A system dynamics model to achieve sustainable production of oil in Iran

Gholamreza Eslamifar, Amir MohammadShirazi, Ali N. Mashayekhi

Graduate School of Management and Economics
Sharif University of Technology, Tehran, Iran
+982166165856

eslamifar@alum.sharif.edu, amshirazi25@gmail.com, mashayekhi@sharif.edu,

Abstract

Oil Exporting Countries may encounter the problem of managing oil production because of changes in the volume of available oil resources and the depreciation of infrastructures. In Iran, on one hand, oil revenues are supposed to cover expenditure of socioeconomic development. On the other hand, based on statistics, its oil wells are in the middle of their life and the industry requires high investment to build-up and maintains infrastructures to produce at the current rate of production. In this paper, a model is presented to capture the realities and complexities of oil production industry. In the model, the oil sector is fragmented into four sectors including production, market, consumption and investment sectors. Finally, based on the results of the model, an investment policy to achieve the sustainable production of oil in Iran is proposed.

Keywords

Iran, Oil Production, Oil Wells, Oil Revenues, Sustainability, Policy Making

Introduction

Recently the expediency discernment council of Iran has passed a strategic planning (The vision of Iran in 1404). This action is made for convergence of all countries subsystems; including oil and gas industry. The deadline of this planning is 2025. In this document oil and gas industry should achieve following

point that Iran should preserve the second position in OPEC oil production with building enough capacity for ensuring the security. Despite the fact that the objective is wage and unclear but the minimum requirement of this objective is sustainable production.

In this part, three sections are discussed. The first section is about world energy market which price and level of production and consumption are determined. The next part is about trends of Iran's macroeconomic indexes which fundamental characteristics are evaluated. In the third section, Iran oil industry is analyzed.

World Future Energy Outlook

World Energy System is a complicated set of numerous parts with large amounts of interactions and specialties. But this complexity can be simplified by operational thinking which helps to define some few major parameters to track energy market. These parameters are investigated in the sequence of time and represent specifications of two sides of energy market; including demand and supply. There are 3 main scenarios[1] based on nations' decisions which can lead to different futures. The *Current Policy scenario* is obtained from today's macro policies. New Policy *scenario* comes from new policy-making and the *450 scenario* concentrates on reducing CO2 concentration below 450 ppm. The projections of energy demand and supply accordingly vary significantly across the three scenarios.

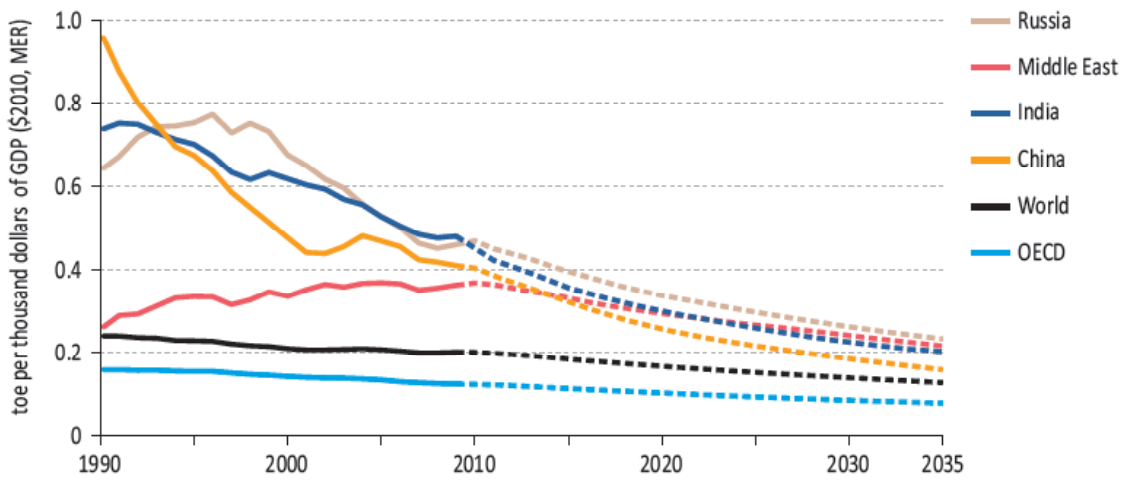

Figure 1, Energy intensity in some countries and regions in the New Policies Scenario, Energy Outlook 2011[2]

There are large differences in energy intensity among countries, primarily due to differences in energy efficiency of infrastructures, economic structure and climate. In most cases, non-OECD[1] countries have higher value of energy intensity while they are experiencing much faster reductions.

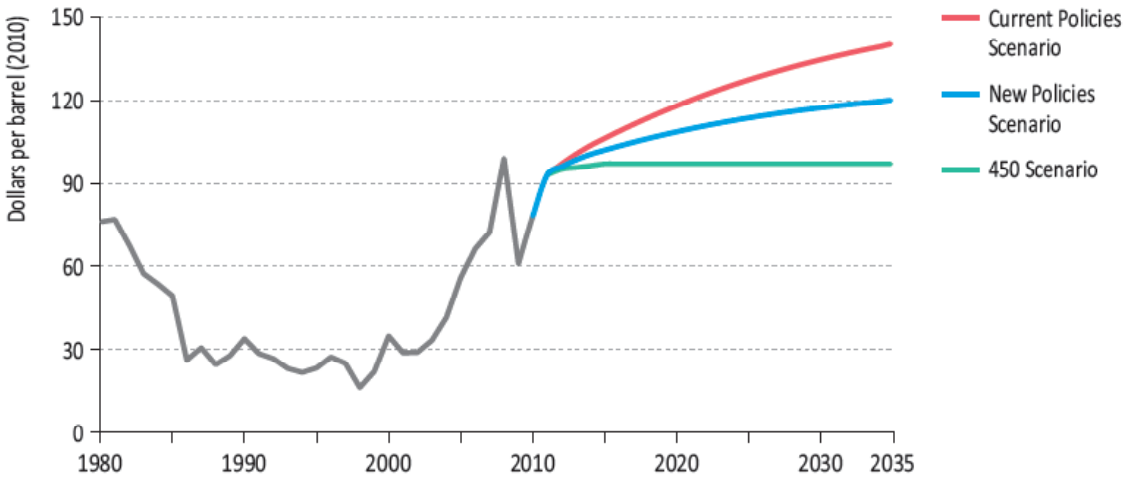

Figure 2, Average IEA crude oil import price(annual data), Energy Outlook 2011[3]

It can be seen in Figure 2 that the crude oil import price will not fall down in all scenarios. Therefore increasing price means decreasing demand in the way of

[1] OECD: Organization for Economic Co-operation and Development

omitting low affordable customers. As a result, there are always customers, who are willing to pay for cheaper oil, which maintaining supply side security in the market. It should be noted also that these are trends which will be disturbed and fluctuated by market uncertainties which are originated in politics issues.

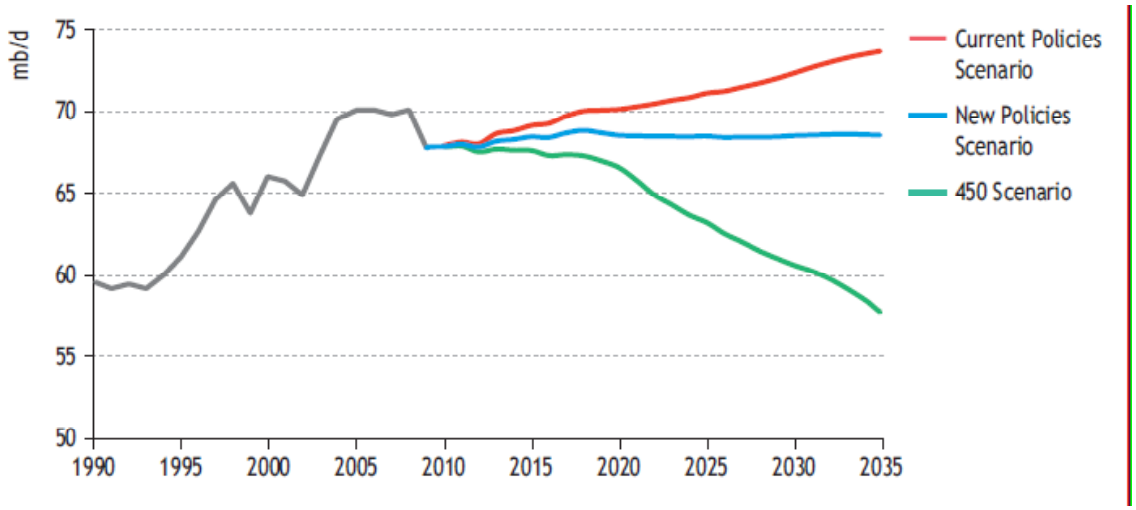

Figure 3, World crude oil production by scenario, Energy Outlook 2011 [4]

There is a notable difference in crude oil production forecasting across the scenarios. In current policy scenario, oil production will reach to 74 million barrel per day by 2035 from 68 mb/d in 2010. This trend should be supported by higher prices which will be followed by higher amount of investment in production capacity. Slower global demand growth and lower prices in the New Policy Scenario cause steady production capacity. In this scenario production will remain in the same amount. But in 450 Scenario, related policies in order to reduce emissions make the demand rate into reverse position, causing prices to level off and less investment in conventional oilfields. As we can conclude from figure 2 and 3, in Current Policy Scenario and New Policy Scenario, the market volume will be increased so Iran has the tendency of keeping its oil production capacity but the situation in 450 Scenario is different.

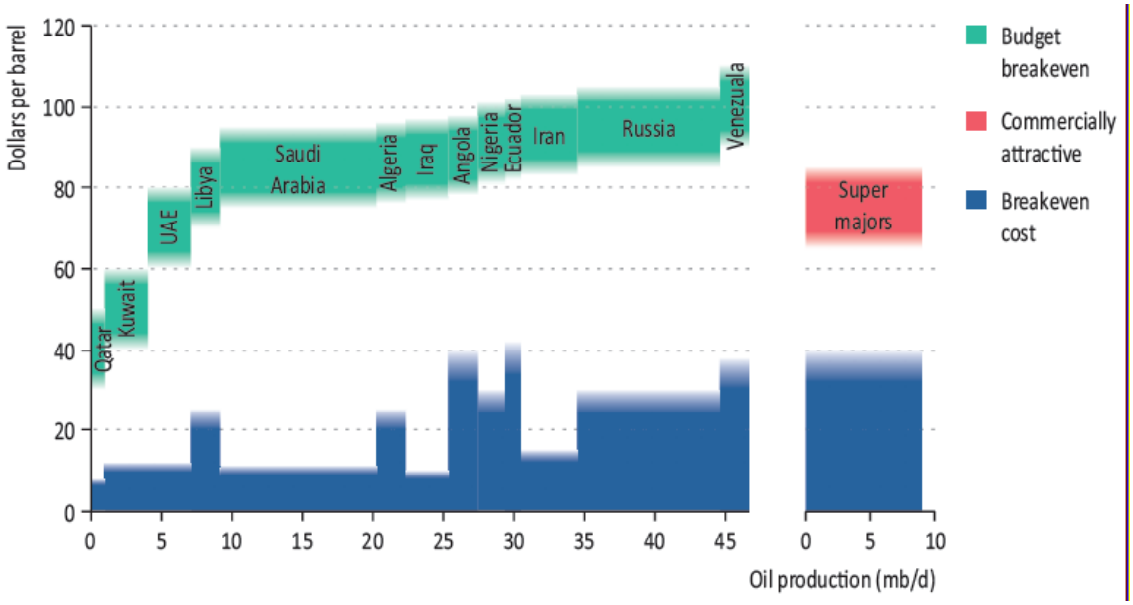

Figure 4, Breakeven costs, budget breakeven and commercially attractive prices for current oil production for selected producers, Energy Outlook 2011[5]

In figure 4, it is illustrated that the lowest production cost is related to OPEC countries and with consistent high oil prices in recent years, all OPEC wells are economically justifiable for production. But by decreasing oil prices in 450 Scenario, most of competitors will lose their margins; as a result OPEC countries including Iran have the power of leading market price.

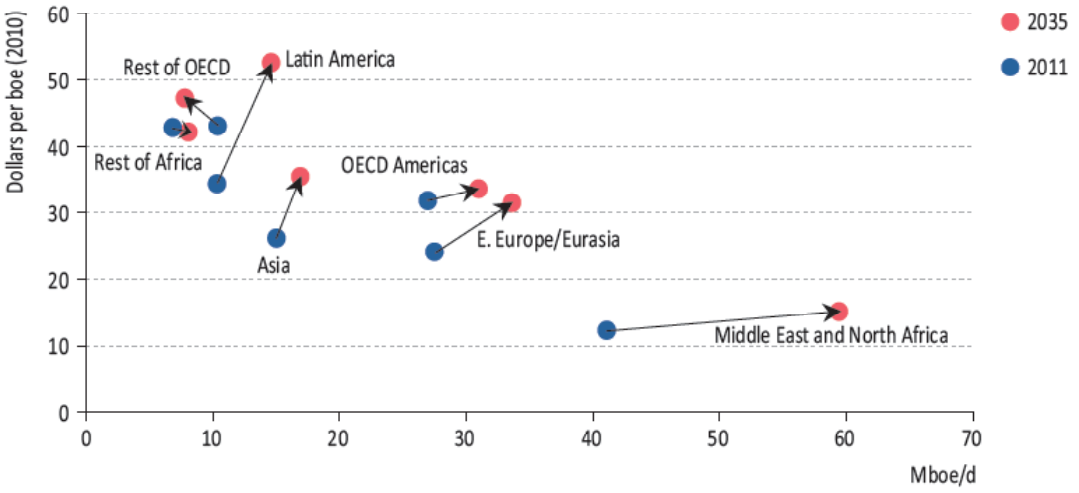

Figure 5, Oil production breakeven costs in the New Policies Scenario, Energy Outlook 2011[6]

As we can see from figure 5, production cost for Middle East countries will not increase so much, from $12 per barrel in 2011 to $16 per barrel in 2035, despite the fact that the production will increase from 42 million barrel oil equivalent per day in 2011 to 59 Mboe/d in 2035.

Iran's macroeconomic key indicators

The next step is clarifying Iran's economic conditions. Iran's economic structure can be presented by a few major factors including Population, Oil Income, Government Income and Expenditure, Oil Production and Export.

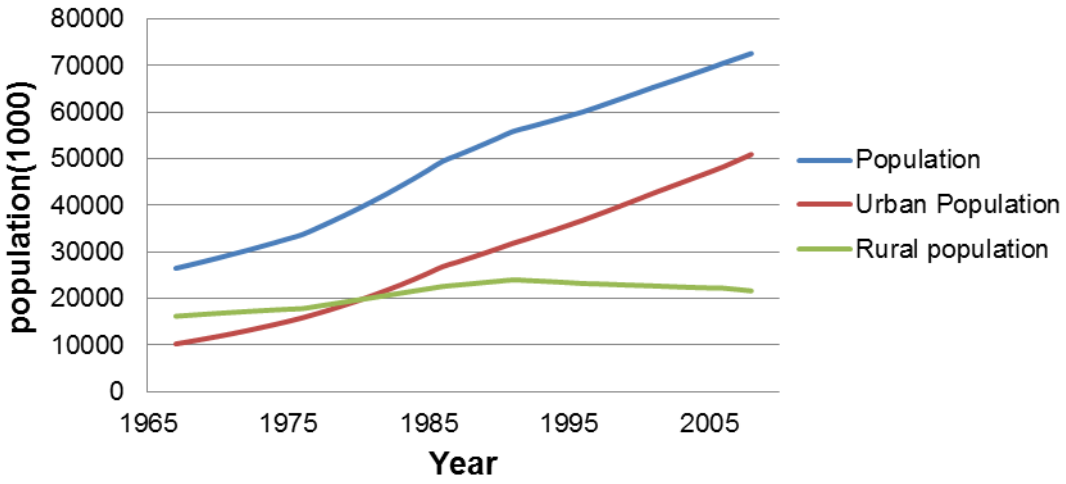

Figure 6, Iran Population[7]

As it can be seen in figure 6, it doesn't seem that population comes down or even stabilizes in near future. As a result, in the next decade, Iran's population will increase smoothly.

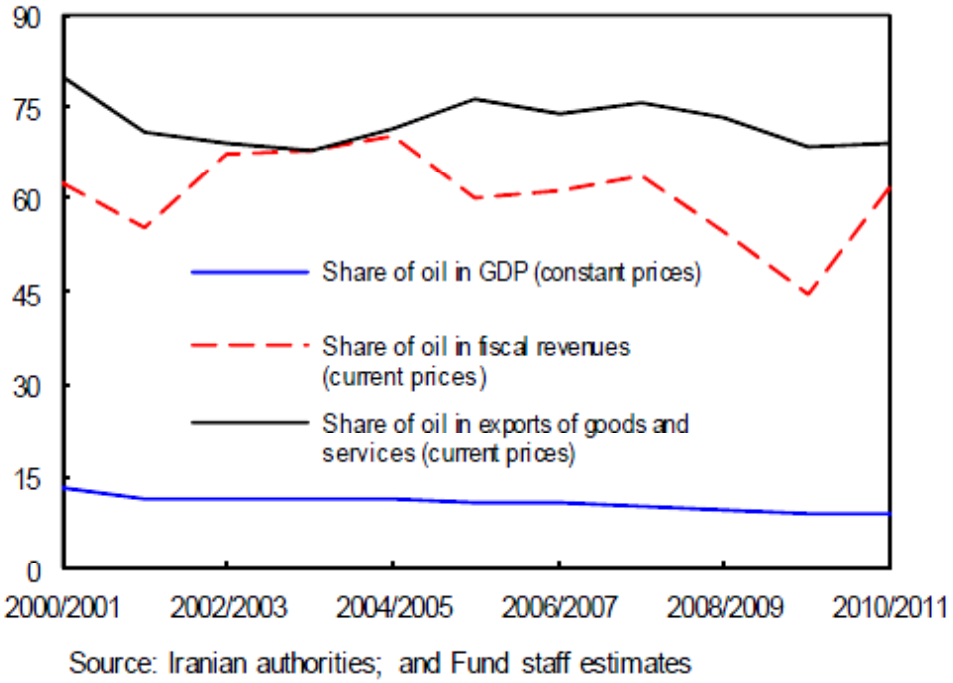

Figure 7, Share of Oil in GDP, Fiscal Revenues, and Exports (in percent), Guillaume, , 2011[8]

As shown in figure 7, although oil revenues have smaller share of GDP but these revenues remain as a main source of foreign exchange income and fiscal revenues. Despite rapid non-oil export growth, oil revenues accounted for about 72 percent of export revenues in last decade. These revenues account for 65 percent of fiscal revenues as well, and are likely to remain the main source of financing for development projects. Iran's high dependency on oil export revenues has a huge impact on whole business cycle. During 2002-2008, in most recent business cycle, fiscal spending and credit growth increased at the same time as export revenues and oil prices which are followed by overheating of the economy and a surge in inflation. As a matter of fact, the price of increasing quality of Iranian people's life was producing more Oil and this living standard is not sustainable while the source of this life standard is not sustainable.

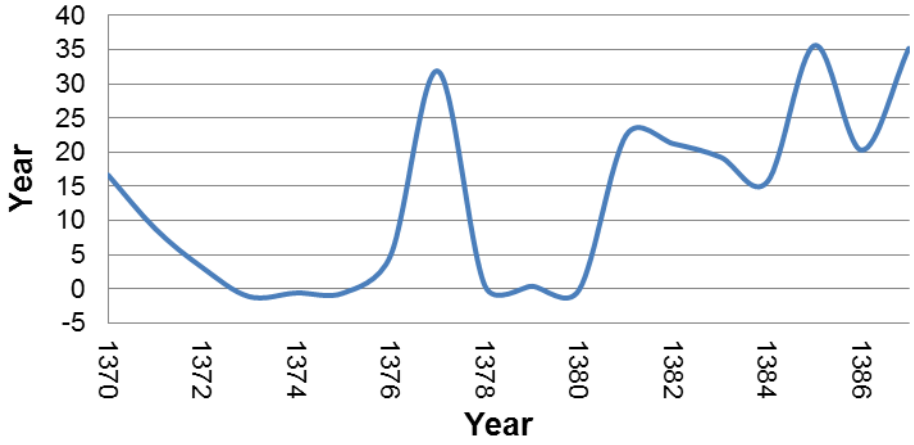

Figure 8, Iran Percent Deficit[9]

The final major factor for interpreting macroeconomy of Iran is the result of government balance. As it can be seen in figure 8, Iran has always had deficit problems in the last decade. This deficit is covered by borrowing from Central Bank which will be followed by increased liquidity and raising pressure of inflation. This procedure makes government employees financially weak, because of increased monetary base which will be followed by reduced purchasing power. Due to the high share of Oil revenue in fiscal revenue, any changes in world oil market can change the government sector balance. As a result, because of Iran's economic structure, controlled market, its macroeconomy is very sensitive to oil market movements.

Iran oil industry specification

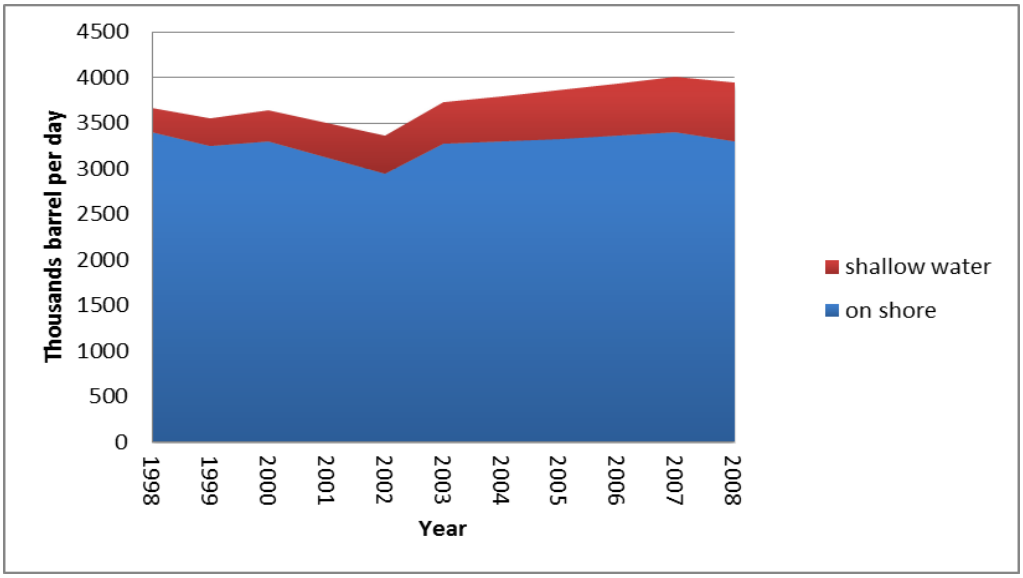

Figure 9, Iran oil reservoirs geographical distribution, Iran Hydrocarbon Balance Sheet 1387[10]

As it can be seen from figure 9, most of Iran reservoirs are located in the land and it reduces the production cost of crude oil and its required technology level which is less than offshore reservoirs. Moreover, Persian Gulf maximum depth is 90 meters and the average depth is 50 meters which decreases oil production cost significantly lower than deep water production.

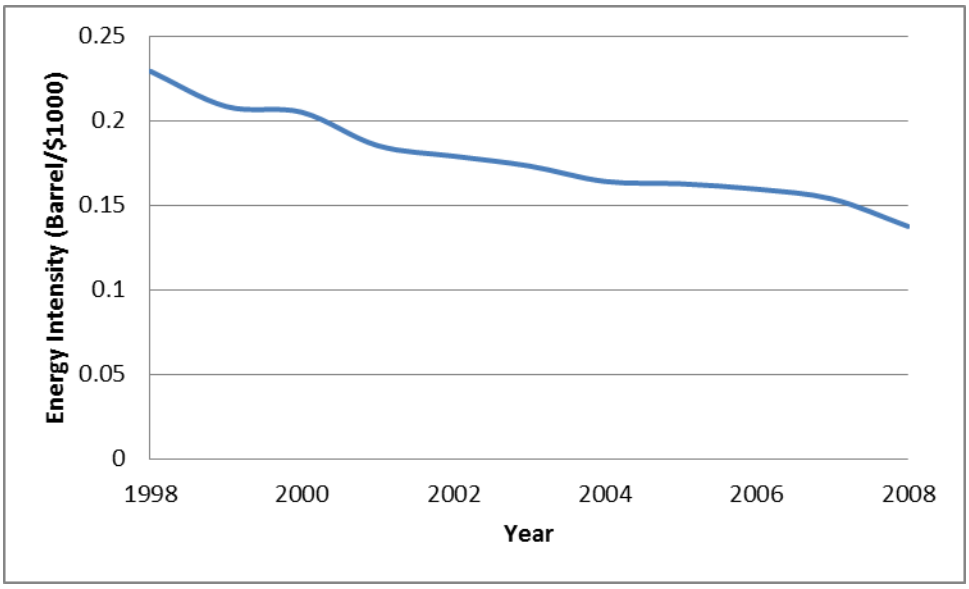

Figure 10, Iran household energy intensity, IIES, Iran Hydrocarbon Balance Sheet 1387[11]

As we can see from figure 10, Iran household energy intensity decreased over time, the main reason of this increase is improvement of Iranian people life style. By life style improvement, the necessity of energy consumption especially electrical energy for appliances, gasoline for transportation and gas for households cooking is increasing.

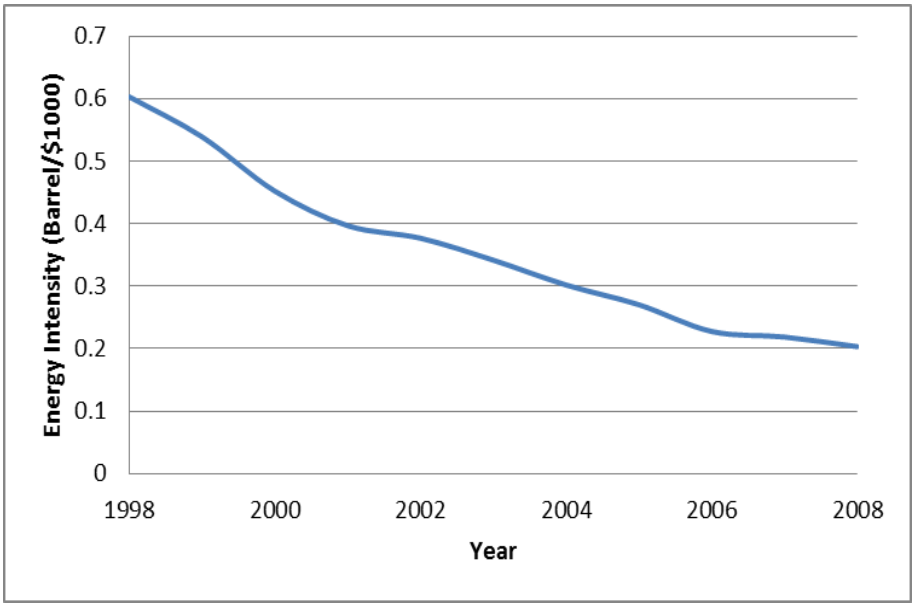

Figure 11, Iran industrial sector energy intensity, IIES, Iran Hydrocarbon Balance Sheet 1387[12]

As it is clear in figure 11, energy intensity of Iran industrial sector is going to be decrease over time, but it is limited to best practices. Based on the vision of Iran in 1404, Iran industrial sector energy intensity should be below 0.3 (1 ton of oil/ $1000 of GDP, year 2000) in 2025 which was 1.48 in 2008. (1 ton oil equivalent = 7.11, 7.33, or 7.4 barrel oil equivalent)

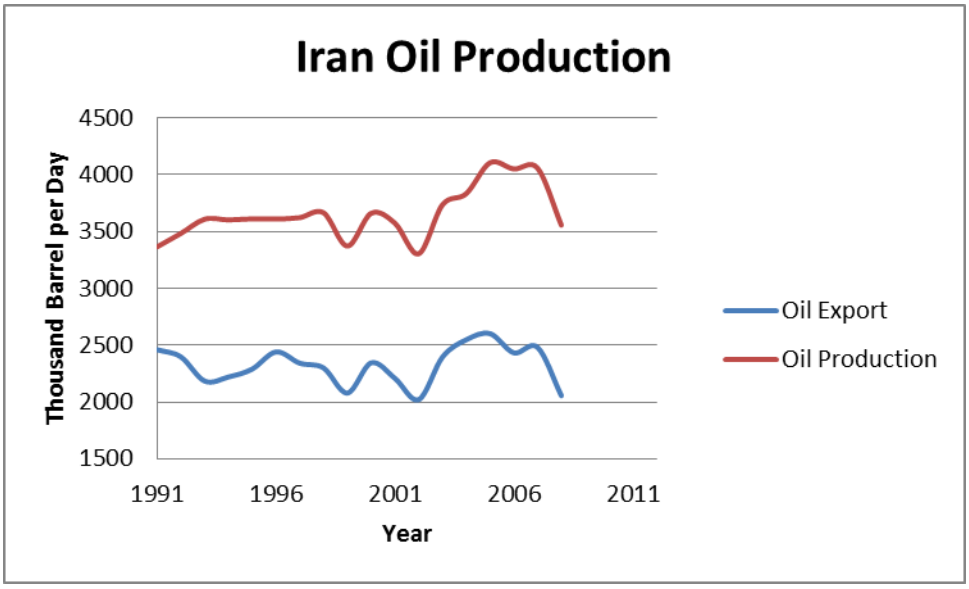

Figure 12, Iran Oil Production and Export[13]

In figure 12, the difference between oil production and export refers to internal consumption, but this consumption can be divided to final consumption and production of other oil downstream products.

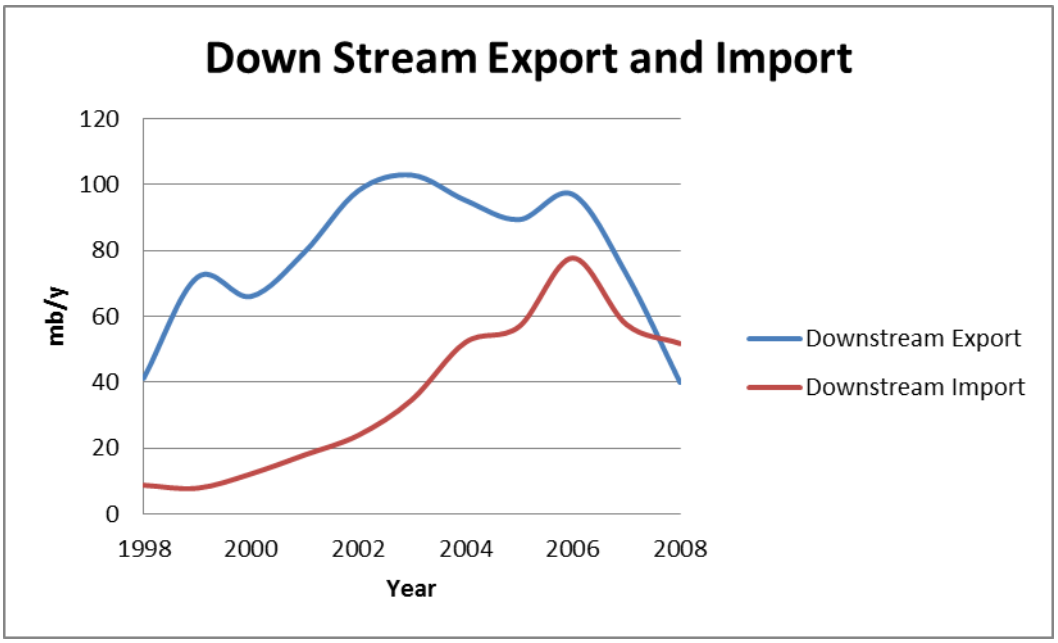

Figure 13, Iran downstream export and import[14]

One may justify the reduction trend of oil export by implementing policy of focusing on downstream production and increasing export value. But as it is

showed in figure 13, import had an increasing trend in recent years while the downstream production had a decreasing trend. In 2008, importing value surpassed the exporting value.

Problem definition

According to the vision of Iran in 1404, Iran should secure its second position of oil production in OPEC. Additionally, if Iran wants to keep its evolution trend and improve its economic status which is deeply related to oil revenues, needs to ensure and improve oil production. Despite all these facts, Iran oil exports had not any improvement in recent years and it is important to evaluate Iran oil industry performance in order to solve the problem.

Regarding to the figures mentioned in Introduction, future of Iran oil production without considering suitable amount of investment faces serious problems. In other words, the main question is how Iran oil industry specification and investing policies play roles. If we concentrate from internal point of view, the main ambiguity is, how should invest in the industry for sustainability of oil production. As a result for investigating components of the structure, four sections are considered, including market, production, consumption and investment. Finally simulation is done due internal segments and their interdependencies.

In production sector, considering Iran reservoirs, OPEC quota, oil fields age, efficiency, technology and infrastructure are essential. Oil production is proportional to capacity generation. Capacity is increased by higher amount of investment and with oil fields and infrastructure depreciation, it decreases. There is a delay between investment and building of refineries and required infrastructures. Higher level of production technology in extraction and production can cause reduction in production cost, enhancement in efficiency and lower rate of depreciation. In most cases, Iran has not enough capability in developing required technologies and it is forced to import these technologies by involving foreign investment.

In consumption sector, there are two groups; households and industry. Industry uses energy in order to produce goods and services with added value. Additionally, this production is a share of GDP. Downstream industry satisfies portion of internal demand and the rest of demand is supplied by imports. Moreover, internal consumption increases with population growth and is affected by people's life style.

Oil price is determined by balance of supply and demand in international market. Internal market demand is affected by price like other markets and by increasing price, demand decreases. Price of oil down streams, whether they are produced internally or externally, follow international price with delay. Profit of each produced oil barrel is calculated by difference of production cost and international price. By multiplying this profit to the volume which Iran produces subtracted by internal consumption, Iran oil revenue can be calculated.

Investing can be done by private and governmental organizations. Government based on its motivation and financial power makes decision for investing in oil industry. Private investment is divided into two groups of domestic and foreign investment. Foreign organizations make decision regarding to profitability and market security which are influenced by political and economic security. Economic security is affected by domestic economy fluctuation. Regarding political problem of Iran with other countries such as US and related UN sanctions against Iran and cooperative companies, foreign investment does not exist in this industry. In internal sector, government is the only investor which assigns portion of oil revenue to this investment.

Sector Map

In the following figure, different sectors of problem are illustrated.

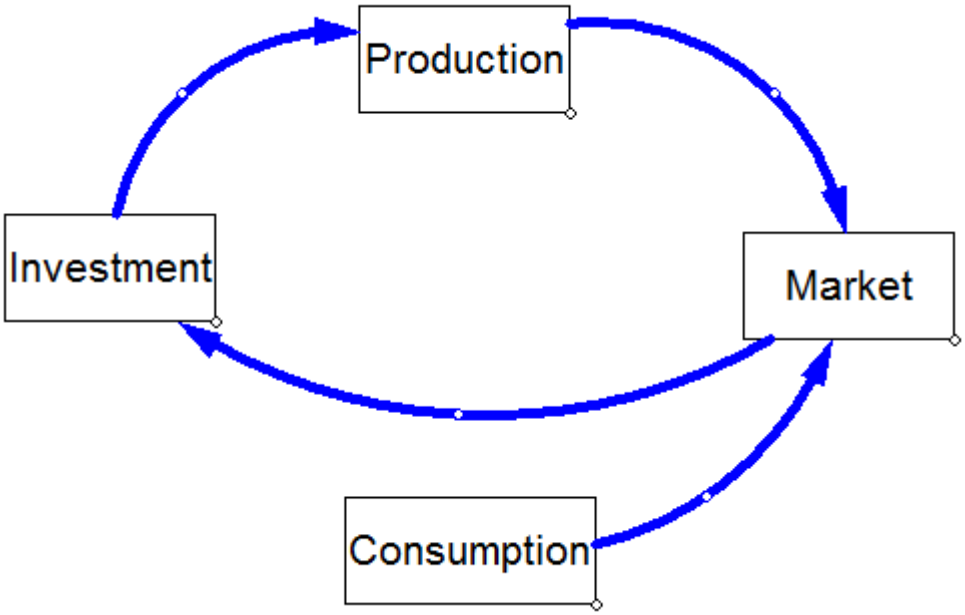

Figure 14, sector map

As it can be seen from figure 15, there are 4 sectors; production, investment, market and consumption. Investment creates new capacity which normally without investment is depreciated. Production satisfies demand from consumption sector in market. By increasing production, price in the market will be decreased when market share of production is relatively high. Price in market can change consumption rate and higher rate of consumption increases price. Market and availability of oil and its revenue determine whether there should be investment or not and in case of appropriate condition of investing how much should be invested.

Model description

Basic assumptions

In this simulation it is assumed that, Iran wants to keep the trend of development in next 20 years. As a result, population will grow with the same last year's trend.

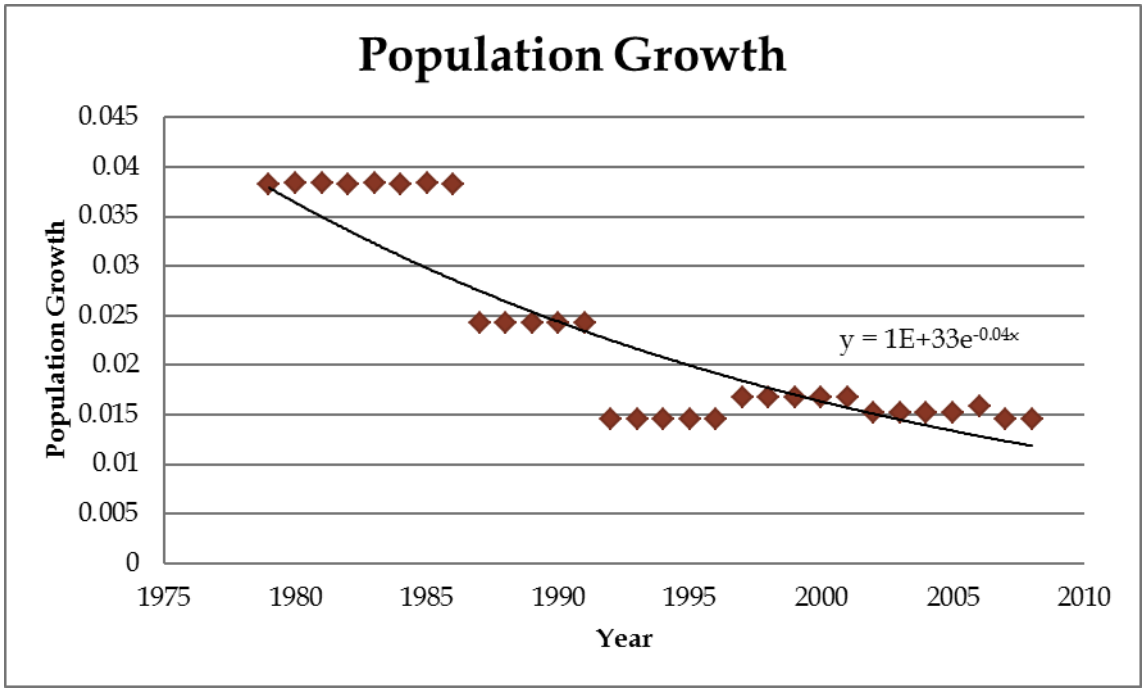

Figure 15, population growth[15]

In figure 15, the trend of Iran population growth is extracted.

Moreover, household consumption is assumed to track the same trend of recent years. This parameter is affected both technology and lifestyle. The combinations of these two effects create the total response of household equivalent oil consumption.

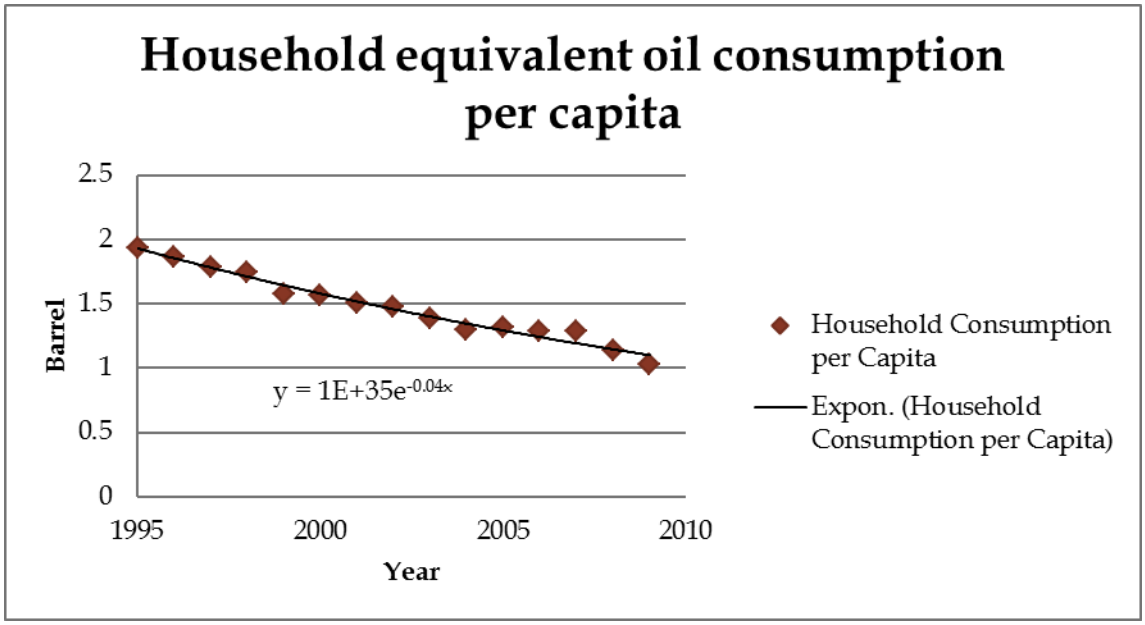

Figure 16, household equivalent oil consumption per capita[16]

As it can be seen in figure 16, Iran household consumption will decrease in next years. In far future, Iran can experience the best result of consumption like developed countries, as a result household consumption in 2025 is assumed to be 0.7982 barrel/year for each individual. In the next step, the energy intensity of Iran's industry should be modeled.

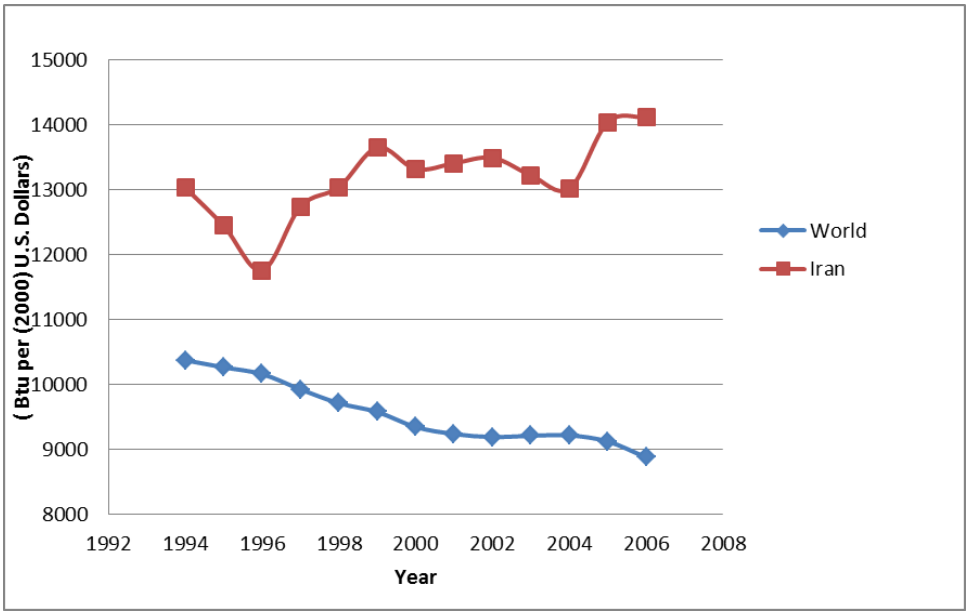

Figure 17, Iran vs. world (energy intensity), International Energy Annual 2006[17]

As it is showed in the figure 17, Iran energy intensity is much higher than other nations record but it is going to be stabilized in a fewer amount. The best scenario is Iran can keep its difference with world constantly in future. The average difference is considered to predict Iran industry energy intensity.

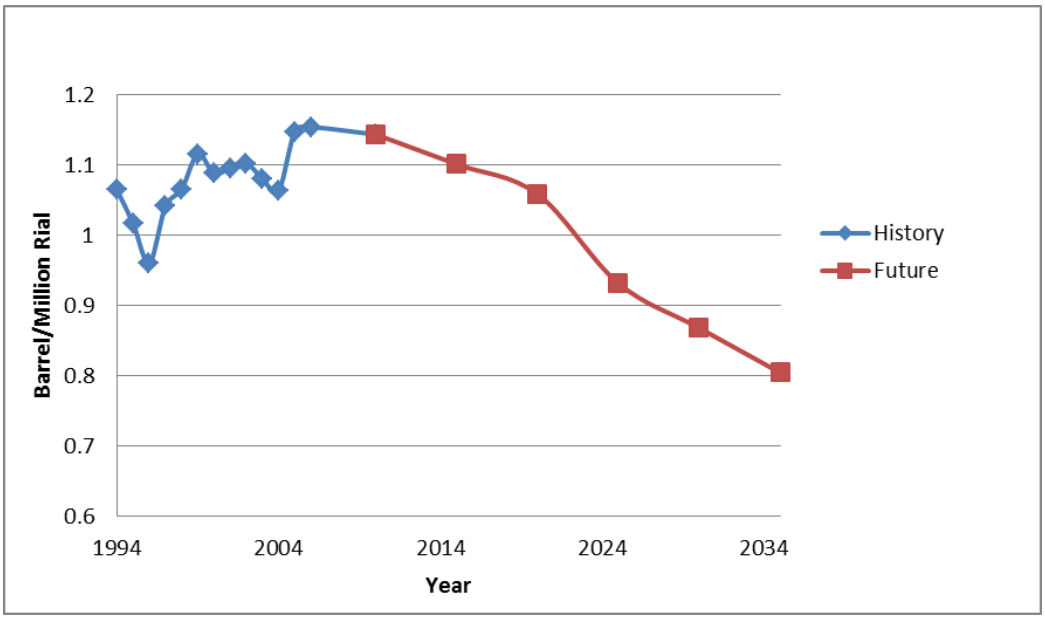

Figure 18, prediction of Iran industry energy intensity, Energy Information Administration, 2006[18]

In Figure 18 Iran industry energy intensity prediction is noted. This factor will be decreased in the future regarding new policy of government in energy pricing. It is assumed that Iran will keep the difference of energy intensity from the world constantly in the future.

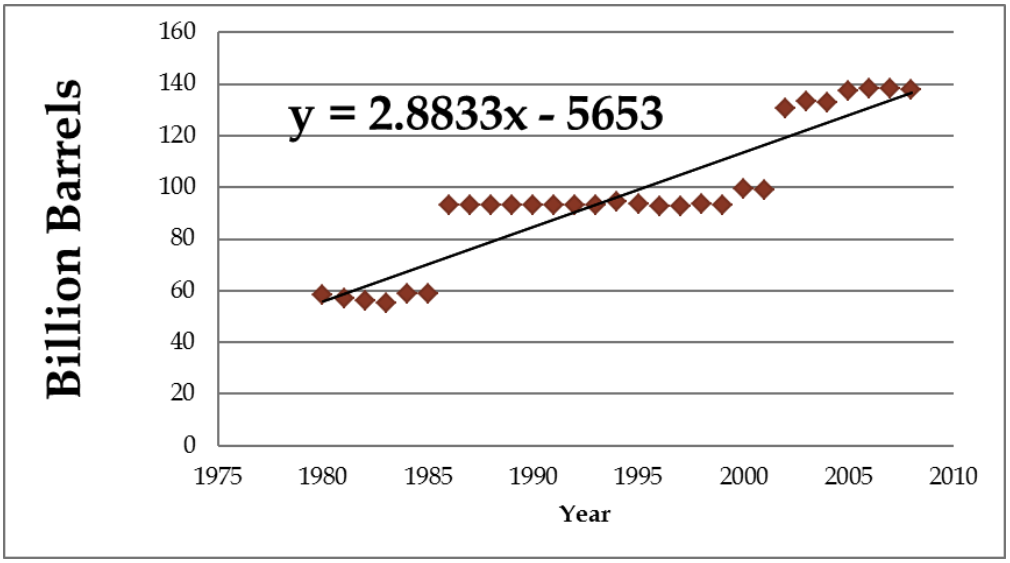

Figure 19, Iran oil resources, BP Statistical Review of World Energy[19]

As it is showed in Figure 19, Iran has enough resources to maintain its production in the future but the trend of oil field exploration is considered. This trend in short term is completely constant and reliable and for long ranges has acceptable accuracy.

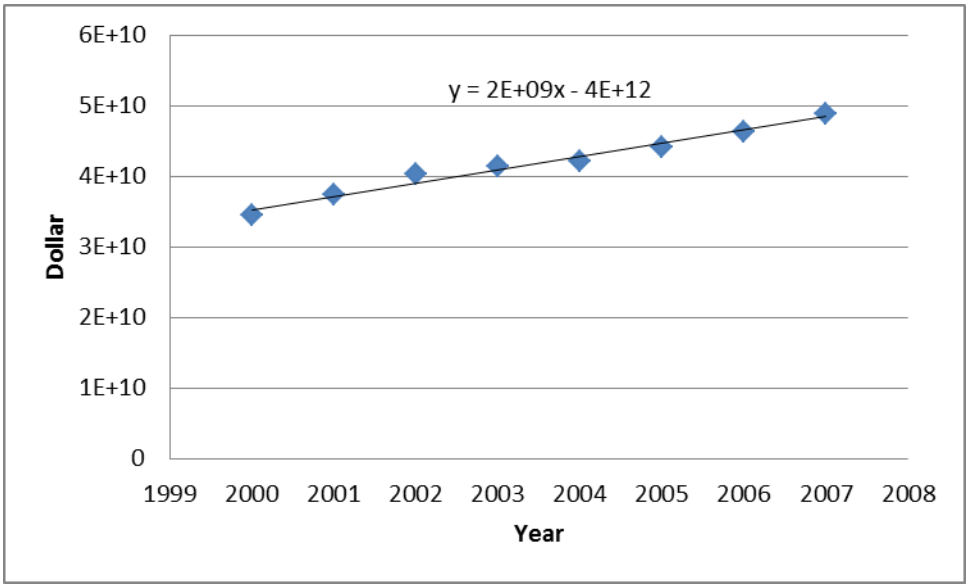

Figure 20, Iran industry production[20]

As it is in figure 20, Iran industry production grows steadily in recent years and it is highly probable to keep this trend.

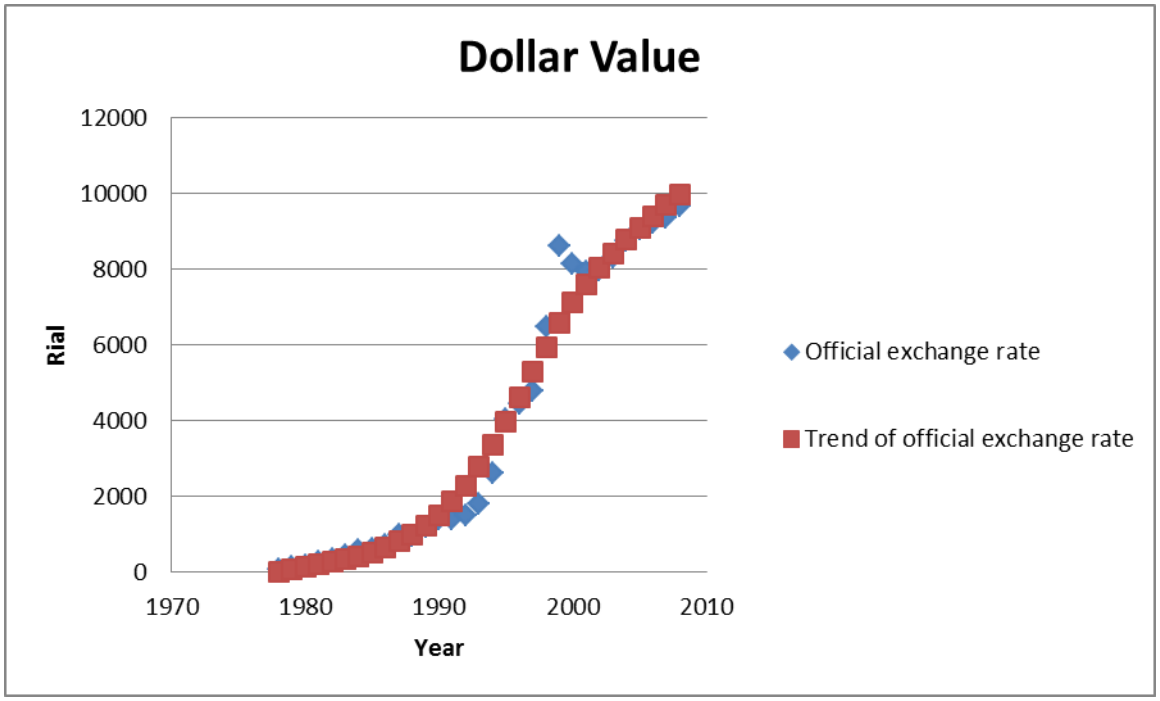

Figure 21, Dollar value in Rial[21]

Dollar value and consequently exchange rates in Iran are determined by central bank of Iran. This organization determines the value out of supply-demand balance. In figure 21, the exchange rate which is determined by governments is showed over time.

There are other assumptions which greatly influence the modeling process. Iran has numerous numbers of oil wells and modeling such a complex system, it is tried to integrate the behavior of oil wells as a behavior of one huge oil well. Age of the oil well is the average of all oil wells and the end life age is average of all end life ages. The distribution of oil wells end life ages are determine in a normal distribution with average of 8 years for initial value and minimum of 4 years and maximum of 12 years. This average is calculated as the average of all oil well ages and it is used as initial value based on the fact that most of Iran oil wells are in the second half of their life.

The volumes of oil wells are determined as normal distribution with average of all oil wells in the world. 94% of earth oil is located in 1500 wells. The maximum

volume is determined by the biggest oil well in the Saudi Arabia with the name of Ghawar.

For modeling rate of production related to oil well age, real data of one oil well sample is used.

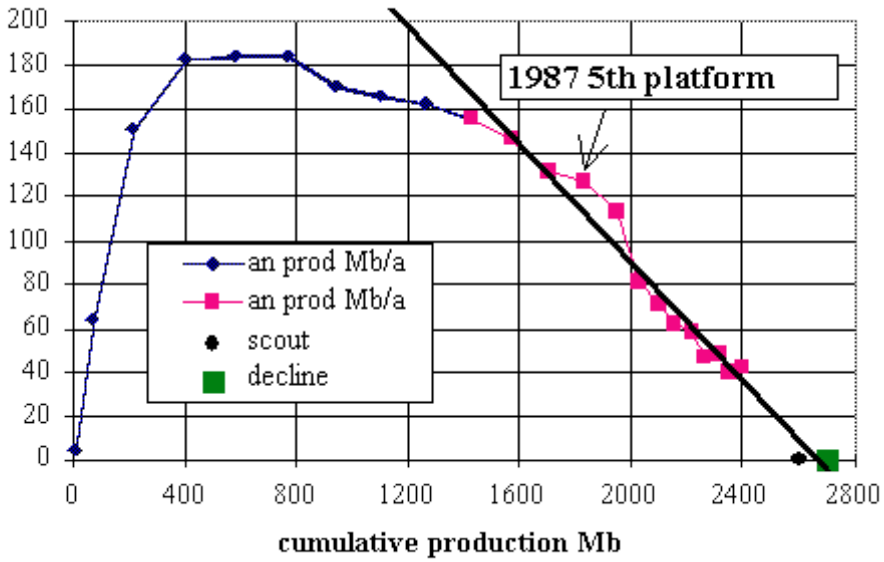

Figure 22, Annual production versus cumulative production[22]

As it can be seen in figure 22, production rate increases in the first life stage of oil field but it will decrease when approximately 40% of oil is extracted. Moreover, all capacity of an oil well is not possible to be extracted because oil well pressure reduction, as a result primary recovery factor should be used which for Iran is 26%.[23] In this paper oil well production trend is assumed based on the data presented on Figure 23.

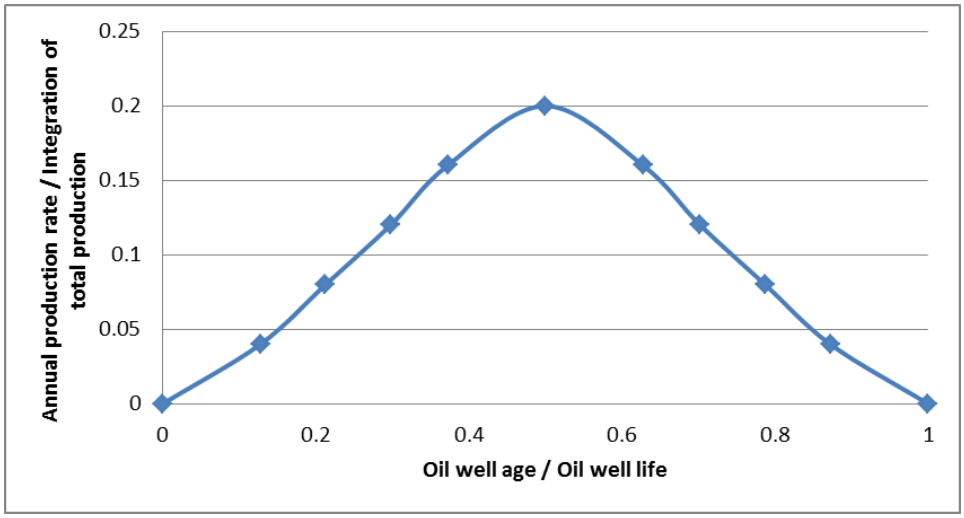

Figure 23, Oil well production trend

It is assumed that in order to build 1 new barrel capacity of production, Iran should invest $25000 if the well is located in land and for shallow water this factor is $35000.[24]

Because of lack of information about amount of Iran investment in oil industry in recent, related data is confidential and Iran oil and gas ministry does not help, the initial time is considered 2008 while the data is available for stocks and initial values.

It is assumed that, because of Iranian government financial problem, Iran uses all its capacity in crude oil production.

The first goal in Iran oil industry is keeping a constant rate of production. This production level should satisfy internal demand and generate enough export revenue. Increasing oil production upper than this level is not recommended because the main goal is sustainable and secure oil consumption in next decades and for all generations.

Stock and flow model

One model in order to simulate oil industry performance is developed which takes effect from consumption and investment policies. Oil market including

internal and international markets is developed for measuring policies applicability.

Production

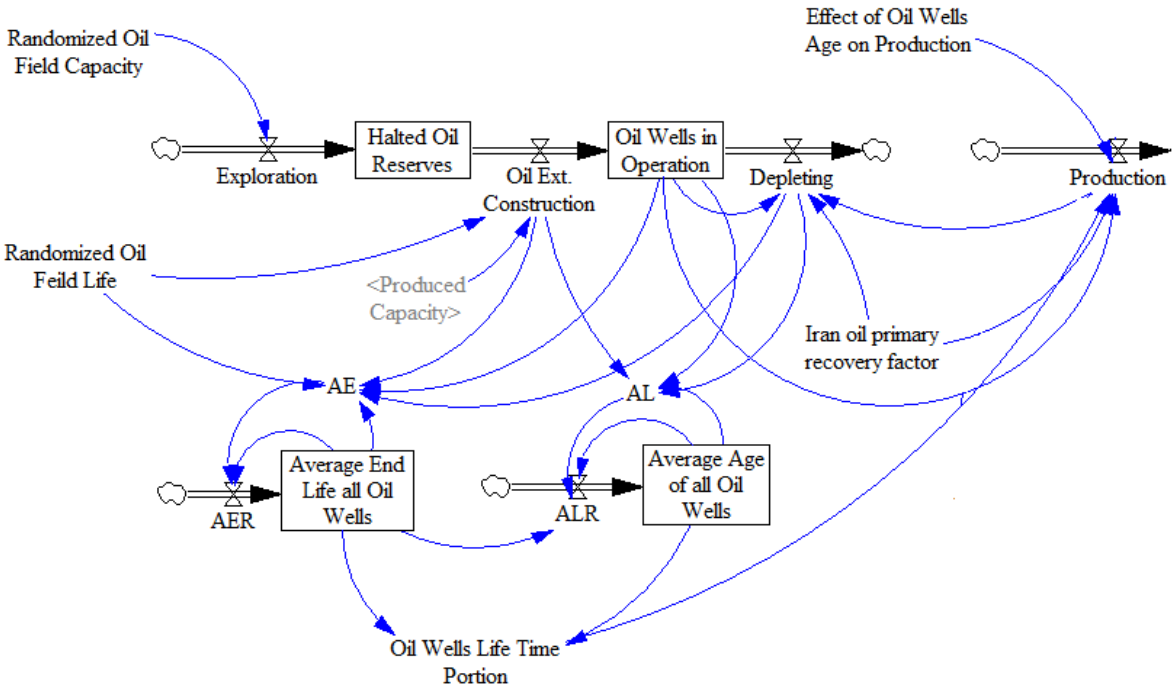

Figure 24, Production

As it is showed in Figure 24, in production sector some important stock should be considered. The first stock is the result of exploration which will be used in order to produce crude oil by construction. This stock will be deployed by construction rate and will transform to operation phase. In the stock oil wells produce crude oil. The important factor for modeling production is estimating oil wells age and their end life because this factor determines the rate of production which modeled from real simulation of oil fields' performance. Primary recovery factor is used to model the percent of oil which can be extracted from each oil well with their natural pressure.

Market

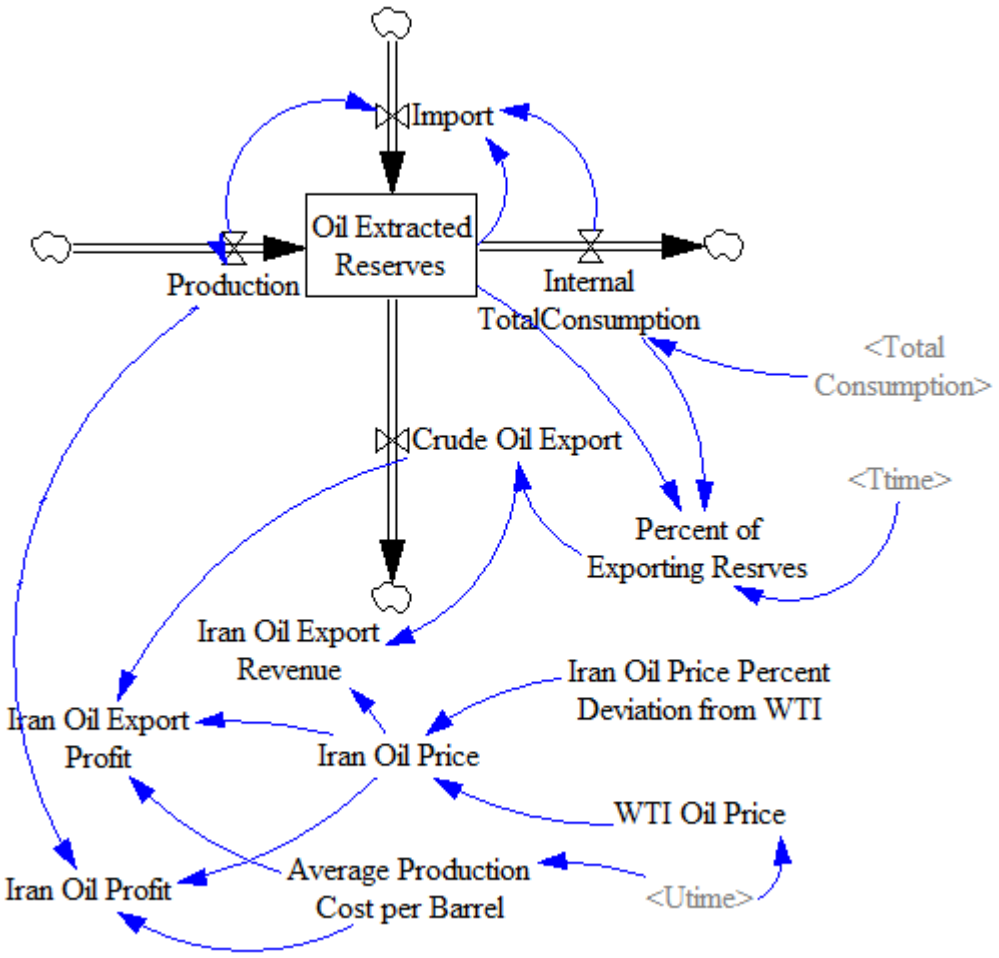

Figure 25, Market

In market, two major forces interact with each other. Production represents supply side and consumption represents demand side. Oil price is considered exogenous which increases over time smoothly. Different conditions for importing and exporting of surpluses or shortages are considered as well. Cost of production is modeled from estimated data and it increases over time. Other details are presented in Figure 25.

Consumption

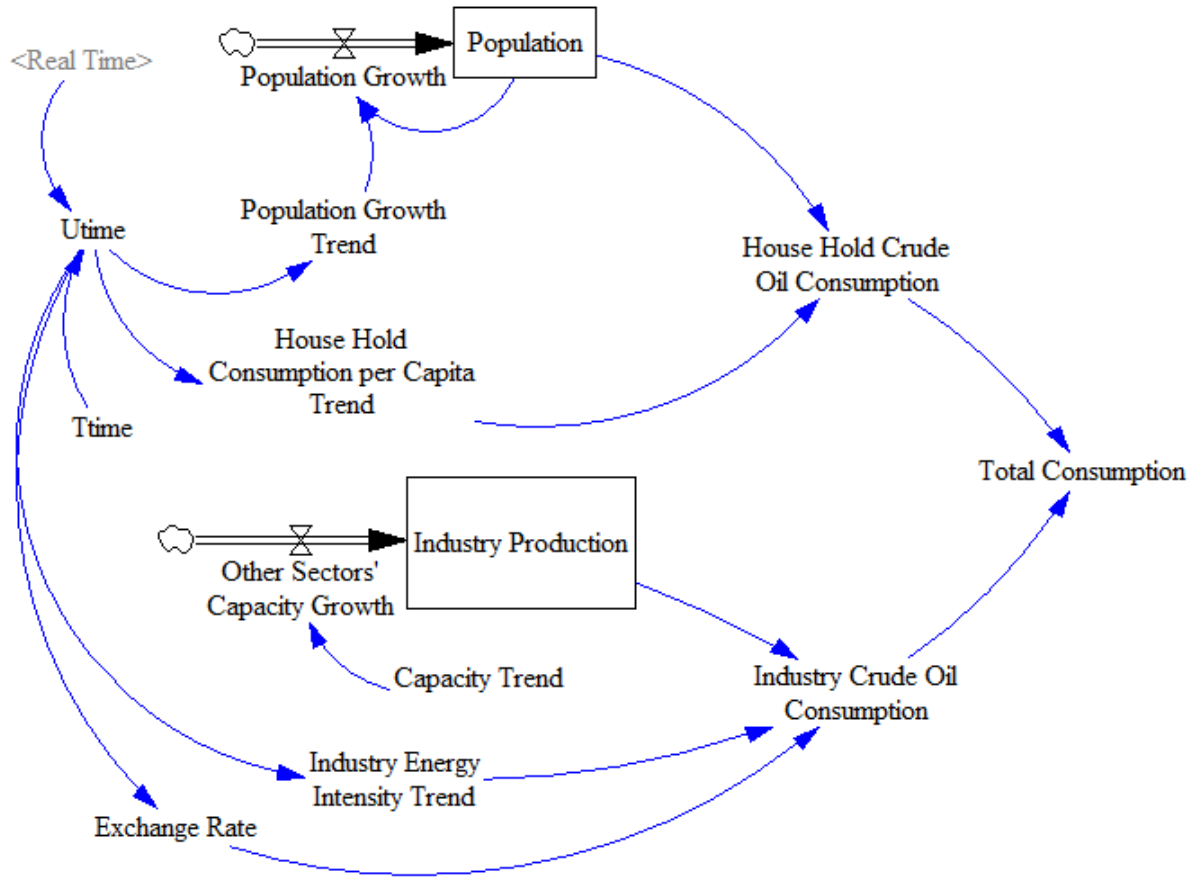

Figure 26, Consumption

As showed in Figure 26, Iran oil consumption is resulted from two sectors, households and industry. Household consumption is related to population and people life style which reflects the amount of oil consumption per capita. In industry section, production capacity and technology determine the industry consumption which by higher amount of production and lower level of technology, oil consumption increases. Production capacity trend, energy intensity trend, population growth and household consumption per capita are considered as exogenous.

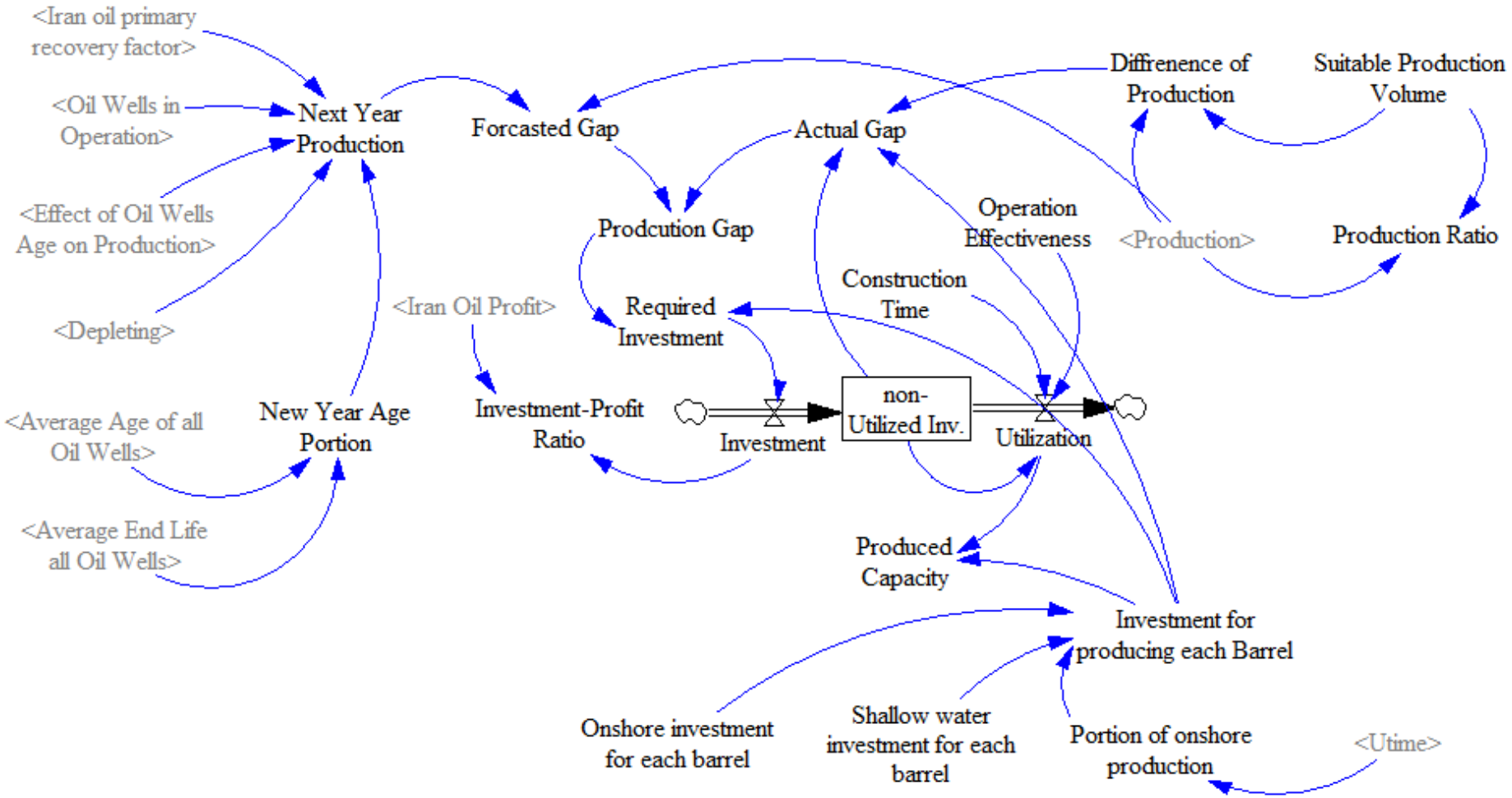

Figure 27, investment

Investment

In investment section, all policies regarding keeping the production level constant are taken. Firstly, the production difference with desired level is calculated. The amount of non-utilized investment represents the production capacity which will cover a share of total gap. In the future, because of increasing oil wells ages, production will be decreased and forecasted gap estimates this reduction. Finally the whole production gap is estimated. The cost of increasing each barrel production per day capacity is calculated. This cost increases over time and by using this parameter it can be estimated that how much should be invested in industry in order to cover total gap. The policy making section is where required investment and other decisions combined and make the final investing policy. Other details are showed in Figure 27.

Simulation & Results

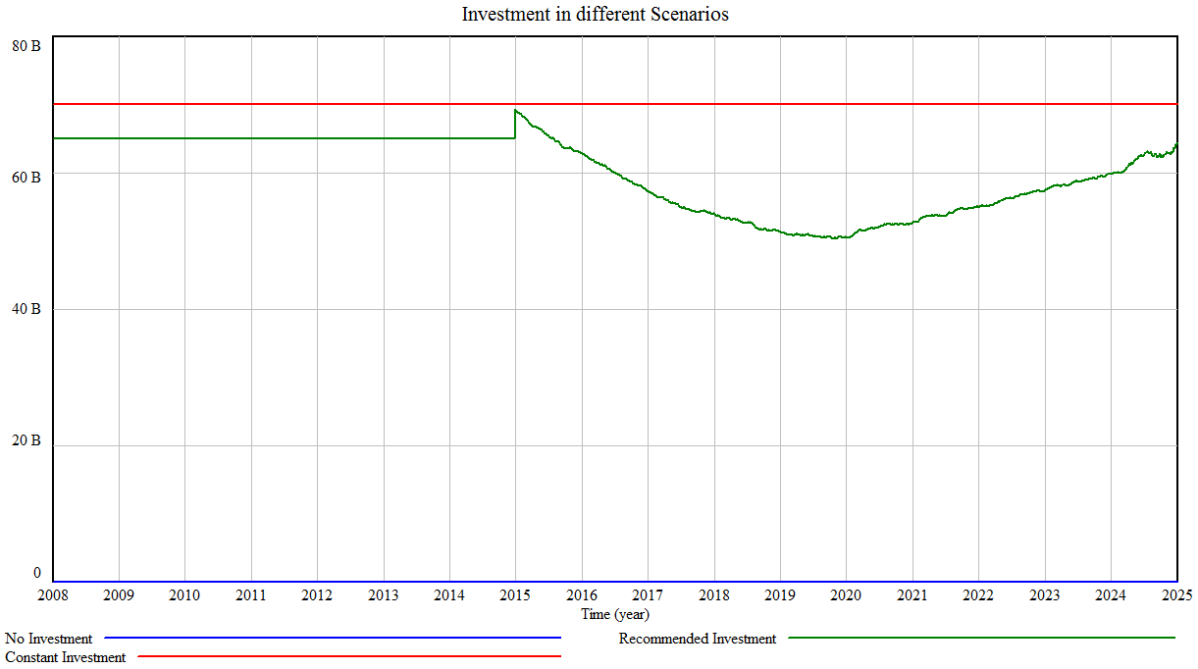

Figure 28, Investment

In order to differentiate policies, three scenarios are defined and showed in Figure 28. In “No Investment” scenario, there is no financial support for the industry. In “Constant Investment”, each year $70 billion is invested and in “Recommended Investment”, in the first 8 years, yearly constant investment of $65 billion is done and in the next years flexible investing approach is taken.

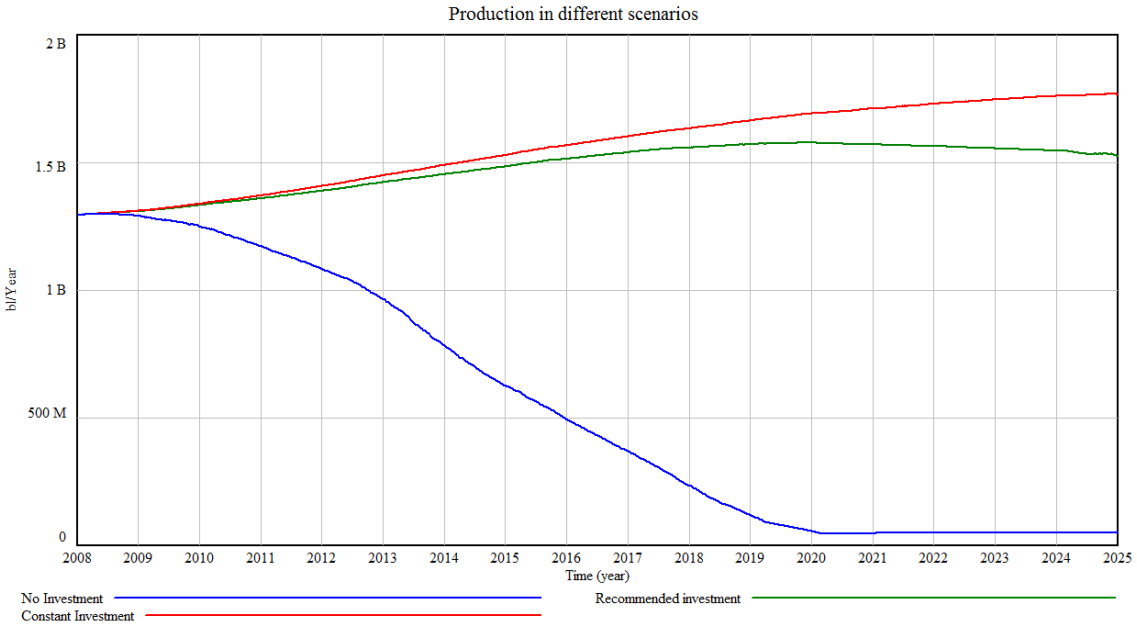

Figure 29, Production in different scenarios

In figure 29, productions of different scenarios are illustrated. In no investment scenario, Iran oil production will decrease and in 2020 will receive its lowest level. But in constant scenario, Iran oil production will increase smoothly and overshoot the suitable production level of 1.46 billion barrel per year in 2014. Finally in recommended investment scenario, production will increase and approach suitable production level.

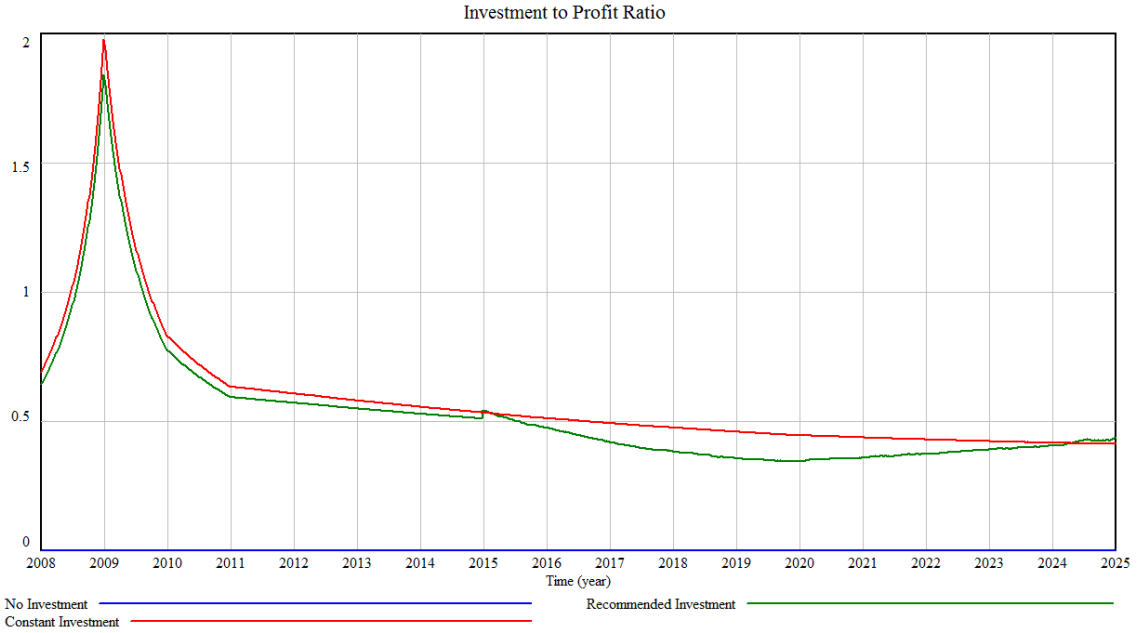

Figure 30, Investment to Profit Ratio

In the figure 30, trend of investment to profit ratio is illustrated. In Both constant and recommended investment scenario in first two years, investment surpasses the profit but it decrease smoothly and after 7 years the interest rate of oil industry will receive 50%.

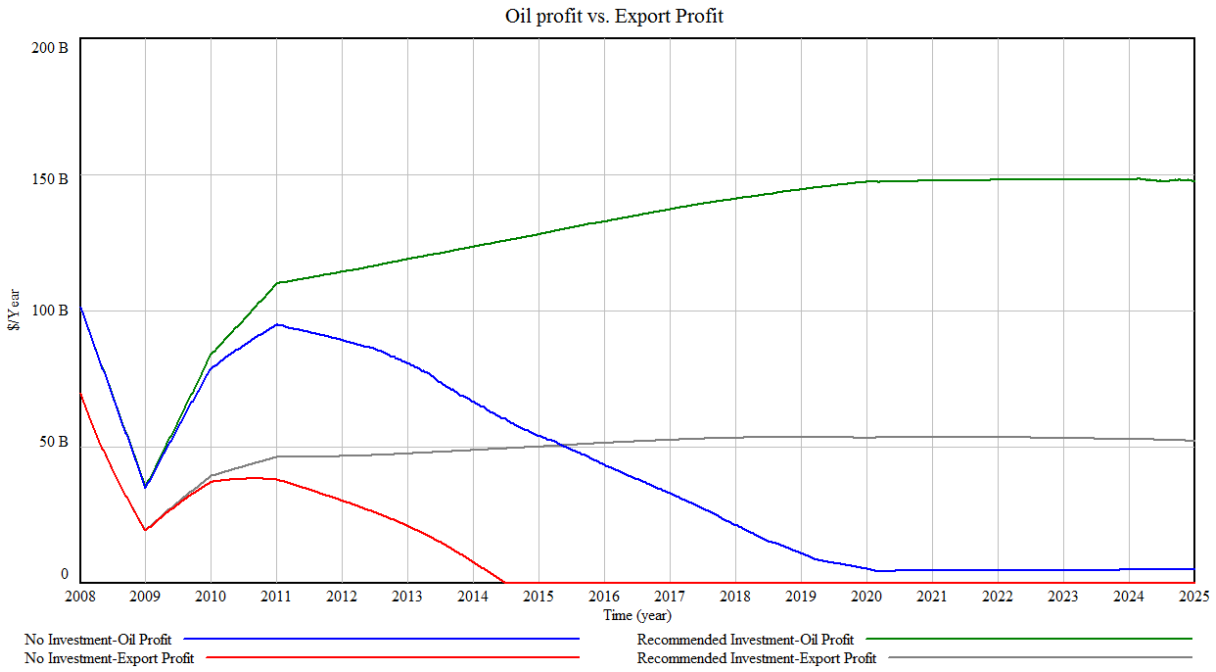

Figure 31, Profit versus Export Profit

As it can be seen in figure 31, Iran oil profit will be lost in 2020 if there is no investment and export profit will be lost in 2015. But in recommended investment scenario, both profits will be stabilized. Oil profit will reach its maximum level of $150 billion after 2020 and export profit will receive $55 billion after 2016.

Conclusion

Understanding the relations of different elements of oil production industry and the changes of its component over the time could help decision makers to select affordable policies to achieve sustainable production rate. In the model, there are some leverage points; Investment rate as one of them is discussed. As a result of simulation, concurrently, a temporary fixed rate of investment and percentage of required investment for covering annual gap could drive the whole structure to sustainable rate of oil production. In this model effects of under-investment and over-investment in extreme conditions are considered.

In investing policy making, it is possible also to enhance technological parameters such as primary recovery factor in order to increasing oil production rate from oil wells and established model has the ability of considering this difference. In real world, this condition is not possible for short term future of Iran, because required technology is not accessible and needs well equipped infrastructures.

This model is established based on real data which allows investigating different scenarios with diverse goals such as constant or increasing oil export revenues or profit, satisfying only internal demand, maximum production in specified period of time and effects of different oil industry cost structure for production.

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