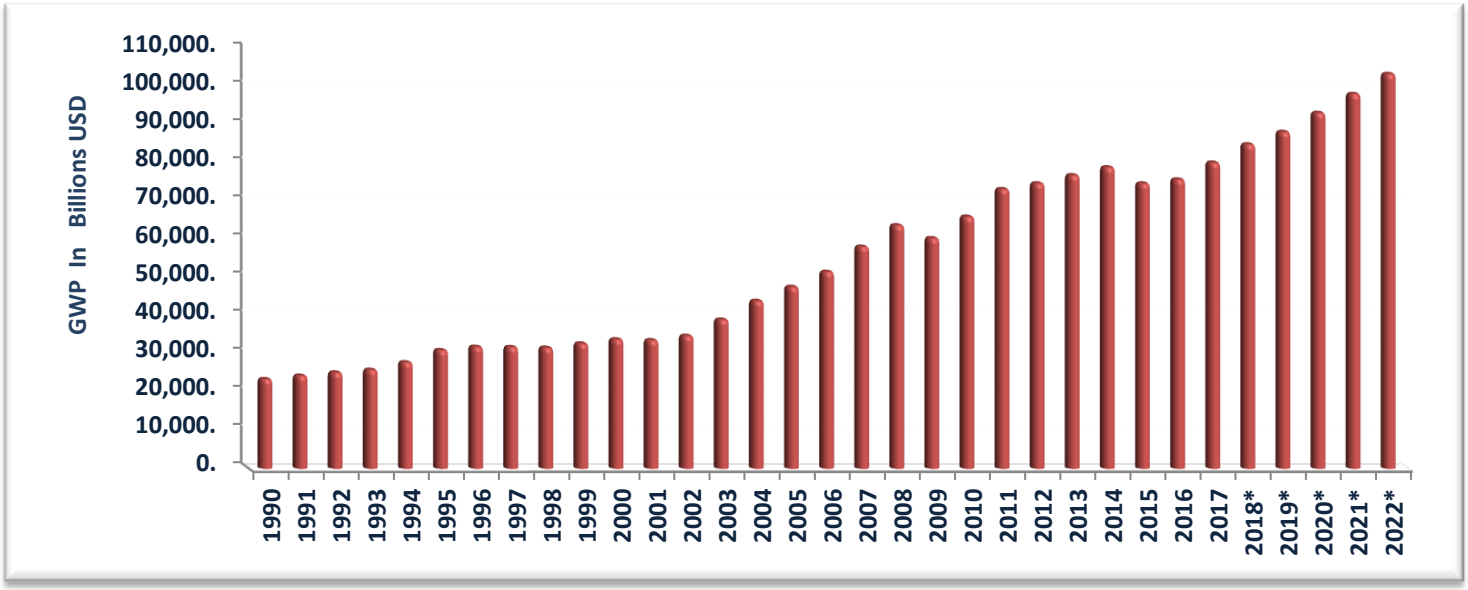


Figure – 28: GWP Growth Per Year between 1990-2022. [G]

Figures' Analysis:

- The statistic shows global gross domestic product (GDP) from 1990 to 2017, with projections up until 2022. In 2017, global GDP amounted to about 80.05 trillion U.S. dollars.
- Global GDP has experienced a growth every year over the past decade with the exception of 2009.
- The drop in GWP that occurred in 2009 is related to the huge Economic global recession that occurred in 2008, which led to lower the GWP Globally.
- Recall that in 2008, oil prices witnessed a high peak close to $150/bbl, this is accompanied an economic recession and also affected the GWP by lowering it. **See section 7.2.1.1.**

2008	63,649.97
2009	60,280.21
2010	65,906.43

A huge drop in GWP In 2009 due to the Economic recession which also witnessed a high peak in oil prices at the same year.

- Another minor drop in GWP can also be seen in Year 2001, when the GWP dropped from $33,823.08 billion in 2000 to $33,579.21 billion in 2001 causing a negative change of **-0.7%.**

- This drop in GWP occurred in 2001 is again linked to the peak in oil prices in 2001, which was followed later by a global recession in 2002, which confirms the fact that when an oil prices goes up, it is an indication of an upcoming economic recession, thus a slow growth or even a drop in GWP is expected to occur. **But Why?**

  Answer: When an Economic recession occurs, this means that the wheel of business, industry, production and transportation will slow down, causing reduced demands on crude oils, affecting eventually the oil prices and pushing them to drop down, especially if oil supply is kept the same, and this is exactly what we can see after every economic recession, where prices of crude oil goes down after reaching a peak value during or just prior the economic recession. **See figure 27**

- Therefore, when huge economies are active and growing, products are made, raw materials are ordered, causing a gigantic movement of goods and materials, which increases the demand on crude oil globally, thus stabilizing and refreshing oil prices pushing them to increase, on the contrary at the times of recessions, the needs of oil will go down, pushing oil prices to drop down.

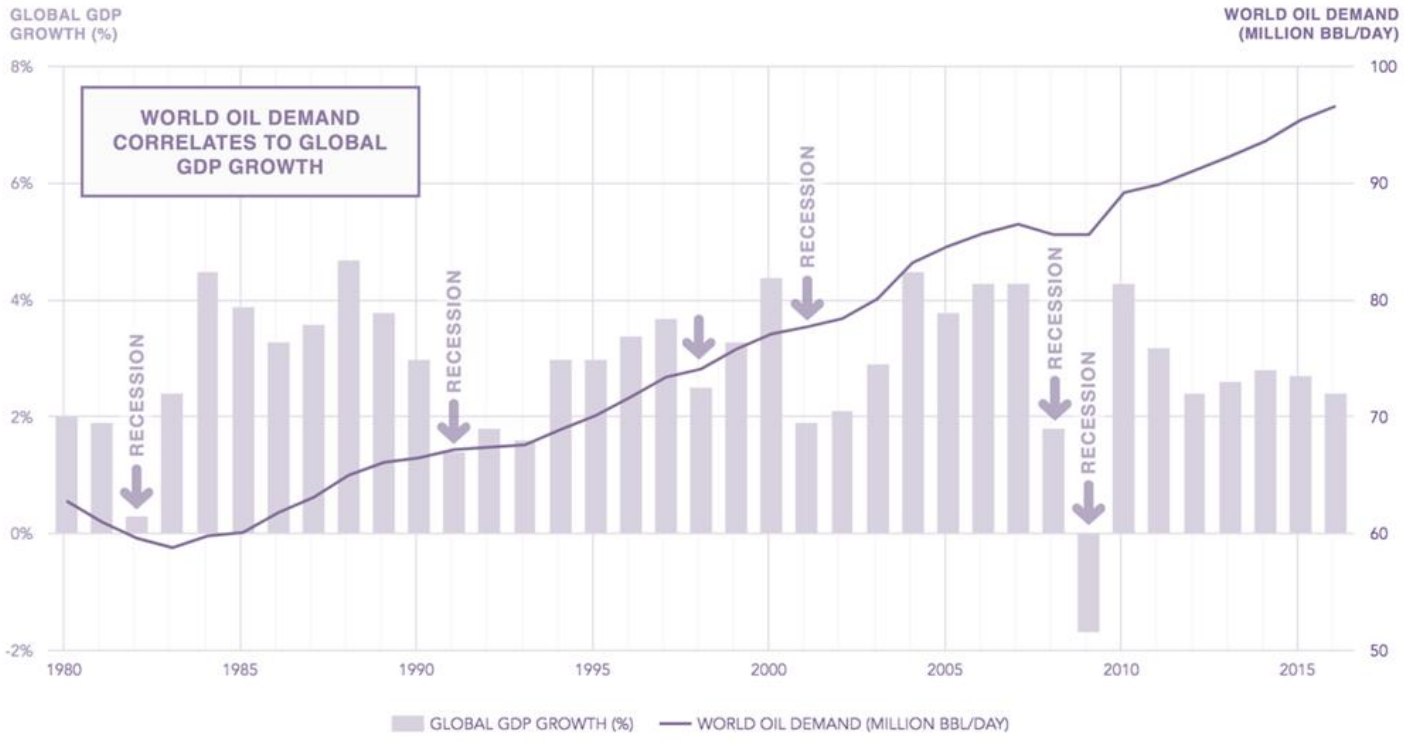


Figure – 29 : Global Oil Demand in correlation with GWP

- Let me address this simple but important fact when talking about global GDP's, Outside of the Middle-East, Russia, Canada, Venezuela and Norway, most of the world's largest economies are not energy importers, the largest being the US, Europe, China, India and Japan. Therefore, a low oil price is therefore a key to their economic growth.
- Since 2005, most of the world's GDP growth has come from emerging markets, predominantly China, India and Southeast Asia. Although recent global GDP data has been soft, surprisingly, it's being dragged lower by developed countries, where demand for oil is relatively stagnant.

Conclusion of Figure 28+29 Analysis.

1. The relationship between oil prices and global demand is non-linear. Although a low oil price is generally good for most economies, it increases demand, which puts upward pressure on oil prices. However, if prices get too high, global markets can easily tip into recession, limiting demand for crude.
2. Global economic growth is therefore a key variable in projecting where oil prices are headed.

7.2.1.3 GLOBAL GASOLINE CONSUMPTION:

Fuel consumption for roads remains one of the largest drivers of oil demand the world, according to *the US Energy Administration Report*, in 2017 American drivers alone consumed 9.33 million bbl/day of gasoline, followed by Japanese who have consumed 880K bbl/day, followed by Canadians who have consumed around 850K bbl/day.

In EU Zone, Germany was the biggest consumer where drivers have consumed around 427K bbl/day, and Iceland came last as drivers there have just consumed 3,300 barrels of gasoline per day.

Fresh collected data for Gasoline consumption worldwide by country is not available "According to the US Energy Administration", but I have prepared a chart that demonstrates the consumption of crude oil by 34 countries, *excluding USA*, **See figure 30**

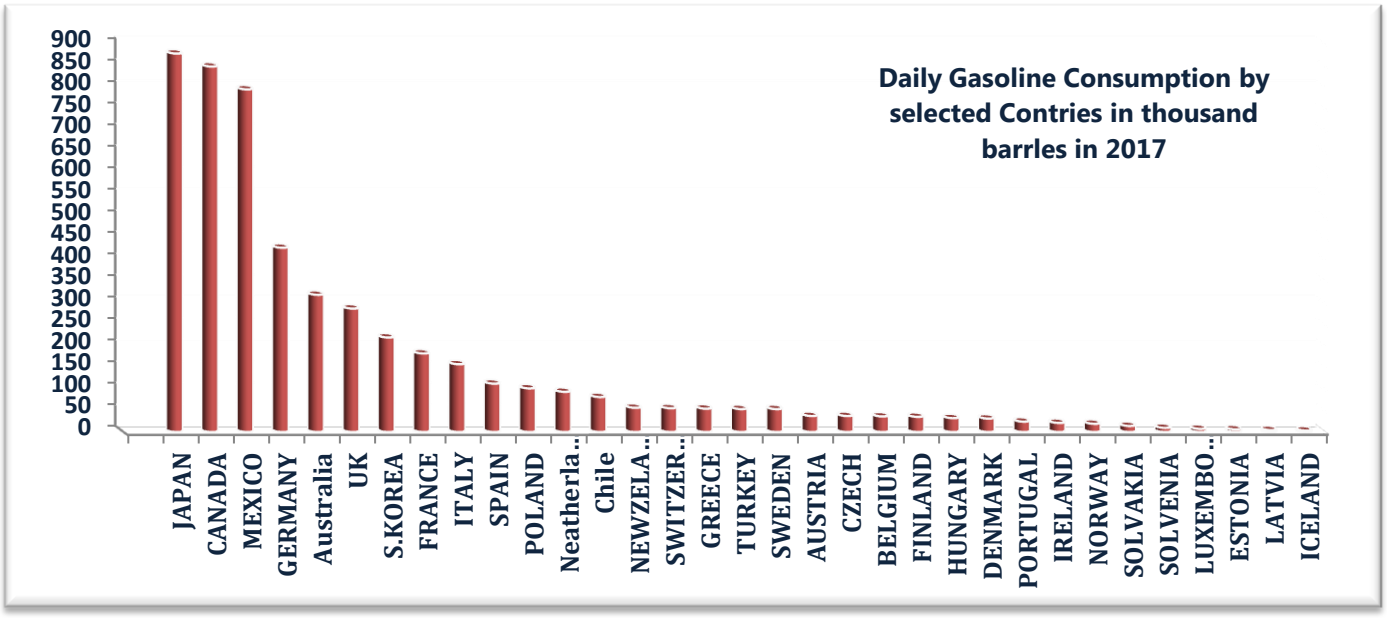


Figure –30: Daily consumption of Gasoline in selected countries in 2017. (H)

- The United States has been at least for the recent 40 years continuously collecting data on vehicle fleet efficiency, and then it works hard on regulating fuel standards for automakers to support its huge automobile industry, additionally, being the world's largest buyer of vehicles; American drivers also shift trends in the automotive industry worldwide.

- As gasoline prices began rising, specially at early 1980's, fuel economy standards became a necessity, encouraging automakers to shift towards more economically consuming vehicles, this helped the Japanese automobile industry big time, as in a span of 20 years, The sale of Japanese cars doubled between 1980 & 2000, as Americans shifted from huge cars with huge motors to Toyota and other Japanese made brands.

- Similar situation of American drivers, occurred worldwide as well, by making the demand on compact and economic cars increase, pushing Gasoline prices to drop through the late 1980s, causing demand to rise.

- Another interesting fact, is that as oil prices started accelerating rapidly following the year 2005, high gasoline prices have not only driven up demand for smaller vehicles, but it newly-introduced hybrids

- However, as gasoline prices began again to fall down fast after the high peak of 2008, automotive consumers have revived their desires for larger vehicles, such as SUVs & 4x4, causing again the demand on fuel to come up once again. *Demand is therefore a lagging indicator, and will improve prior to increases in oil prices*.

- Transportation fuels of road vehicles, still account for 50% of the world's total energy demands, but experts claim that this percentage is expected to decrease over the upcoming few decades, and in spite of the fact that in 2017, no more than 1% of the world's vehicles are functioning fully electrically; some experts debate that the internal combustion engine used in –Traditional Cars Technology - will eventually vanish, which potentially will cause major changes in energy demand.

- Finally, in some markets especially in South American market and also in USA & Canada, The introduction of bio-fuel blends standards in 2005 had played a major role as well in displacing several million barrels of demand.

- **In Figure 31**, I have prepared a chart that Introduces the global gasoline consumption by year, in thousands of barrels per day, the general trend is increasing, but we can witness 3 years which witnessed a drop in those consumption rates of gasoline in 1989, 1992 & 2008. While in **Figure 32**, I have prepared a chart that introduces the changes percentage in Gasoline Demand globally,

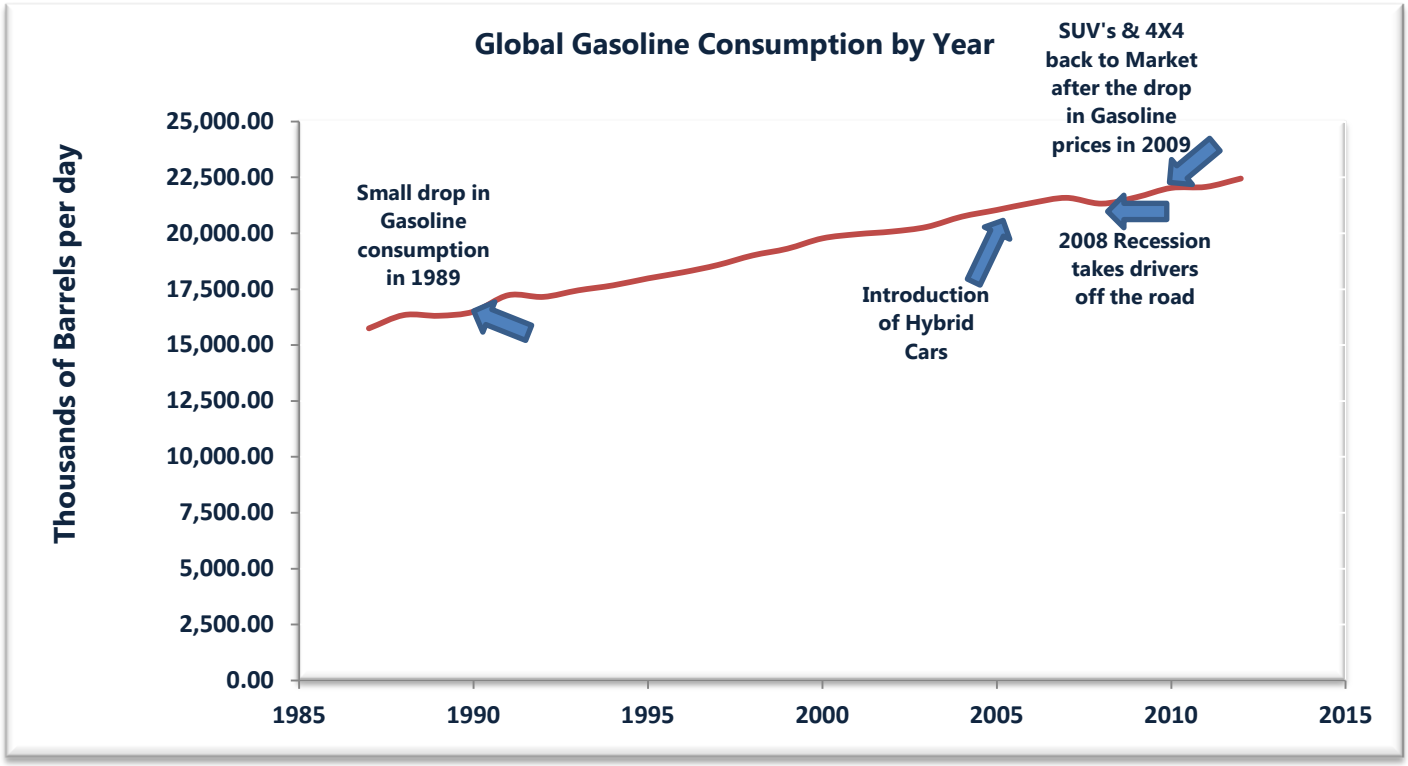


Figure – 31 Global Gasoline Consumption by Year.

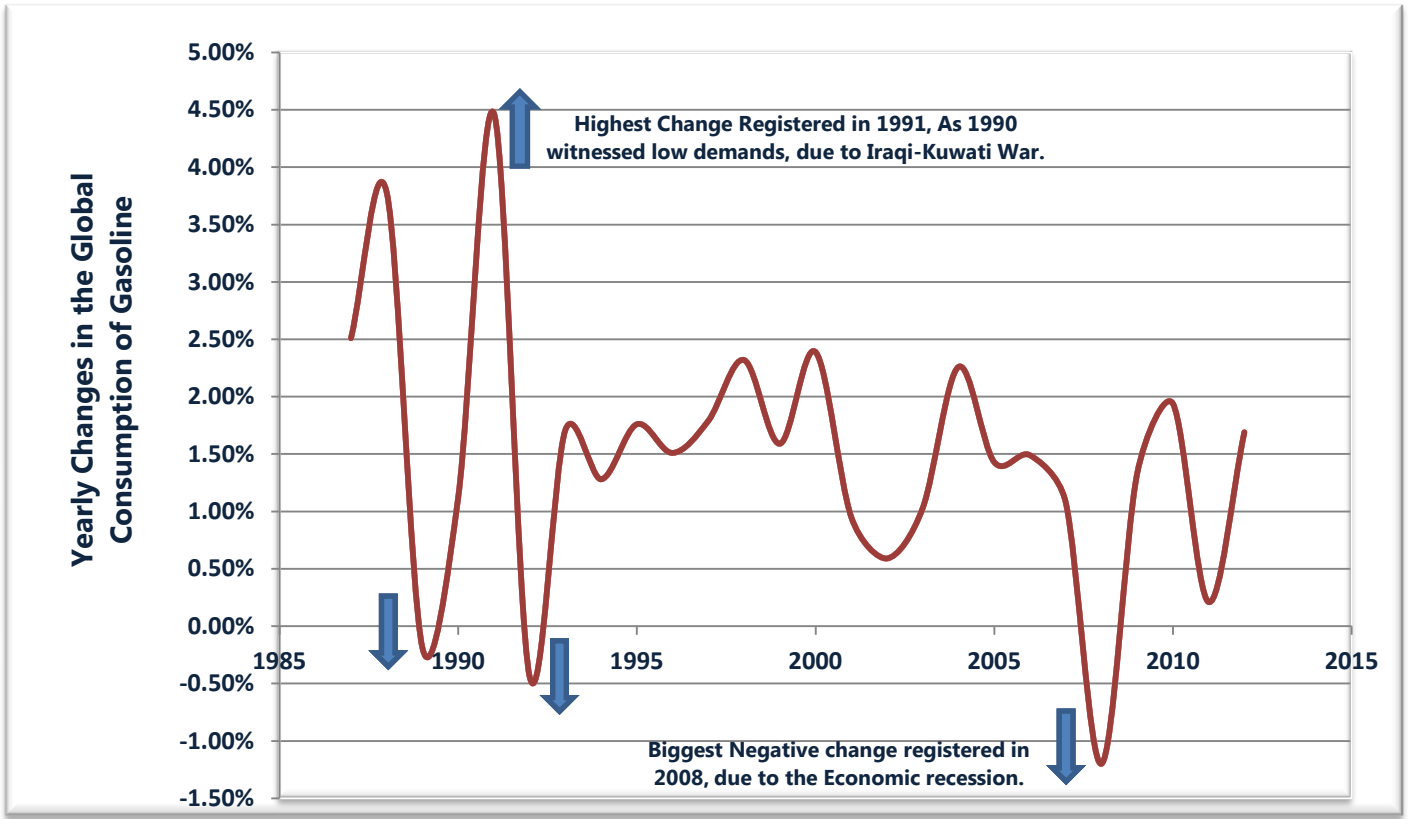


Figure –32: Yearly Changes in The Global Consumption of Gasoline.

7.2.1.4 SEASONALITY:

- a seasonality pattern are very common when talking about oil prices, These patterns originate from the fluctuations of supply and demand occurring annually but throughout the four different seasons of the year, Yet, I can see that those changes in seasonality are but are mainly a demand story.

7.2.1.4.1 SEASONALITY IN GASOLINE DEMAND:

Seasonality in gasoline demand is extremely repeated, frequent and can be thought of as cyclic; Gasoline demand is also weather dependent. Also - see **section 7.2.1.3**

- Peak demand of Gasoline and for sure that of crude oil, *since 50% of global world oil demand goes to Gasoline*, happens during the summer seasons, typically ranging between from late May to September. Afterwards, demand on gasoline then starts to decline during autumn and following winter.

- **See Figure 33:** which represents the monthly gasoline consumption in US by thousands of barrels between 1988 – 2018, this figure supports the seasonality idea mentioned above. *The source of the data is EIA, October 2018.*

- It is obviously observed that seasonality on yearly basis is present, in every year, we can see a peak that occurs between May/June & September, demands throughout these months tend to increase then they decline back after September, driving prices to rise up in summer season, but also pushing them to drop as well after September. All **blue circles** shown on figure reflect the seasonality patterns, and the increase in demands for the summer months.

7.2.1.4.2 REFINERIES OPRERATINS:

- Another important factor related to seasonality of crude demand is refineries, their operations, in addition to their planned maintenance shutdowns. In the US, I have found that most planned maintenance shutdown take place around the "Autumn/Winter" period, reducing demands for crude.

- Generally speaking, stockpiles rise throughout winter season, which leads the oil prices to drop and witness their maximum bottom values in and/or January.

- On the contrary, the use of crude oil for heating purposes increase in Winter time specially in cold countries such as Euro-Zone , USA, Canada & Russia, but those needs are usually satisfied by the stockpiles and inventory taken from previous months, thus It's not uncommon for oil prices to fall in the middle of winter.

- Upon the beginning of the first summer wave and it is the time for the summer season to start -this usually happens at the beginning of June 2 - Refineries will come back to work and will run of stockpiles, causing oil prices to rise once again. Oil prices tend to peak in summer months **as mentioned in section 7.2.1.4**, just before the cycle starts one more time.

- A Very Interesting idea that crossed my mind to prove seasonality throughout my research is to draw the *Monthly Average Price of Oil for my Benchmark for the period of the study 1988-2018.* Meaning that I will calculate the average price of oil for every month of the year, as an average of 30 months, of the past 30 years, between 1988 & 2018.

- Those averages are calculated in **Table-1 found in CHAPTER-2**, but again **Table-33** below shows a summary of those 30-years Average Prices of oil, and example-5 provides the numerical methods of calculations.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30 – years Average Price IN $US	43.31	44.05	45.50	46.89	47.51	47.70	48.25	48.31	47.10	46.43	44.92	43.53

Table 33 – Thirty-Years Average Price of Crude [1988-2018]

Example 8: Yearly Average of Crude Oil Calculations

To demonstrate how those numbers were generated, let us refer to **Table-1** , that records all Nominal Monthly Crude Oil Spot Prices in $US for [1988-2018], then for example to calculate the Average of January that we will use in generating **figure 26** , we will calculate the average of all averages of January that appears in Table-1.

Meaning that we will sum up all values of nominal average monthly spot price of crude for January, for all the years between 1988 & 2018 then divide this value by 30 years.

= $1299.34 / 30

= $43.31

Similarly, I followed the same approach for all other months, and we will generate the values seen in table

- The result of the graph was very surprising, and totally matching my above mentioned seasonality explanation mentioned above, **see Figure- 33**, as the graph shows that:
  - The Month that recorded the lowest Average values of Oil Price is January followed by Dec.
  - The Months that recorded the Highest Average Values of oil prices are August followed by July.
  - The Average Prices of Oil Tends to show significant increase starting by May/June.
  - Summer months records the highest average values of oil prices, Between May & September.
  - Once summer season ends, prices drops dramatically, and goes to its lower values again in Dec/Jan.

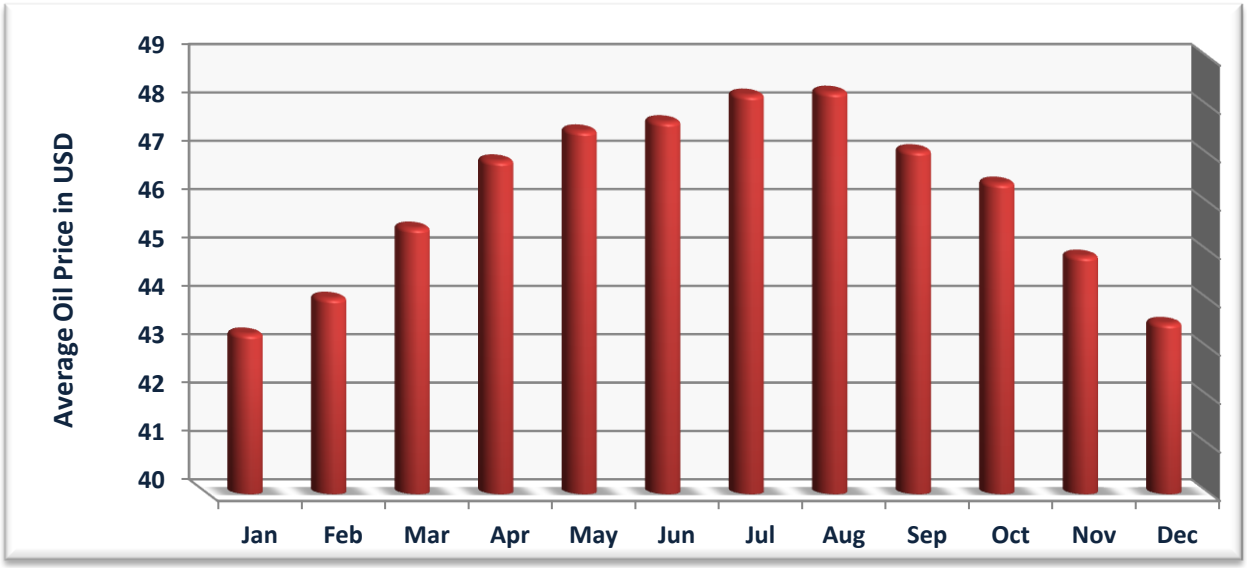


Figure –33 : 30 -Years Average Monthly Price For Every Month of The Year Between 1988-2018

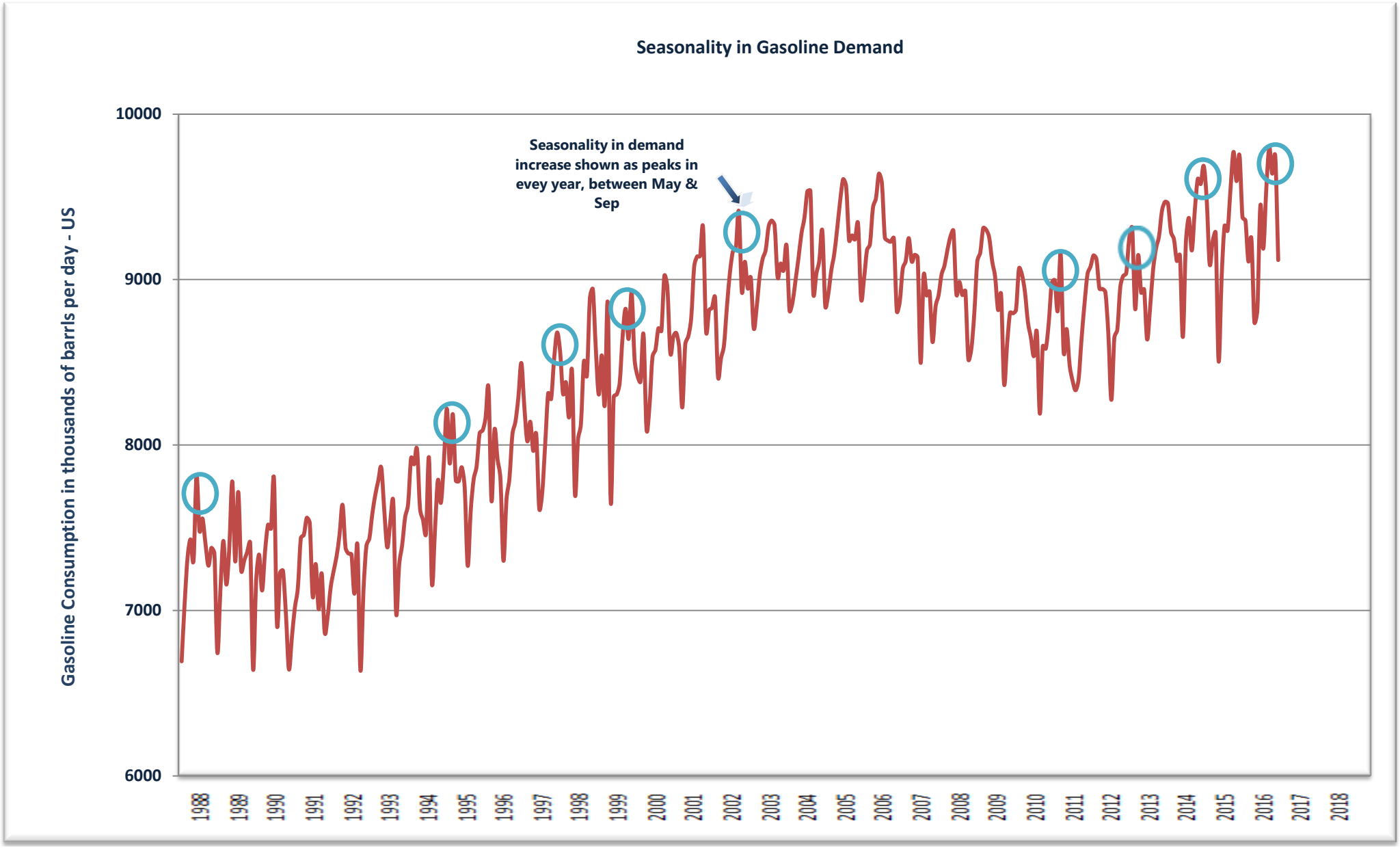


Figure –34 : monthly gasoline consumption in US in thousand of barrels 1988-2018

CHAPTER 8: Non Conventional Forecasting Models / 2019:

8.1 Approach I – Month By Month Forecasting Model :

- In this Model I will treat every month of 2019 individually, and I will try to forecast the oil price for every month of the year 2019 "[Jan to Dec], solely based on the recorded oil prices for the same month in previous years.
- Same assumptions mentioned throughout this thesis applies and are valid here as well, **see Figure-5**
- I will use two forecasting methods to do so which are:
  - **i. 3, 4, 6, 12, Moving Average Method.**
  - **ii. Exponential smoothing with α value of 0.1, 0.2, 0.3 & 0.4/ Taking into consideration the oil prices of the last 12 years only.**
- This will generate 8 different forecasted values for every month in2019 as follows:

- This will also generate different 12 values for every model, each value representing a different month.
- In order to measure the accuracy of every method, "Since 2018 Actual Prices Already Available**".** I will examine the Error Values of Each Model, and the model that generated best/Lower Error values will be the one chosen to forecast the 2019 Monthly Oil Prices.

8.1.1 Approach I – Input Data :

the input data for the different forecasting model will be the Average Monthly Crude Oil Price for the years [2006-2018], for every month and are summarized as follows in **tables 34/A, 34/B & 34/C shown below.**:

Year	January Average Crude Price in $US.	Year	Feb Average Crude Price in $US.	Year	March Average Crude Price in $US.	Year	April Average Crude Price in $US.
2006	62.46	2006	59.7	2006	60.93	2006	67.97
2007	53.52	2007	57.56	2007	60.6	2007	65.06
2008	90.69	2008	93.39	2008	101.84	2008	108.76
2009	43.86	2009	41.84	2009	46.65	2009	50.28
2010	77.12	2010	74.76	2010	79.3	2010	84.18
2011	92.69	2011	97.91	2011	108.65	2011	116.24
2012	107.07	2012	112.69	2012	117.79	2012	113.67
2013	105.10	2013	107.64	2013	102.52	2013	98.85
2014	102.10	2014	104.83	2014	104.04	2014	104.87
2015	47.11	2015	54.79	2015	52.83	2015	57.54
2016	29.78	2016	31.03	2016	37.34	2016	40.75
2017	53.59	2017	54.35	2017	50.9	2017	52.16
2018	66.23	2018	63.46	2018	64.17	2018	68.79

Table 34/A– Average Price of Crude by Month [2006-2018]

Year	May Average Crude Price in $US.	Year	June Average Crude Price in $US.	Year	July Average Crude Price in $US.	Year	August Average Crude Price in $US.
2006	68.68	2006	68.29	2006	72.45	2006	71.81
2007	65.16	2007	68.19	2007	73.6	2007	70.13
2008	122.63	2008	131.52	2008	132.83	2008	114.57
2009	58.15	2009	69.15	2009	64.67	2009	71.63
2010	75.62	2010	74.73	2010	74.58	2010	75.83
2011	108.07	2011	105.85	2011	107.92	2011	100.49
2012	104.09	2012	90.73	2012	96.75	2012	105.27
2013	99.37	2013	99.74	2013	105.26	2013	108.16
2014	105.71	2014	108.37	2014	105.23	2014	100.05
2015	62.51	2015	61.31	2015	54.34	2015	45.69
2016	45.94	2016	47.69	2016	44.13	2016	44.88
2017	49.89	2017	46.17	2017	47.66	2017	49.94
2018	73.43	2018	71.98	2018	72.67	2018	71.08

Table 34/B– Average Price of Crude by Month [2006-2018]

Year	September Average Crude Price in $US.	Year	October Average Crude Price in $US.	Year	November Average Crude Price in $US.	Year	December Average Crude Price in $US.
2006	62.12	2006	57.91	2006	58.14	2006	60.99
2007	76.76	2007	81.97	2007	91.34	2007	89.52
2008	99.66	2008	72.69	2008	53.97	2008	41.34
2009	68.35	2009	74.08	2009	77.55	2009	74.88
2010	76.12	2010	81.72	2010	84.53	2010	90.01
2011	100.82	2011	99.85	2011	105.41	2011	104.23
2012	106.28	2012	103.41	2012	101.17	2012	101.19
2013	108.76	2013	105.43	2013	102.63	2013	105.48
2014	95.85	2014	86.08	2014	76.99	2014	60.7
2015	46.28	2015	46.96	2015	43.11	2015	36.57
2016	45.04	2016	49.29	2016	45.26	2016	52.62
2017	52.95	2017	54.92	2017	59.93	2017	61.19
2018	75.36	2018	76.73	2018	62.32	2018	53.96

Table 34/C– Average Price of Crude by Month [2006-2018]

8.1.2 Approach I – Additional Input Data :

- For forecasting the monthly oil prices for year 2018 & 2019 using the exponential smoothing method, an initial forecast for the month - under interest – in year 2007 is required. *Note that No Initial forecasts are required when using the Moving Average Method.*
- I have used the estimated forecasts of the 3-moving average method generated in **Table-15**, as those initial forecasts, and those estimates are summarized in the following Mini-table.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Initial Forecast Input for Exponential smoothing	59.01	57.55	57.36	57.23	61.07	63.61	66.14	68.98	70.64	73.50	76.29	83.36

8.1.3 Approach I –Forecasting– 2018 :

- Then By applying the proper formulas of both forecasting methods, using the different month periods & α-values, **See CH-5**, forecasted results of input data relevant to every month individually were generate. I have gathered those forecasted results in **Tables 35** for the years 2018, and they were as follows. *All calculations were made by carefully reviewed Excel sheets.*

Month /2018	Actual Prices $US	Forecasting Method							
		Moving Average				Exponential Smoothing			
		MVA-3	MVA-4	MVA-6	MVA-12	α=0.1	α=0.2	α=0.3	α=0.4
January	66.23	43.49	58.15	74.13	72.09	66.92	65.81	61.38	56.56
Februarys	63.46	46.72	61.25	77.56	74.21	68.29	68.15	63.88	58.89
March	64.17	47.02	61.28	77.57	76.95	69.63	69.24	64.39	58.89
April	68.79	50.15	63.83	77.97	80.03	71.20	71.15	66.36	60.90
May	73.43	52.78	66.01	77.92	80.49	72.61	71.84	67.02	61.63
June	71.98	51.72	65.89	75.67	80.98	73.29	71.39	65.99	60.30
July	72.67	48.71	62.84	75.56	81.62	73.98	71.07	65.15	59.28
August	71.08	46.84	60.14	75.67	79.87	74.18	70.45	64.54	58.94
September	75.36	48.09	60.03	75.86	78.25	74.14	70.57	65.08	59.92
October	76.73	50.39	59.31	74.35	76.19	74.17	70.28	65.25	60.71
November	62.32	49.43	56.32	71.52	75.00	74.08	69.30	64.32	60.31
December	53.96	50.13	52.77	69.63	73.23	75.09	68.77	63.83	60.37

Table 35 – Non Conventional Forecasting Results – 2018 / Approach-I / $US

- As mentioned above, I will use those generated results of 2018 to calculate the Errors of each model, and try to numerically judge each model's accuracy, then the one that showed best accuracy will be used to calculate the 2019 Forecasts. **Section 8.3** summarizes the corresponding Error values of each method, The Errors Used for judgment are:

  i. Mean Absolute Deviation **(MAD).** *See section 6.4.1*
  ii. Mean Square Error **(MSE).** *See section 6.4.2*
  iii. Mean Average Percentage Error **(MAPE).** *See section 6.4.3*

8.1.4 Approach-I / 2018 Forecasting Results Summary:

Error Type	Moving Average				Exponential Smoothing			
	3-Month	4-Month	6-Month	12-Month	α=0.1	α=0.2	α=0.3	α=0.4
MAD	19.59	7.70	7.33	9.15	4.72	4.17	5.67	9.69
MSE	421.31	82.29	77.03	105.71	55.50	32.66	45.40	112.25
MAPE	28.01%	10.81%	11.47%	14.12%	7.73%	6.57%	8.21%	13.81%

Table – 36: Approach-I / 2018-Faorecasting Results Summary

8.1.5 Numerical Judgment / Unconventional Forecasting Models / Approach I

8.1.5.1 Observations : Moving Average Models:

i. The **3-Months Model** did not perform well under Approach-I, as it registered high error values and did not seem to function properly to forecast oil prices on Monthly Basis.

ii. The **4-Months Model** under Approach-I showed the best performance in terms of **MAPE** with an error value of **10.81%**. Yet this result is ***not better*** than that recorded under the conventional nominal prices forecasting, where the same 4-Months model had already generated lower error values of (MAD, MSE & MAPE), ***See section 6.6.1.***

iii. I can also observe that **6-Month Model** has the best value for **MSE of 77.03,** and also a value of **11.47% as MAPE**, generally speaking using The 6-Months model under Approach-I provided **better/lower** error values than the same 6-Months Model when used under conventional nominal prices forecasting, where MSE was found to be 86.36 & MAPE had the value of 12.35% & as we can see, both are higher.

iv. In spite the fact that the **12-Months Model** under Approach-I performed worse by generating higher error values compared to the 4-Months & 6-Months Models, yet the 12-Month Model in Approach-I performed even **better** than the same 12-Month mode under the conventional nominal prices forecasting.

v. **Using Approach-I,** The accuracy of Moving Average Forecasting Models decreases for forecasting the oil prices on short term basis, by including a smaller number of older data, or very large number of data as well.

vi. I only recommend using the moving average models under Approach-I for forecasting the monthly prices of oil only using models ranging between 4-6 months.

8.1.5.2 Observations: - Exponential Smoothing Models:

i. Using Exponential Smoothing Method under Approach-I leads to **much better and enhanced values** of Errors than when using the same exponential smoothing models under the conventional nominal prices forecasting, this is totally true for α values of 0.1, 0.2 & 0.3.

ii. Lowest Error values using the Exponential Smoothing Method were generated by the model that adopts the value of **(α=0.2),** where **MSE =32.66 & MAPE=4.17%.** This is way better than the same Errors recorded by using Exponential smoothing Method of **(α=0.2)** under the conventional forecasting, where **MSE =88.07 & MAPE=12.44%.**

iii. Using Exponential Smoothing Method under Approach-I leads to **much better and enhanced values** of Errors than when using the moving average models under Approach-I.

iv. Using Exponential Smoothing Method under Approach-I has achieved well in minimizing errors when forecasting Oil Prices on Monthly basis.

8.1.5.3 Numerical Judgment:

i. I can confidently say that it is a smart idea to investigate Approach-I in enhancing the errors for forecasting monthly oil prices on short term basis.

ii. In order to demonstrate the improvement achieved via using **Approach-I** under the *Unconventional forecasting*, I have prepared the below **Table-37** that shows improvement achieved by percentage by applying **Approach-I** compare to the *conventional nominal prices forecasting*

Mean Percentage Error "MAPE"

Model	Conventional Forecasting	Unconventional Approach-I	Change Percentage*	Comments
3-MVA	9.02%	28.01%	210.53%	*No Improvement, Don't Use Approach-I*
4-MVA	10.32%	10.81%	4.75%	*No Improvement, Don't Use Approach-I*
6-MVA	12.30%	11.47%	-6.75%**	*Minor Reduction in Error No Significant Improvement*
12-MVA	15.91%	14.12%	-11.25%**	*Better Error Value Fair Improvement.*
Exps / α =0.1	16.01%	7.73%	-51.72%**	*Huge Reduction in Error Significant Improvement. Good Model to Predict 2019 Oil Prices.*
Exps / α =0.2	12.36%	6.57%	-46.84%**	*Lowest Error Value, Huge Error Reduction Significant Improvement Best Model to Predict 2019 Oil Prices*
Exps / α =0.3	10.38%	8.21%	-20.91%**	*Better Error Value Fair Improvement.*
Exps / α =0.4	9.08%	13.81%	52.09%	*No Improvement, Don't Use Approach-I*

Notes :

*Change Percentage is calculated as:

= % [Unconventional Error – Conventional Error] / Conventional Error

** Negative Sign means reduction in Error Value, thus it indicates Improvement in Error.

- MVA: Moving Average Method
- Exps: Exponential Smoothing Method

Table-37: Conventional Forecasting Vs. Unconventional Forecasting / MAPE Comparison

iii. According to **Table-37**, we can see that unconventional forecasting under **Approach-I** has strongly proven better performance in forecasting and in **Error Reduction** as well, Especially when it comes to Exponential smoothing method, Numbers also demonstrates and suggests that **Exponential Smoothing** when used with smaller values of α= 0.1, 0.2 & 0.3 provide significant improvement in Forecasting models and tend to minimize results, where improvement reached values up to **51%** and **MAPE** can reach values as low as **6.50%**.

iv. In order to Emphasis further the improvement achieved via using **Approach-I** under the Unconventional forecasting, I have prepared similarly below **Table-38** that shows improvement achieved by percentage by applying Approach-I compare to the conventional nominal prices forecasting

Mean Squared Error "MSE"

Model	Conventional Forecasting	Unconventional Approach-I	Change Percentage*	Comments
3-MVA	45.73	421.31	**821.30%**	*No Improvement, Don't Use Approach-I*
4-MVA	59.88	82.29	**37.42%**	*No Improvement, Don't Use Approach-I*
6-MVA	86.36	77.03	**-10.80%**	*Minor Reduction in Error No Significant Improvement*
12-MVA	139.91	105.71	**-24.44%**	*Better Error Value Fair Improvement.*
Exps / α =0.1	135.03	55.50	**-58.90%**	*Huge Reduction in Error Significant Improvement. Good Model to Predict 2019 Oil Prices.*
Exps / α =0.2	82.07	32.66	**-60.20%**	*Lowest Error Value, Huge Error Reduction Best Improvement Best Model to Predict 2019 Oil Prices*
Exps / α =0.3	59.40	45.40	**-23.57%**	*Better Error Value Fair Improvement.*
Exps / α =0.4	46.10	112.25	**143.49%**	*No Improvement, Don't Use Approach-I*

Notes :

*Change Percentage is calculated as:

= % [Unconventional Error – Conventional Error] / Conventional Error

** Negative Sign means reduction in Error Value, thus it indicates Improvement in Error.

- MVA: Moving Average Method
- Exps: Exponential Smoothing Method

Table 38 –Conventional Forecasting Vs. Unconventional Forecasting / MSE Comparison

v. According to **Table-38**, we can see that unconventional forecasting again under Approach-I has strongly proven better performance in forecasting and in **MSE Error Reduction** as well, Especially when it comes to Exponential smoothing method, figures also demonstrate and suggest that **Exponential Smoothing** when used with smaller values of α= 0.1, 0.2 & 0.3 can provide significant improvement in forecasting results and tend to minimize errors, where improvement reached values up to **60%** and **MSE** can reach values as low as **32.66** while the lowest achieved using conventional methods was **45.73.**

8.1.6 Approach I –Forecasting– 2019 :

- Since Approach-I has resulted in 8 different forecasting models, in order to decide the best model to use in order to forecast 2019 Monthly prices, criteria used is to use the model that generated the lower Error values, then use this model to forecast 2019 Oil Monthly Prices.

- I have already forecasted the 2019-Monthly prices of Oil using the 8 different Models, and according to the set up criteria, the best model to be used for Forecasting 2019 Monthly oil prices will under Approach I, Will be Exponential Smoothing Model with α = 0.2, as it recorded the lowest values of Error among all other 8 models generated under Approach-I.

- Below is a **Table-39** that summarizes all forecasting results of Monthly Oil Prices of 2019, using the 8 models, and the one chosen is presented in **Bold & Dark Red Color.**

BY applying the 8 forecasting models, using Excel Sheets, the following summary results are generated for 2019:

Month / 2019	Forecasting Method							
	Moving Average				Exponential Smoothing			
	MVA-3	MVA-4	MVA-6	MVA-12	α=0.1	α=0.2	α=0.3	α=0.4
January	49.87	49.18	67.32	72.41	66.85	**65.90**	62.84	60.43
Februarys	49.61	50.91	69.35	74.52	67.81	**67.21**	63.75	60.72
March	50.80	51.31	68.63	77.22	69.08	**68.22**	64.32	61.00
April	53.90	54.81	70.49	80.10	70.95	**70.68**	67.09	64.06
May	56.42	57.94	72.81	80.88	72.69	**72.16**	68.94	66.35
June	55.28	56.79	72.54	81.29	73.16	**71.51**	67.79	64.97
July	54.82	54.70	71.55	81.64	73.85	**71.39**	67.41	64.63
August	55.30	52.90	69.97	79.81	73.87	**70.58**	66.50	63.80
September	57.78	54.91	70.71	79.35	74.26	**71.53**	68.16	66.09
October	60.31	56.98	69.90	77.76	74.43	**71.57**	68.69	67.12
November	55.84	52.66	65.04	75.35	72.90	**67.91**	63.72	61.11
December	55.92	51.09	61.75	72.64	72.97	**65.81**	60.87	57.81

Table 39 – Non Conventional Forecasting Results – 2019 / Approach-I

Selected Method for forecasting 2019 Monthly Oil Prices according to unconventional forecasting method approach-I. Is exponential smoothing model Using α = 0.2.

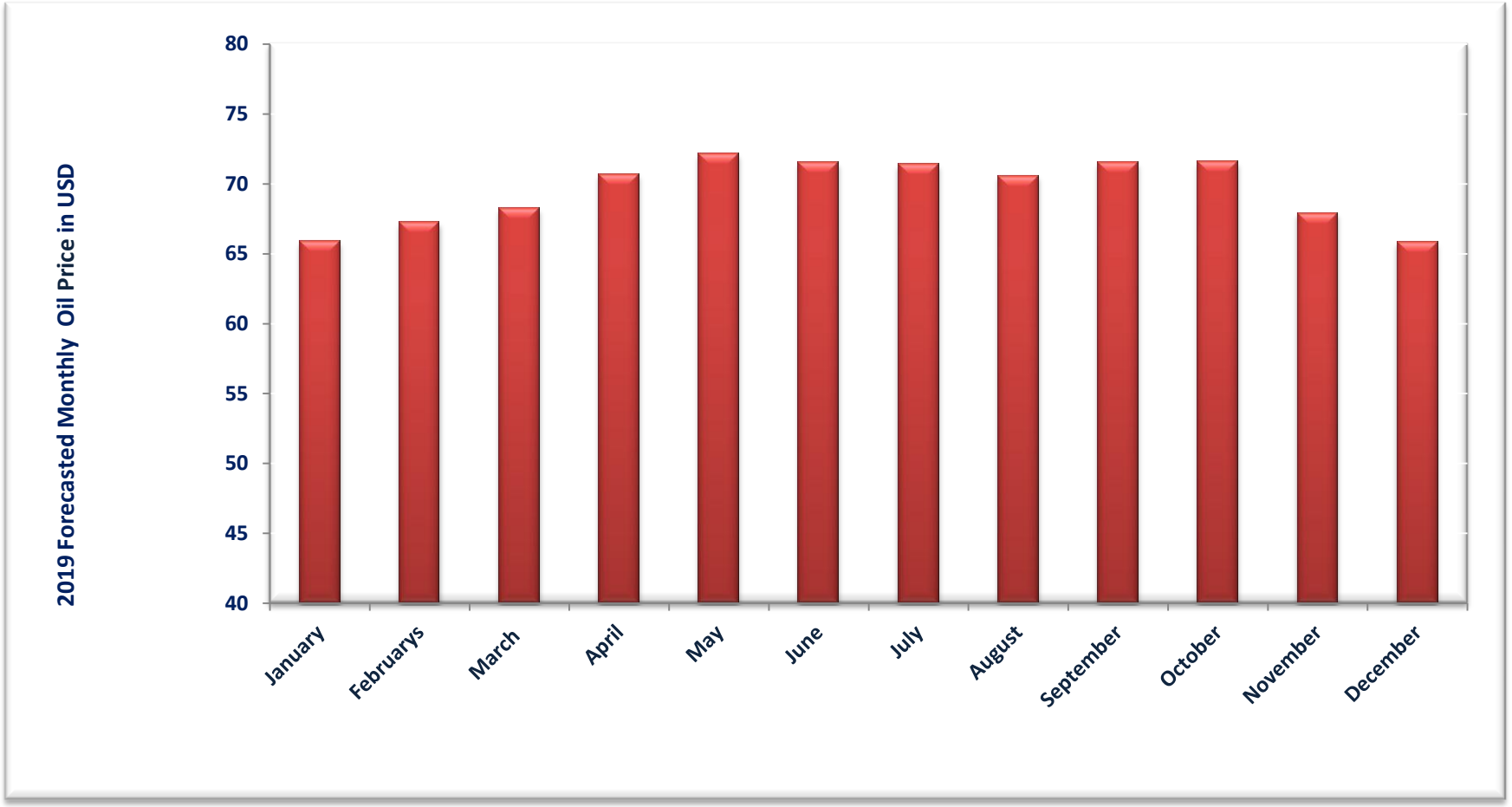


Figure-35: 2019–Forecasted Monthly Crude Oil Prices in $US using Unconventional Forecasting method / Approach-I

8.2 Approach II – Hybrid "Month By Month " Forecasting Model :

- Similarly to Approach I, in this model I will treat every month of 2019 individually, and I will forecast the oil price for every month of the year 2019 "[Jan to Dec], solely based on the recorded oil prices for the same month in previous years.
- Same assumptions mentioned throughout this thesis applies and are valid here as well, **see Figure-5**
- I will use two forecasting methods to do so which are:
  - **i. 3, 4, 6, 12, Moving Average Method.**
  - **ii. Exponential smoothing with α value of 0.1, 0.2, 0.3 & 0.4/ Taking into consideration the oil prices of the last 12 years only.**
- This will generate 8 different forecasted values for every month in 2019 as follows:

- This will also generate different 12 values for every model, each value representing a different month.

8.2.1 Approach II – Input Data :

the input data for the different forecasting model will be the same Average Monthly Crude Oil Price for the years [2006-2018] used in **Approach I** , for every month and are summarized in **Previously shown tables 34/A, 34/B & 34/C.**

8.2.2 Approach I – Additional Input Data :

- For forecasting the monthly oil prices for year 2018 using the exponential smoothing method, an initial forecast for the month - under interest – in year 2007 is required. *Note that **No** Initial forecasts are required when using the Moving Average Method.*
- I have used the estimated forecasts of the 3-moving average method generated in **Table-15**, as those initial forecasts, and those estimates are summarized in the following Mini-table.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Initial Forecast Input for Exponential smoothing	59.01	57.55	57.36	57.23	61.07	63.61	66.14	68.98	70.64	73.50	76.29	83.36

8.2.3 Approach II–Forecasting– 2018 :

- Then via applying the proper formulas of both forecasting methods, using the different month periods for moving average models & different α-values for exponential smoothing models, **See CH-5**, forecasted results corresponding to every month individually were generated.
- I have gathered those forecasted results in **Tables 35** "*See it in section 8.1.3*", for the years 2018. *All calculations were made by carefully reviewed Excel sheets.*

- Then I will define a Measure Value **"Absolute Error",** which measures the absolute difference between the forecasted price of any month under certain model and the actual monthly price for that month.

Example 9: Approach-II Absolute Error Calculation

To calculate the **Absolute Error** for **March** under the **3-Moving Average Model** :

I will follow the upcoming formula,

$$\text{Absolute Error @}_{\text{March-3MVA}} = \left|\text{Forecasted Price @}_{\text{March-3MVA}} - \text{Actual Price@}_{\text{March}}\right|$$

$$= |47.02 - 64.17|$$

$$= |-17.15|$$

$$= 17.15$$

To calculate the **Absolute Error** for **March** under the **Exponential Smoothing Model** with **α=0.3** :

$$\text{Absolute Error @}_{\text{March-EXPS } \alpha=0.3} = \left|\text{Forecasted Price @}_{\text{March-EXPS } \alpha=0.3} - \text{Actual Price@}_{\text{March}}\right|$$

$$= |64.39 - 64.17|$$

$$= |0.22|$$

$$= 0.22$$

*Similarly, I will calculate the Absolute Error for every reading within **Table 36** using the above Formula.*

- I have performed the above step on Table 33, and I have collected and summarized all calculations of **absolute errors** in the following **Table – 40**.
- As we can see that **Table-40** provides 8 different values of Absolute Errors per month, each corresponds to different forecasting model.
- In this step, I will find the **Minimum Absolute Error Value** among the 8 different error values, and shade that in **Green & Bold Color** within **Table-40**

Month/2018	Actual Prices$	Forecasting Method															
		Moving Average								Exponential Smoothing							
		MVA-3	Absolute Error	MVA-4	Absolute Error	MVA-6	Absolute Error	MVA-12	Absolute Error	α=0.1	Absolute Error	α=0.2	Absolute Error	α=0.3	Absolute Error	α=0.4	Absolute Error
January	66.23	43.49	22.74	58.15	8.08	74.13	7.9	72.09	5.86	66.92	0.69	**65.81**	**0.42**	61.38	4.85	56.56	9.67
Februarys	63.46	46.72	16.74	61.25	2.21	77.56	14.1	74.21	10.75	68.29	4.83	68.15	4.69	**63.88**	**0.42**	58.89	4.57
March	64.17	47.02	17.15	61.28	2.89	77.57	13.4	76.95	12.78	69.63	5.46	69.24	5.07	**64.39**	**0.22**	58.89	5.28
April	68.79	50.15	18.64	63.83	4.96	77.97	9.18	80.03	11.24	71.2	2.41	**71.15**	**2.36**	66.36	2.43	60.9	7.89
May	73.43	52.78	20.65	66.01	7.42	77.92	4.49	80.49	7.06	**72.61**	**0.82**	71.84	1.59	67.02	6.41	61.63	11.8
June	71.98	51.72	20.26	65.89	6.09	75.67	3.69	80.98	9	73.29	1.31	**71.39**	**0.59**	65.99	5.99	60.3	11.68
July	72.67	48.71	23.96	62.84	9.83	75.56	2.89	81.62	8.95	**73.98**	**1.31**	71.07	1.6	65.15	7.52	59.28	13.39
August	71.08	46.84	24.24	60.14	10.94	75.67	4.59	79.87	8.79	74.18	3.1	**70.45**	**0.63**	64.54	6.54	58.94	12.14
September	75.36	48.09	27.27	60.03	15.33	**75.86**	**0.5**	78.25	2.89	74.14	1.22	70.57	4.79	65.08	10.28	59.92	15.44
October	76.73	50.39	26.34	59.31	17.42	74.35	2.38	**76.19**	**0.54**	74.17	2.56	70.28	6.45	65.25	11.48	60.71	16.02
November	62.32	49.43	12.89	56.32	6	71.52	9.2	75	12.68	74.08	11.76	69.3	6.98	**64.32**	**2**	60.31	2.01
December	53.96	50.13	3.83	**52.77**	**1.19**	69.63	15.67	73.23	19.27	75.09	21.13	68.77	14.81	63.83	9.87	60.37	6.41

Table-40: Absolute Error Calculation – 2018 Forecasting / Approach-II

- Next, I will choose the Method that corresponds to the **Minimum Absolute Error Value** per month and utilize this method to forecast the Monthly Oil Price for this month in 2019. E.g. **Table-37** *indicates that for January, the Minimum Absolute Error Value was Generated by Exponential Smoothing α=0.2*, thus according to **Approach II**, I will use this method to forecast January Monthly Oil Price in 2019.

- But before to do so, I will present for the newly combined forecasted model called **Approach II,** in Forecasting 2018 oil prices, and then I will calculate the different Error Values including **"MAD, MSE & MAPE**" for **Approach II**, since I already have the actual monthly oil prices of 2018.

- **Approach II** Summary results are presented in Table **– 38** , including Errors calculations.

Month /2018	Actual Prices $US	Forecasting Method				
		Method	Forecasted Price	Absolute Error	Squared Error	Percentage Error
January	66.23	Exps α=0.2	65.81	0.42	72.09	66.92
Februarys	63.46	Exps α=0.3	63.88	0.42	74.21	68.29
March	64.17	Exps α=0.3	64.39	0.22	76.95	69.63
April	68.79	Exps α=0.2	71.15	2.36	80.03	71.20
May	73.43	Exps α=0.1	72.61	0.82	80.49	72.61
June	71.98	Exps α=0.2	71.39	0.59	80.98	73.29
July	72.67	Exps α=0.1	73.98	1.31	81.62	73.98
August	71.08	Exps α=0.2	70.45	0.63	79.87	74.18
September	75.36	6- MVA	75.86	0.5	78.25	74.14
October	76.73	12-MVA	76.19	0.54	76.19	74.17
November	62.32	Exps α=0.3	64.32	2	75.00	74.08
December	53.96	4-MVA	52.77	1.19	73.23	75.09
Errors				MAD = 0.92	MSE= 1.26	MAPE = 1.37%

Table 41 – 2018 Forecasting Results & Error Calculations / Approach-II

- Errors Calculation for **Approach II will** be used to show and support that by using Approach-II , I could improve forecasting results by achieving significant improvement in Error Values and generate reductions in error values.
- It is noticeable that by using the newly combined model **"Approach II"**, I could generate much better forecasting results of Monthly Oil Prices, and additionally achieve significant improvement / reduction in corresponding error, As **Table-41** indicates, the newly combined model was successful to reduce **Errors to** significantly low values Where:
  - Mean Average Deviation **MAD** go to a low value of **0.92**
  - Mean Squared Error **MSE** recorded a value of **1.26**
  - Mean Average Percentage Error **MAPE** went down to only **1.37%**

In Chapter 9 "Conclusion" more detailed comparison of All approaches will be further discussed.

8.2.4 Approach II–Forecasting– 2019 :

- In order to forecast monthly prices for 2019, Next, I will choose the Method that corresponds to the **Minimum Absolute Error Value** per month in year 2018, and I will utilize this method to forecast the Monthly Oil Price in 2019. E.g. **Table-40** *indicates that for January, the Minimum Absolute Error Value was Generated by Exponential Smoothing α=0.2*, thus according to **Approach II**, I will use this method to forecast January Monthly Oil Price in 2019.
- **Table-42** presents clearly those methods corresponding to the **Minimum Absolute Error Values per Month**, which will be used for forecasting 2019 monthly oil prices.

Month	Used Method For Forecasting
January	Exps α=0.2
Februarys	Exps α=0.3
March	Exps α=0.3
April	Exps α=0.2
May	Exps α=0.1
June	Exps α=0.2
July	Exps α=0.1
August	Exps α=0.2
September	6- MVA
October	12-MVA
November	Exps α=0.3
December	4-MVA

Table 42 – Used Method for forecasting crude oil price 2019 / Approach-II

- Therefore, by applying each corresponding method according to **Table-42** to forecast the monthly oil price on all months individually, a single unique **Combined Model** will be generated for the Monthly Oil Prices Forecast of **2019** as follows:

- Below is a **Table-43** that summarizes all forecasting results of Monthly Oil Prices of 2019, using Approach-II

Month	2019 Forecast	Comments
January	65.90	Generated by Exps α=0.2
Februarys	63.75	Generated by Exps α=0.3
March	64.32	Generated by Exps α=0.3
April	70.68	Generated by Exps α=0.2
May	72.69	Generated by Exps α=0.1
June	71.51	Generated by Exps α=0.2
July	73.85	Generated by Exps α=0.1
August	70.58	Exps α=0.2
September	70.71	6 -MVA
October	77.76	12-MVA
November	63.72	Exps α=0.3
December	51.09	4-MVA

Table 43 – 2019–Forecasted Monthly Crude Oil Prices in $US using Unconventional Forecasting method / Approach-II

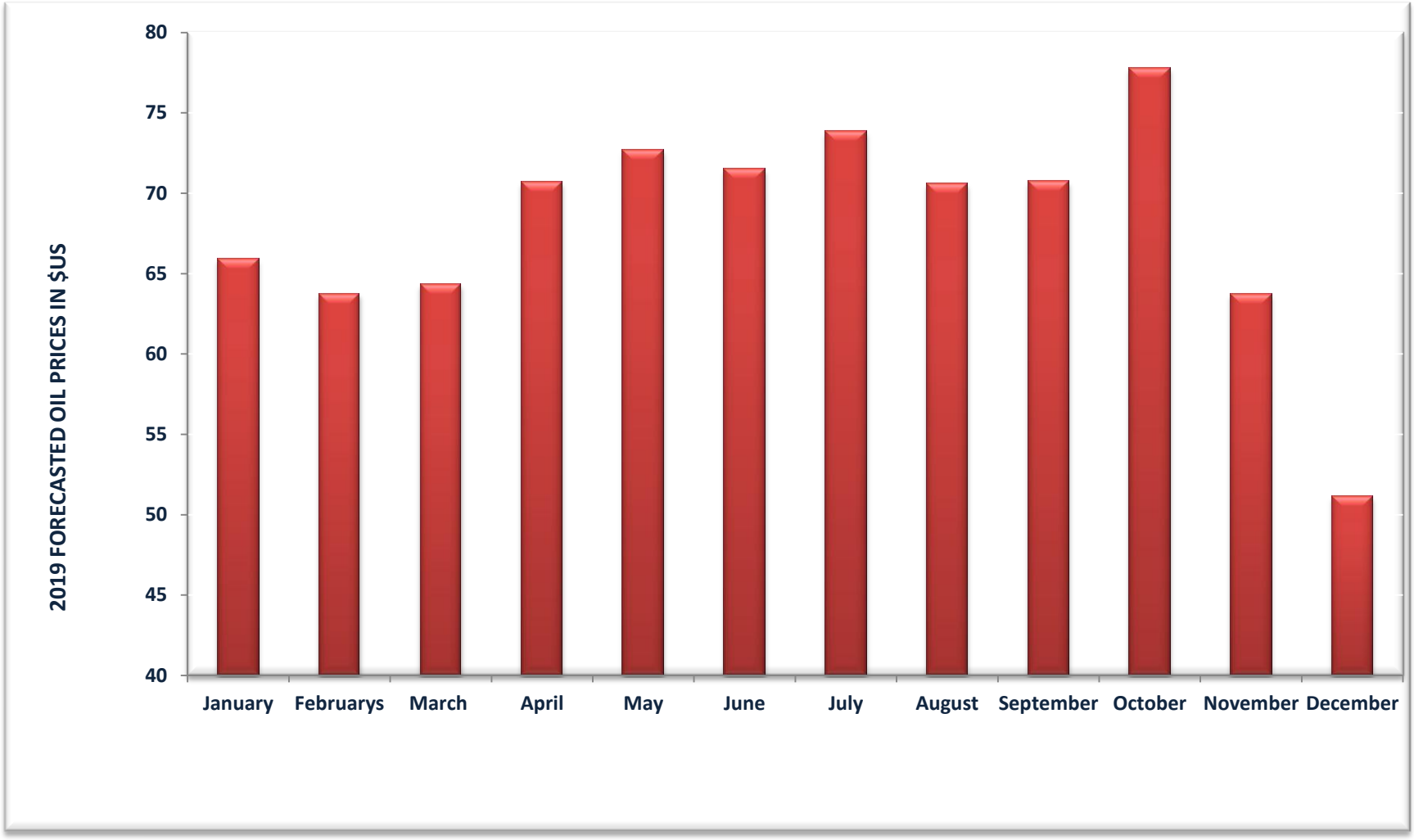


Figure-36 2019–Forecasted Monthly Crude Oil Prices in $US using Unconventional Forecasting method / Approach-II

CHAPTER 9: CONCLUSION

9.1 Concluding Chapters Reviews:

The choice of the topic of my thesis never came random, it actually reflects a passion that I have for the engineering economy and it combines my passion as an industrial engineer with the contents of this course along with my previous professional experience and my future plans of joining the petroleum industry as an engineering economist or an academic advisor.

I tried hard throughout the writing process of this thesis to show my passion and also to submit a proper degree of professionalism, I look to this thesis not only as a way to get my degree but also as an essential tool that might open the horizon for me to penetrate the petroleum industry opportunities specially that I come from the middle east where petroleum opportunities are unlimited and it a region that owns the share of the lion of petroleum globally.

Therefore, I was making sure that this thesis is written in a way trying to allow the reader to understand and comprehend all the elements of its topic in a simple yet a scientific manner, in order to do so I have used various descriptive tools such as smart figures, reader friendly tables and also clear examples to assist the reader to easily follow.

My thesis consists of 9 carefully written chapters, the first chapter of this thesis reflects an introductory basic information about petroleum and crude oil, it discusses in few lines the scientific definition of oil, its history, how it is extracted and the major benchmarks in market, chapter 1 as well gives the reader the necessary idea of oil quality and grades and how this can impact oil prices globally.

The second chapter of this thesis provides the major assumptions followed throughout the context of the thesis on hand which will grant the reader a better opportunity to facilitate a better understanding of the contents of this thesis, such as that all prices reflect the spot prices and are all quoted in US Dollar of a benchmark consisting of Brent, Dubai & WTI, equally weighed.

The numerical input data for forecasting were monthly crude oil prices of the above mentioned forecast for 30 year between [1988 & 2018]. Moreover; chapter-2 also addresses definitions of terms such as spot prices, oil market types, inflation and several other definitions of expressions of high importance to the petroleum economics and to this thesis. Chapter-2 additionally; shows the calculations of the monthly crude oil spot prices and presents them in clearly in reader friendly tables that can be easily interpreted by the reader of this thesis.

The third chapter of this thesis I have presented a new approach called Inflation-Adjusted Prices Approach, where all the monthly prices of crude oil for the above mentioned benchmark between [1988-2018] have been corrected/adjusted using consumer prices indices of US Dollar in USA to the year 2018, and then I have applied the same conventional forecasting approach used previously on those adjusted spot prices to conduct the forecasting model. The main purpose of this adjustment is to allow me to see the influence of inflation rates solely on the crude oil prices nowadays, those adjusted prices represents the monthly crude oil prices of our benchmark in today's US Dollar value, and in other words the price you would have actually paid at the time. In this chapter I was also successful to analyze and interpret related facts out of a graph that reflects those adjusted prices of crude oil.

By moving to the fourth chapter, the reader could enjoy a careful qualitative analysis of the crude oil prices between 1988 & 2018, For the purpose of descriptive analysis of this 30 full year range had been divided Into 8 periods, decided based on significant events that influences the analysis and can observe a difference.

I dedicated chapter five of this thesis to discuss the different aspects of forecasting, its definition in literature and according to some experts, and its application in oil industry. Furthermore, I went to deep discussion about forecasting methods types, and a comparative analysis between those different types as well, Then I have addressed 2 different approaches of time series forecasting "Moving Average & Exponential Smoothing", and then I gave numerical examples that explains how they work and how I utilized forecasting throughout this thesis

Chapter-7 titled, "Variables of Crude Oil" have enlightened on major facts relating oil prices fluctuations with demand and supply and also have discussed different types of oil suppliers, , this chapter as well also have introduced in depth the main supply shift categories, and the main demand shifts categories of crude oil, I used several graphs, tables and figures in this chapter, and linked the fluctuations of oil prices with those different shift in demand and supply.

9.2 Forecasting Concluding Review:

Within the sixth and eighth chapters of this thesis I have applied several time-series forecasting models to monthly crude oil prices and then forecasted monthly oil price changes based on these models. In this thesis, all quoted prices represent the crude oil spot price in US Dollar of a benchmark consisting of Brent, Dubai & WTI, equally weighed. The numerical input data for forecasting were monthly crude oil prices of the above mentioned forecast for 30 year between 1988-2018.

In this thesis I have used four different approaches for forecasting process of monthly crude oil prices:

Conventional Nominal Price Forecasting Approach

- Conventional Time Series Approach using 4 Models which have utilized the moving average approach with different periods "3, 4, 6 & 12 months".
- Conventional Time Series Approach using 4 Models that have utilized the exponential smoothing approach with different Alpha α values "0.1, 0.2, 0.3 & 0.4".

Inflation-Adjusted Prices Forecasting Approach

As mentioned above, In thesis I have used a new approach called Inflation-Adjusted Prices Approach, where all the monthly prices of crude oil for the above mentioned benchmark between [1988-2018] have been corrected/adjusted using consumer prices indices of US Dollar in USA to the year 2018, and then I have applied the same conventional forecasting approach used previously on those adjusted spot prices to conduct the forecasting model.

The output of this approach was 8 Different models as follows:

- Inflation-Adjusted Forecasting Approach using 4 Models which have utilized the moving average approach with different periods "3, 4, 6 & 12 months".
- Inflation-Adjusted Forecasting Approach using 4 Models that have utilized the exponential smoothing approach with different Alpha α values "0.1, 0.2, 0.3 & 0.4"

Unconventional Approach-I: Month by Month Forecasting Model:

In this Model I have treated every month of the year individually, and I aimed to forecast the oil price for every month of the year in 2019 "[Jan to Dec], solely based on the recorded monthly crude oil prices for the same month in the past 12 years.

To do so, as a start I was ought to start using Approach-I to forecast the 2018 monthly crude oil prices using

- Four (4) Models which have utilized the moving average approach with different periods "3, 4, 6 & 12 months".
- Four (4) Models that have utilized the exponential smoothing approach with different Alpha α values "0.1, 0.2, 0.3 & 0.4".

The accuracy of those 8 generated models was evaluated using different error measures including "MAD, MSE & MAPE", and then the model that showed best forecasting result with lowest error values in forecasting 2018 prices was selected to perform the forecasting of 2019. This approach showed huge significant improvement in forecasting results than the first two conventional models and have generated significant reduction in errors as well.

Unconventional Approach-II: The Hygiene Forecasting Model:

Similar to Unconventional Approach-I I have also treated every month of the year individually, and I aimed to forecast the oil price for every month of the year in 2019 "[Jan to Dec], solely based on the recorded monthly crude oil prices for the same month in the past 12 years.

To do so, as a start I was ought to start using Approach-I to forecast the 2018 monthly crude oil prices using:

- Four (4) Models which have utilized the moving average approach with different periods "3, 4, 6 & 12 months".
- Four (4) Models that have utilized the exponential smoothing approach with different Alpha α values "0.1, 0.2, 0.3 & 0.4".

Then instead of evaluating the accuracy of every model using the different error measures, I have defined a numerical measure value called it the Absolute Error which measures the absolute difference between the forecasted price of any month under certain model and the actual monthly price for that month.

This means that 8 different values of Absolute Errors per month are generated; each corresponds to different forecasting model. Next, I found the Minimum Absolute Error Value among those 8 different error values, and then I will choose the Method that corresponds to the Minimum Absolute Error Value per month to utilize this method in order to forecast the Monthly Oil Price for this month in 2019. Approach-II showed the most significant improvement in forecasting results than all previous conventional and unconventional models and has generated the hugest reduction in error measures.

9.3 Numerical Results:

I have prepared the below table which shows the best **numerical forecasted results** achieved by every approach used in this thesis, I have decided here to only include the best results in order to show the improvement achieved by applying the non conventional approaches as well.

	Method					
	Conventional Nominal Prices Forecasting		Inflation- Adjusted Prices Approach		Unconventional Approach I	Unconventional Approach II
Best Model	3-MVA	Exps α=0.4	3-MVA	Exps α=0.4	Exps α=0.2	Not Applicable
MAD	4.05	4.03	4.95	4.94	4.17	0.92
MSE	45.73	46.10	64.03	64.14	32.66	1.26
MAPE	9.14%	9.15%	9.02%	9.08%	6.57%	1.37%

Table 44– Comparison of Best Errors Generated by each Method.

As we can see by applying the unconventional Approach II, a significant improvement and huge error reduction can be generated on all types of Errors, for example MAD has been improved by a percentage of 77.3% than the conventional approaches, while MSE Showed a reduction of 97.24%, the same behavior of MAPE is also noticed which exhibits a reduction of 85.02%.

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DATA SOURCES:

A- Source of nominal spot prices of WTI & Brent Crude Oil is provided by ***US Energy Information Administration*** 2018/2019.

B- Source of nominal spot prices of Dubai Crude Oil is provided by ***Chicago Mercantile Exchange***.

C- Consumer Price Indices "CPI's values", according to the US Dollar Values**, provided by a Bureau of Labor Statistics of USA.**

D- Figure-6: is taken from **https://inflationdata.com/articles/charts/inflation-adjusted-oil-prices-chart/,** date accessed, 28/09/2018.

E-Data source for Figure-25/A represents the distribution of oil demand worldwide by sector in 2016; data source is **OPEC**, published in Nov 2017, by the 2017 world oil outlook.

F- Data source for Figure-25/B that represent the Daily Average Demand of Crude Oil Globally in Millions of Barrels between [1988 – 2019] is **OPEC**, data published in Nov 2017, by the 2017 world oil outlook

G- Data Source for Figure – 28: that represents that Growth per Year between [1990-2022] is **IMF**, published very recently in Oct 2018, by the world Economic outlook database.

H-Data Source for Gasoline consumption worldwide by country is According to **the US Energy Administration.**