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A Dynamic Model for Maximization of External Profits of Natural Gas Reserves of Iran and its Application

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Abstract- *In this article, one of the most important challenges facing the National Iranian Oil Company - the optimum allocation of natural gas to the different consuming sectors such as export, petrochemical plants and injection into oil fields – is discussed employing the optimization and preference analysis theory of Professor Harry Markowitz!. Our results show that gas export, gas injection and petrochemicals are the optimal preferences from the mean expected present value and risk points of view. When choosing the optimal portfolio employing a risk-return frontier, if less risk is desired, then the weight (ratio) of gas allocated to export projects should be decreased. On the other hand, decreasing the weight ratio for gas injection and petrochemicals will mean that the risk (as well as the expected value) increases. Put another way, in the case of Iran at the present time, it appears that the more risk averse is the investor, the smaller the gas ratio allocated to gas exportation projects.*

Keywords - Portfolio, Expected Present Value, Frontier Portfolio, Dynamic Planning Model, Risk Tolerance, Certainty Equivalent, Preference Analysis Theory.

1. INTRODUCTION

Iran with 27[i] trillion cubic meters of natural gas, equivalent to some 15% of world gas reserves is the second biggest gas rich country after Russia. Optimum use of such great reserves requires a long-term scientific planning. This, in turn, requires a thorough recognition of different aspects of relevant points.

Considerable benefits of gas revenues are accounted for by such factors as natural gas export projects, petrochemicals export (in which gas is known as raw material), increased petroleum production due to gas injection into oil fields, or increased export of oil products due to natural gas replacement. Thus, study of different features and scientific knowledge can lead to preparation of an economical model for each of abovementioned issues.

Natural gas consumption in different countries of the world, particularly in the industrialized and developing countries has increased during recent years. According to the predictions of leading international institutions, this trend will ascend in coming decades. Rising trend of the global demand for natural gas and geographical dispersion of the world's major natural gas reserves on one hand and existing technical problems regarding gas transport has given rise to a complicated global natural gas market.

Each important market like America, Europe, east-southern Asia, India and china has its own particular features. Accordingly, any change or development in aforementioned markets has impacts on international natural gas prices. At the present time, it is believed that natural gas export projects, particularly for new comerplayers, come with less economic value and more risk. Considering high number of gas suppliers and increasing competition, it is suggested that the new suppliers should take careful steps towards long-run contracts.

Significant increase of oil prices and bullish forecast of this trend indicates a structural evolution in the international energy market. Iran with huge oil and gas reserves considers the price of petroleum the base of natural gas pricing calculations (with upper and lower limits). Considering recent discussions on increased recovery factor by means of gas injection into oil fields, appropriate studies should be done regarding long-term contracts.

According to increasing international oil prices, surplus oil revenues resulted from gas injection into the oil fields is of high importance. So indication of revenue function will be important and complicated. This requires first technical studies of oil and gas reserves of the country and second development of a forecast model for oil prices.

Petrochemicals sales are the other part of natural gas benefits. Wide range petrochemical products and increasing applications of these products in different industrial and non-industrial areas have led to profitable petrochemical projects. Huge natural gas reserves in our country have forced the petrochemical industries to shift to natural gas their feedstock. In this regards, optimum allocation of natural gas in this field in order to achieve maximum profit is of great importance. Thus considering the nature of problem and existing numerous variables which may be affected by predicted and unpredicted factors over the time, using dynamic optimization models with risky factors will be helpful. In this paper, a combination of portfolio management and preference analysis has been used to this end.

In this article, Markowitz! portfolio management theory and preference analysis theory are first introduced and briefly discussed. Second, the problem of natural gas optimum allocation is stated and relevant data are provided. Third, economic evaluation indicators and risks of each group of projects are calculated and the

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application of the combined model will be discussed. And finally, the results are concluded.

2. PORTFOLIO OPTIMIZATION THEORY

Portfolio optimization theory is a new investment analysis method, presented by famous Chicago school economist Harry Markowitz!, the winner of Nobel Prize in economics in 1990. In this theory, Harry Markowitz! looks for a method to choose the best mix of investment with the highest efficiency. This technique helps the investor choose a mix or portfolio a mong different investment choices with the same economic value, which has the least risk or with the same risk but highest economical efficiency. This theory, which was initially used in stock market, provides an opportunity for investor to achieve a portfolio with highest efficiency [1].

Companies attempt to increase their income and total value of their assets through investing in projects and taking different opportunities. But risk prone investment is influenced by the conditions of the projects. Therefore, companies that make investments are accountable to their stakeholders. Private companies with their goals of maximizing profit are encountered with different challenges like improved efficiency, optimum use of existing facilities, optimum allocation of project resources and investment opportunities.

Oil and gas companies are encountered with risky but economically valuable projects. Investment management of these projects requires simultaneous risk analysis and project evaluation where new methods for risk analysis and investment evaluation are used. In such cases, the portfolio management theory is used more frequently.

Wide variety of the projects and considerable investments in oil and gas projects on one side and mutual relations of projects and their effects on economical values of related projects on the other side, make the oil and gas company managers develop medium to long-term investment strategies [2]. This enables the managers to discuss allocation of the resources and budget to the projects, preference of projects according to their importance, prioritizing the projects, estimating the projects' costs and civil costs of company in future.

The base of portfolio optimization theory is choosing a series of assets by investor using an effective method, so that investor achieves maximum profitability by minimizing the risks. New and suitable method to this end is a mathematical optimization model called Markowitz! Model [3]. The main structure of portfolio optimization theory presented by Harry Markowitz! is as follows:

If V_o^t is total portfolio value in time $t\,(t=1,2,...,t)$, and X_i^t is the number of stokes of each assets $(i=1/2/.../n)i$ in market prices of P_i^t, and $E(r_i^t)$ is the expected value of each asset, the total expected value of the portfolio will be [3]:

$$E(r_p^t)=\frac{1}{V_0^t}\sum_{i=1}^{n}E(r_i^t)X_i^tP_i^t \quad (1)$$

portfolio variance is given as:

$$\sigma_p^2=\frac{1}{V_o^t}\sum_{i=1}^{n}\sum_{j=1}^{n}X_iP_i^tX_jP_j^t\sigma_{ij} \quad (2)$$

so that σ_{ij} is covariance of each asset couple.

Markowitz! portfolio optimization can be formulated as follows:

$$\text{Max.}\left(\frac{1}{V_o^t}\sum_{i=1}^{n}E(r_i^t)X_i^tP_i^t\right) \quad (3)$$

According to the constraints:

$$\text{ST}: \sum_{i=1}^{n} X_i^tP_i^t = V_o^t \quad (4)$$

or:

$$\text{Min}\left(\frac{1}{V_o^t}\sum_{i=1}^{n}\sum_{j=1}^{n} X_iP_i^tX_jP_j^t\sigma_{ij}\right) \quad (5)$$

According to the constraints:

$$\text{S.T}: \frac{1}{V_o^t}\sum_{i=1}^{n} X_i^tP_i^tr_i^t \geq r \quad (6)$$

In which r is the least expected return.

One can assume that there are n risky assets. Also, it is assumed that W is a vector n*1 of each risky asset weights in portfolio. V is a covariance matrix n*n, r is a vector n*1 and indicates expected return matrix for all the risky assets and r_f is insured interest without risk and r_p is expected return of portfolio.

On the other hand, preferences and interests of investor are indicated by utility function. General form of utility function is

$$U(r_p,\sigma_p)=r_p-\lambda\frac{1}{2}\sigma_p^2=W^Tr+(1-W^T1)r_f-\lambda\frac{1}{2}W^TVW. \quad (7)$$

First part of this function, shows expected return of 1$ invested in portfolio and the second part equals with half variance of 1$ invested in portfolio multiplied with an adjusting coefficient. This type of utility function is suitable, because maximizing it leads to finding portfolio located on frontier portfolio [1]. Coefficient λ is interpreted as a risk averse factor. Although, it can not be assumed as absolute risk averse like Arrow index, $U''(0)/U'(0)$. Higher levels of $U(°/°)$ indicates higher utility level requested by managers. This utility level relates with expected return and asset variance, directly and adversely, respectively. A suitable amount for these variations is specified for a manager through coefficient λ.

An efficient portfolio is one that maximize expected return in a specified level of standard deviation. In other term:

$$\underset{\{w\}}{\text{Max.}}\quad W^Tr+(1-W^T1)r_f \quad (8)$$

Considering the constraints:

$$\text{S.T}: \frac{1}{2}W^T\sum W=\sigma_p^2 \quad (9)$$

This is a maximizing problem with Lagrange method. Lagrange function for this problem is:

$$L = W^Tr + (1 - W^T1)r_f - \lambda\left(\frac{1}{2}W^TVW - \sigma_p^2\right) \quad (10)$$

where λ is a positive constant factor. First order condition is:

$$\frac{\partial L}{\partial W}=r-1r_f-\lambda VW_p=0 \quad (11)$$

$$\frac{\sigma L}{\sigma W}=r_p-W_p^Tr-(1-W^T1)r_f=0 \quad (12)$$

As it can be seen, Eq.10 is same as Eq.7. Also, first order condition of Eq.7 equals with Eq.11. V is a positive finite matrix and indicates that first order condition is the necessary and sufficient condition of global optimality. In this case, portfolio weights are given as follows:

$$W_p = \frac{1}{\lambda} V^{-1}(r - 1r_f) \tag{13}$$

3. PREFERENCE ANALYSIS THEORY

Strategic investment decision making comes with risk and uncertainty, and in the meantime leads to long-term commitments. Therefore, the tendency of a company to make decisions while tolerating acceptable risks has a major role in strategic investment decision-making. Accordingly, an economical decision making analysis for evaluating such decisions requires measures to define risk tolerance [4].

Extension of Von Neumann and Morgenstern (1953) and Savage (1954) rational decision making ideas to the level of the firm, where firms make choices among risky alternatives based on preference theory, provides the framework for incorporating the firm's risk attitude into their capital allocation decision process [5].

The basic principles of preference analysis imply that the attractiveness of alternatives should depend on the likelihood of the possible consequences of each alternative and the preferences of the decision maker for those consequences. By utilizing preference analysis, decision makers can incorporate their firm's financial risk propensity into their choices among alternative portfolios of projects. Though managers are evaluating portfolios which are very different in terms of their risk characteristics, the firm's strength of preference for outcomes and aversion to risk can be consistently applied in the choice process.

The valuation measure we utilize is known in preference theory as the certainty equivalent; it is defined as that certain value for an uncertain event which a decision maker is just willing to accept in lieu of the gamble represented by the event (Holloway, 1979) [1]. It is, in essence, the ''cash value'' attributed to a decision alternative which involves uncertain outcomes. The certainty equivalent of a risky investment is a function of the risk characteristics of the investment and the risk preferences of the decision maker.

Preference analysis theory or expected utility theory is the base of a utility function. Assessment of utility functions of firms, create a mechanism for indication of preferences which produces coordination and relationship between risky states. Methodology of expected utility analysis such as gamble assessment 50/50, financial certainty equivalent approximation is used in measurement of risky performance of firms. The technique used in this study is prepared according to these uniform methods.

Utility function guides the managers to choose the investment opportunity in unconfident conditions when it is not possible to present a uniform utility function for firms, their utility function can be assessed through decision-making analysis with risk or uncertainty. This is an applied method for interpretation of risky behavior of corporations [1]. Walls and Dyer (1996) studies show that previous decisions of corporations, considering risky investments, can be a good base for study of risky and unconfident conditions of a corporation or a trade unit. Managers as corporation factors make decision on investment allocation in risky and unconfident conditions. They should have sufficient knowledge about production capacities and the probabilities. These decisions indicate risky conditions of corporation and in confident conditions can effect on parameters of a Von Neumann and Morgenstern utility function [1].

In order to assess the utility function of a firm, firstly a general function form of utility should be chosen. Exponential utility function is general form of function which is used theoretically and practically and is shown as follows [1]:

$$u(x) = -e^{-x/R} \tag{14}$$

Where R is risk tolerance coefficient, x is interest variable (like NPV) and e is exponential constant. A limited value for R which is a defined positive value between zero and one indicates one's risky behavior. Exponential form of utility function covers a wide range of risky performance of firm. Measurement of risk tolerance is a significant parameter in exponential utility function. This indicates the utility of corporation to make decisions in risky investment. In other words, R indicates total money by which the decision maker is indifferent about 50/50 winning the total figure or leaving half of it. The main problem with the measurement of risky tolerance is the assessment of transactions between upward high profits potential against downward damages under unconfident condition. The situation of the decision maker considering the amount of the damaged investment is important.

Another importance of preference theory goes to valuating measure which is known as certainty equivalent. Certainty equivalent is the least confident value which decision maker accepts it in an unconfident gamble process. In other terms, it is a cash value, which corporation is ready to change its unconfident position [6]. Certainty equivalent equals with expected value minus risk discount which is paid as risk premium. In case of exponential utility function, maximum purchase or minimum sale price of corporation for a risky investment equals with certainty equivalent of corporation [7]. In case of discontinues probable distributions, certainty equivalent formula is defined as:

$$C_x = -RLn\left(\sum_{i=1}^{n} p_i e^{-x/R}\right) \tag{15}$$

Where Pi is manufacturing probability of ith product, xi is ith product value and Ln is natural logarithm. In other words, if features of different choices for risky investment (e.g. xi and Pi definitions), and the amount of money which corporation is ready for participation in risky investment (Cx), is known, therefore we will be able to define R as parameter of corporation risk tolerance [1].

4. APPLICATION OF MIX PORTFOLIO MODEL AND PREFERENCE ANALYSIS IN OPTIMIZED ALLOCATION OF GAS RESERVES

In this section, an attempt is made to simulate Markowitz! portfolio management theory to provide a realistic view on such projects as natural gas export, gas injection oil fields with, and petrochemicals with natural gas feedstock. Considering the position of Iran in global oil and gas markets, unique technical and geological specifications of Iran's natural gas fields have turned to the most crucial economic problem for the officials.

South Pars gas field as the world's biggest natural gas field is shared between Iran and Qatar where the share of Iran is somehow equal to half of total Iranian gas reserves. In the recent decade, the development of the South Pars was commenced, of course with a time lag compared to Qatar, and at the present time, huge investments are made in this field [8].

It seems that these reserves and their particular conditions have impacts on the country's gas and oil projects in coming years. Accordingly, in this paper, optimum allocation of such huge natural gas reserves will be discussed. In other words, it is assumed that natural gas feedstock of all planned projects is supplied from the South Pars gas field.

Any project studied in this model is considered as an asset. All these projects have two main specifications: first, all of them are high capital intensive so that high capital costs (Capex) is required. This high capital costs are paid in a four year period. In the calculations, capital costs in implementation phases during the four year period are assumed to be normally distributed. The project income starts after commissioning (from the fifth year) and continues in a 25 years period which forwards a cash flow of income [9].

In such structures, costs flows and particularly income flows are occurred in a long period, they will be affected by effective variables and many risks. Therefore, accurate assessment of appropriate parameters, indicating the projects risk and efficiency e.g. calculations of mean and deviation will be of particular importance [9].

Now, it is assumed that we have M gas export projects, N gas injection to the oil fields, G Petrochemicals project fed by natural gas and we want to achieve maximum exchange profits through allocating natural gas to above- mentioned projects according to the value and risk of each project. In this stochastic dynamic optimization process, control variation is natural gas allocated to each project.

General structure of the problem is as follows:

	Expected Value of Project	*Gas Quantity Domain for Each Projec*
M, Gas Export Projects	NPV_1^E	$Y_1^E \le Q_1^E \le X_1^E$
	.	.
	.	.
	NPV_M^E	$Y_M^E \le Q_M^E \le X_M^E$
N, Gas Injection Projects	NPV_{M+1}^I	$Y_{M+1}^I \le Q_{M+1}^I \le X_{M+1}^I$
	.	.
	.	.
	NPV_{M+N}^I	$Y_{M+N}^I \le Q_{M+N}^I \le X_{M+N}^1$
G Petrochemical Plants with Gas Feeding	NPV_{M+N+1}^P	$Y_{M+N+1}^P \le Q_{M+N+1}^P \le X_{M+N+1}^P$
	.	.
	.	.
	NPV_{M+N+G}^P	$Y_{M+N+G}^P \le Q_{M+N+G}^P \le X_{M+N+G}^P$

Domain of allocated natural gas for each project, considering different technical and commercial features, shows the minimum and maximum amount of gas allocated to each project. On the other hand, the main constraint factor in optimization problem and considered as a constraint function is total amount of allocated gas. In other terms, total gas allocated to the projects should not be more than maximum gas producing capacity:

$$Q_t^T = \sum_{i=1}^{M+N+G} Q_t^i \tag{16}$$

A wide varieties of different portfolios is achieved through change in Q_t^i for each project in the intended domain and considering above limits.

Appendix 1 shows all of the projects studied in this research.

Expected net present value, E(NPV), for gas export projects is given from the following equation:

$$NPV_i^E = \sum_{k=1}^{9}\sum_{j=1}^{3}\sum_{l=1}^{3} NPV_i^{Ek}.q_i^{Ej}.f_i^{El} \tag{17}$$

In order to achieve a more accurate assessment of prices and costs of projects, 3 scenarios for trend of natural gas price trend, P_{it}^{E1} ، P_{it}^{E2} ، P_{it}^{E3}, with probability q_i^{E1} ، q_i^{E2} ، q_i^{E3} and also 3 scenarios for construction and executing the projects, C_i^{E1} ، C_i^{E2} ، C_i^{E3} with probability of f_i^{E1} ، f_i^{E2} ، f_i^{E3} are considered.

Also, standard deviation of net present value for these projects is:

$$S.D_i^E = \sqrt{\frac{\sum_{j=1}^{N} (NPV_i^{Ej} - NPV_i^E)^2}{N-1}} \tag{18}$$

which is known as a measure for asset risk.

Also, E(NPV) and standard deviation for petrochemical projects group with gas feeding is given as:

$$NPV_u^P = \sum_{k=1}^{9}\sum_{l=1}^{3}\sum_{s=1}^{3} NPV_u^{Pk}.f_u^{Ps}.q_u^{Pl} \tag{19}$$

$$S.D_u^P = \sqrt{\frac{\sum_{k=1}^{N} (NPV_u^{Pk} - NPV_u^P)^2}{N-1}} \tag{20}$$

In order to achieve a more accurate assessment of prices and costs of projects, 3 scenarios for trend of petrochemicals price P_{ut}^{P1} ، P_{ut}^{P2} ، P_{ut}^{P3} with probability q_{ut}^{P1} ، q_{ut}^{P2} ، q_{ut}^{P3} and also 3 scenarios for capital costs of the constructing the petrochemical projects C_{ut}^{P1} ، C_{ut}^{P2} ، C_{ut}^{P3} with probability of f_{ut}^{P1} ، f_{ut}^{P2} ، f_{ut}^{P3} are considered.

Also, E(NPV) and standard deviation for petrochemical projects group with gas feeding is given as:

$$NPV_j^I = \sum_{k=1}^{27}\sum_{h=1}^{3}\sum_{l=1}^{3}\sum_{s=1}^{3} NPV_j^{Ik}.f_j^{Is}.g_j^{Ih}.q_j^{Il} \tag{21}$$

$$S.D_j^I = \sqrt{\frac{\sum_{k=1}^{N} (NPV_j^{Ik} - NPV_j^I)^2}{N-1}} \tag{22}$$

In this section, in order to achieve a more accurate assessment of prices and costs of projects and recovery factors, 3 scenarios for trend of crude oil price P_{jt}^{I1} ، P_{jt}^{I2} ، P_{jt}^{I3} with probability q_{jt}^{I1} ، q_{jt}^{I2} ، q_{jt}^{I3} and also 3 scenarios for capital cost of constructing the facilities, C_{jt}^{I1} ، C_{jt}^{I2} ، C_{jt}^{I3} with probability of f_{jt}^{I1} ، f_{jt}^{I2} ، f_{jt}^{I3} and 3 scenarios for recovery factor, Q_{jt}^{I1} ، Q_{jt}^{I2} ، Q_{jt}^{I3} with probability g_{jt}^{I1} ، g_{jt}^{I2} ، g_{jt}^{I3} are considered.

Natural gas quantity is the most important factor affecting the capital cost of the projects. Considering the economy of scale theory, the rate of the increasing in the capacity of the projects is more than the rate of the increasing of the capital cost of them [8]. This matter is shown in the six tenth rule of thumb formula:

$$C_2 / C_1 = (Q_2 / Q_1)^{0.6} \tag{23}$$

Where C is the capital cost and Q is the capacity of the projects. Since capital cost and net present value of the projects are affected by the capacity of the projects, for achieving more accuracy in final results, we should solve the problem in different scenarios for gas quantity.

Table 1 shows present expected value as a measure of economical efficiency and standard deviation as risk measure for tertiary projects group of gas exportation, petrochemicals and gas injection into the oil fields in five scenarios for gas quantity, 100, 200, 300, 400 and 500 million cubic meter per day(MMSCMD).

Now , it is assumed that produced natural gas from south Pars gas field in different scenarios should be allocated to these groups with the proportion of x1,x2and x3 , so that the most present expected value in different risk domains is achieved:

$$\begin{aligned} &Max.: NPV^T = \sum_{i=1}^{3} x_i NPV_i \\ &S.T: \\ &St.Dev.^T = A \end{aligned} \tag{24}$$

where A is maximum risk intended by investor in each scenario. Results from the optimization programming has been written in MATLAB software, (Appendix 2) have been shown in Table 2 till 6 indicate different mixes of efficient portfolios from tertiary groups of projects in different risks. Also, Fig. 1 shows the related efficient frontier portfolios.

Table 1. Present expected value as a measure of economical efficiency and standard deviation

Gas Quantity / Project Group	500MMSCMD		400MMSCMD		300MMSCMD		200MMSCMD		100MMSCMD	
	St.Deviation	E(NPV)	St.Deviation	E(NPV)	St.Deviation	E(NPV)	St.Deviation	E(NPV)	St.Deviation	E(NPV)
Gas Export	3298	5521	3122	5457	3067	5029	2800	4913	2804	4751
Petrochemical plants	1207	1235	1112	1122	952	957	870	885	835	846
Gas Injection	2821	3621	2677	3484	2317	3420	2118	3215	2022	3017

Table 2. Different mixes of efficient portfolios - 100MMSCMD

Portfolio	St.Deviation	E(NPV)	Projects Combination (Gas Quantity MMSCMD)			
			Total	Gas Export	Gas Injection	Petrochemicals
1	142930	74411	100	7	14	79
2	182930	78629	100	14	20	66
3	202930	84356	100	20	26	54
4	242930	97837	100	23	30	47
5	262930	101597	100	26	34	40
6	282930	115960	100	31	35	34
7	322930	136420	100	37	42	21
8	342930	147033	100	41	45	14
9	362930	158320	100	45	48	7
10	386840	174210	100	49	51	0
11	406840	187730	100	60	40	0
12	426840	210040	100	72	28	0
13	446840	237000	100	84	16	0
14	466840	267220	100	95	5	0
15	475720	279320	100	100	0	0

Table 3. Different mixes of efficient portfolios -200MMSCMD

Portfolio	St.Deviation	E(NPV)	Projects Combination (Gas Quantity MMSCMD)			
			Total	Gas Export	Gas Injection	Petrochemicals
1	300610	154690	200	15	27	158
2	400610	166480	200	32	41	127
3	500610	197670	200	48	56	96
4	550610	221360	200	54	65	81
5	600610	240840	200	65	70	65
6	650610	267730	200	74	77	49
7	700610	290700	200	81	85	34
8	750610	325420	200	89	91	20
9	812617	350980	200	100	100	0
10	842617	372610	200	118	82	0
11	872617	402720	200	135	65	0
12	900617	436950	200	152	48	0
13	912617	453090	200	159	41	0
14	962617	527640	200	188	12	0
15	981797	559650	200	200	0	0

Table 4. Different mixes of efficient portfolios -300MMSCMD

Portfolio	St.Deviation	E(NPV)	Projects Combination (Gas Quantity MMSCMD)			
			Total	Gas Export	Gas Injection	Petrochemicals
1	474950	253910	300	23	40	237
2	574950	261640	300	38	54	208
3	674950	284680	300	54	69	178
4	774950	319750	300	70	83	147
5	824950	346230	300	80	90	130
6	874950	363380	300	85	98	117
7	924950	384920	300	95	104	101
8	974950	412870	300	101	113	87
9	1074950	466360	300	117	127	56
10	1174950	522610	300	132	142	26
11	1255850	569670	300	146	154	0
12	1355850	666160	300	205	95	0
13	1455850	822890	300	267	33	0
14	1495850	873480	300	283	17	0
15	1512760	913720	300	300	0	0

Table 5. Different mixes of efficient portfolios- 400MMSCMD

Portfolio	St.Deviation	E(NPV)	Projects Combination (Gas Quantity MMSCMD)			
			Total	Gas Export	Gas Injection	Petrochemicals
1	743360	390220	400	40	54	306
2	743360	396130	400	56	64	280
3	943360	413460	400	74	74	252
4	1043360	440840	400	91	85	224
5	1143360	476540	400	108	96	196
6	1243360	518860	400	126	106	168
7	1343360	566300	400	143	117	140
8	1443360	617690	400	160	127	113
9	1543360	672120	400	177	138	85
10	1643360	728920	400	194	149	57
11	1743360	787560	400	212	159	29
12	1855270	848690	400	230	170	0
13	1955270	940860	400	285	115	0
14	2055270	1061200	400	335	65	0
15	2155270	1205800	400	386	14	0

Table 6. Different mixes of efficient portfolios- 500MMSCMD

Portfolio	St.Deviation	E(NPV)	Projects Combination (Gas Quantity MMSCMD)			
			Total	Gas Export	Gas Injection	Petrochemicals
1	929440	487750	500	49	66	385
2	1029360	492520	500	66	77	357
3	1129360	506570	500	83	88	329
4	1229360	527320	500	101	98	301
5	1329360	559270	500	118	109	273
6	1429360	595740	500	135	120	245
7	1529360	637590	500	153	130	217
8	1629360	683560	500	169	141	190
9	1729360	733130	500	187	151	162
10	1829360	785530	500	204	162	134
11	1929360	840240	500	222	173	105
12	2029360	896840	500	239	183	78
13	2129360	954980	500	256	194	50
14	2229360	1014400	500	274	204	22
15	2308360	1062100	500	287	213	0
16	2408360	1172300	500	338	162	0
17	2508360	1248900	500	388	112	0
18	2608360	1380600	500	439	61	0
19	2708360	1529400	500	490	10	0
20	2728360	1560800	500	500	0	0

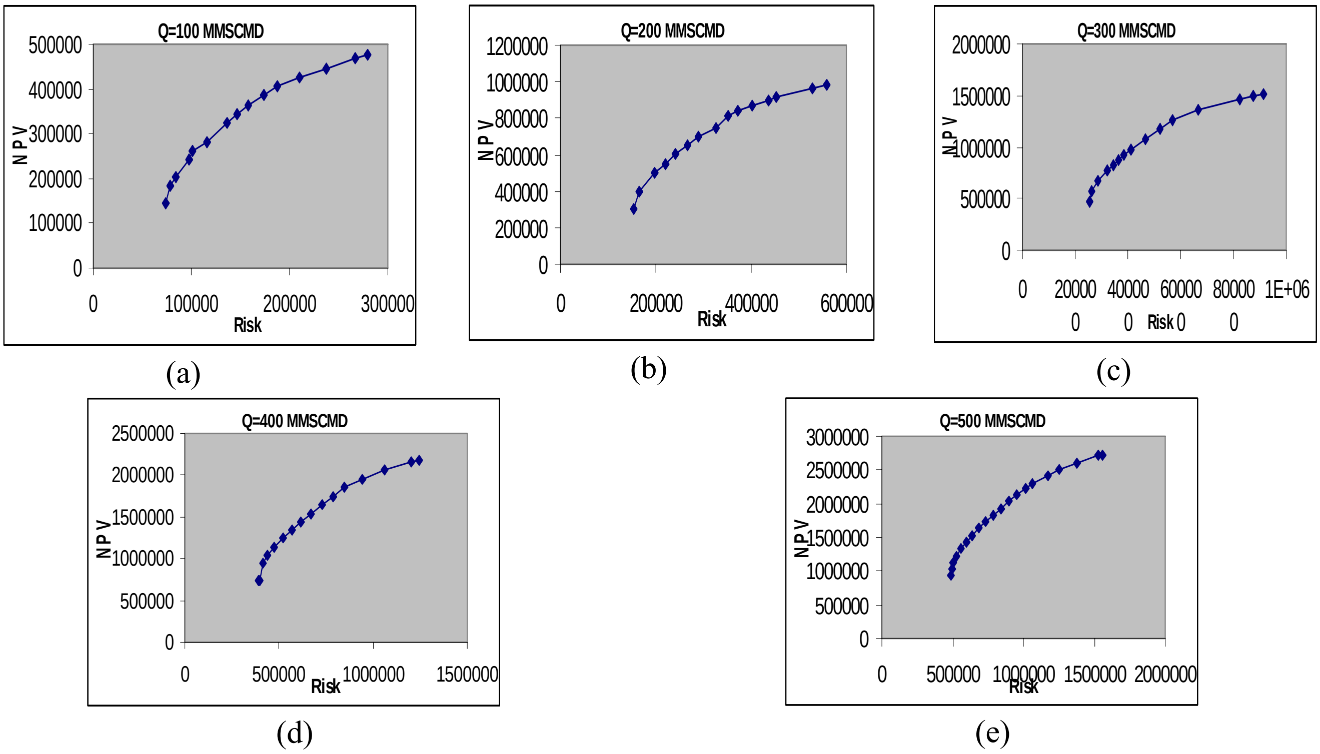

Fig.1 (a-e). Efficient frontiers in different scenarios.

As mentioned earlier, mixes presented in Table 2 are efficient portfolios. One of them is efficient portfolios which relates to the risk tolerance measure of investing corporation. Risk tolerance measure is an important factor in the investor utility function. In the other terms, R is total money which decision maker is indifferent about 50/50 winning the total figure or failure half of it. The measure of valuating in preference analysis theory is certainty equivalent. This is the minimum confident value which decision maker accepts it in a gamble and unconfident process. In case of exponential utility function, maximum corporation purchase price or minimum corporation sale price for a risky investment indicates corporation certainty equivalent in relevant risky investment.

In such a situation, for a frame of mean-variance, Raiffa presented the following equation for certainty equivalent [10]:

$$C_x = \mu - \frac{\sigma^2}{2R} \qquad (25)$$

Where μ is mean of net present values, σ^2 variance of net present values and R is risk tolerance of corporation. Corporation will be encountered with different certainty equivalents in different risk domains. The mix which presents maximum certainty equivalent is the optimum port folio. Tables 7-11 show certainty equivalent in different risk tolerances in optimum allocating of natural gas.

Table 7. Certainty equivalent - 100MMSCMD

Portfolio	St.Deviation	E(NPV)	Certainty Equivalent in Different Risk Tolerance			
			125000=R4	111000=R3	87000=R2	83000=R1
1	142930	74411	120782	117988.6	111108.2	109574.6
2	182930	78629	158199.9	155080.8	147398.3	145685.9
3	202930	84356	174466.3	170876.2	162033.8	160062.9
4	242930	97837	204641.7	199812.5	187918.1	185266.9
5	262930	101597	221642.2	216434.7	203608.4	200749.6
6	282930	115960	229143.1	222359.2	205650	201925.7
7	322930	136420	248488.3	239099.3	215973.6	210819.1
8	342930	147033	256455.2	245548.5	218684.6	212696.8
9	362930	158320	262669.1	250023.6	218877	211934.7
10	386840	174210	265443.5	250132.2	212419.7	204014
11	406840	187730	265869.8	248089.8	204296.6	194535.5
12	426840	210040	250372.8	228115.7	173295.2	161076.1
13	446840	237000	222164	193826.5	124029.7	108472.5
14	466840	267220	181213.9	145189	56457.65	36680.19
15	475720	279320	163641.4	124280.1	27331.14	5722.034

Table 8. Certainty equivalent - 200MMSCMD

Portfolio	St.Deviation	E(NPV)	Certainty Equivalent in Different Risk Tolerance			
			390000=R4	261000=R3	180000=R2	160000=R1
1	300610	154690	269931.8	254769	234140.6	225831.9
2	400610	166480	365077.2	347515	323622.2	313998.8
3	500610	197670	450515.9	425756.7	392072.7	378505.5
4	550610	221360	487789.2	456739.8	414498.2	397484.2
5	600610	240840	526246	489491.4	439488	419347.8
6	650610	267730	558713.4	513293.2	451500.7	426612
7	700610	290700	592268.3	538720.2	465869.8	436527.2
8	750610	325420	614843.1	547739.9	456448.4	419678.2
9	812617	350980	654685	576626.7	470431	427657.7
10	842617	372610	664619.3	576643.4	456955.3	408747.6
11	872617	402720	664689.6	561920.8	422107.6	365793.9
12	900617	436950	655841	534859.7	370268.9	303975.4
13	912617	453090	649424	519340.1	342365.5	271084
14	962617	527640	605688.8	429276.1	189272.6	92604.6
15	981797	559650	580248.1	381781.4	111774.4	3021.617

Table 9. Certainty equivalent - 300MMSCMD

Portfolio	St.Deviation	E(NPV)	Certainty Equivalent in Different Risk Tolerance			
			600000=R4	318000=R3	279000=R2	276000=R1
1	474950	253910	421224.8	373581.6	359411.8	358156
2	574950	261640	517903.8	467315.6	452269.9	450936.4
3	674950	284680	607414.4	547524.4	529712.2	528133.5
4	774950	319750	689749.9	614195.2	591724.1	589732.5
5	824950	346230	725054	636467	610119.9	607784.8
6	874950	363380	764912.5	667332	638310.2	635738
7	924950	384920	801480.5	691988.7	659424.2	656538
8	974950	412870	832898.6	706928.6	669463.2	666142.7
9	1074950	466360	893707	732982	685180	680943.4
10	1174950	522610	947349	745514.1	685485.5	680165.2
11	1255850	569670	985413.4	745592.3	674265.9	667944.4
12	1355850	666160	986042.4	658099.8	560564.8	551920.4
13	1455850	822890	891560	391152	242323.2	229132.7
14	1495850	873480	860043.9	296215.9	128525.1	113662.8
15	1512760	913720	817023.1	200048.9	16551.69	288.5536

Table 10. Certainty equivalent - 400MMSCMD

Portfolio	St.Deviation	E(NPV)	Certainty Equivalent in Different Risk Tolerance			
			830000=R4	448000=R3	398000=R2	357000=R1
1	743360	390220	651630.1	573414	552064	530094.4
2	743360	396130	648830.5	568227.2	546225.6	523585.5
3	943360	413460	840378.6	752568.5	728599.7	703935.4
4	1043360	440840	926287.8	826462.8	799214.4	771175.3
5	1143360	476540	1006559	889910.9	858070.6	825306.3
6	1243360	518860	1081182	942896	905149.3	866307.2
7	1343360	566300	1150170	985440.7	940476	894206.4
8	1443360	617690	1213516	1017533	964037.2	908988.9
9	1543360	672120	1271224	1039180	975840.8	910663.5
10	1643360	728920	1323285	1050364	975867.1	899208.2
11	1743360	787560	1369715	1051116	964150.5	874661.5
12	1855270	848690	1421370	1051392	950402.3	846481.9
13	1955270	940860	1422006	967304	843187.7	715469.5
14	2055270	1061200	1376869	798411.3	640514.4	478035.5
15	2155270	1205800	1279394	532553.9	328695.1	118920.4

Table 11. Certainty equivalent - 500MMSCMD

Portfolio	St.Deviation	E(NPV)	Certainty Equivalent in Different Risk Tolerance			
			586000=R4	539000=R3	492000=R2	447000=R1
1	929440	487750	726453.6	708753.5	687671.6	663332.5
2	1029360	492520	822383.9	804335.9	782839.7	758022.2
3	1129360	506570	910406.8	891314.4	868574.3	842320.7
4	1229360	527320	992102	971413.4	946772.2	918323.8
5	1329360	559270	1062480	1039209	1011491	979490.9
6	1429360	595740	1126539	1100134	1068683	1032373
7	1529360	637590	1182499	1152253	1116229	1074639
8	1629360	683560	1230679	1195914	1154508	1106704
9	1729360	733130	1270760	1230770	1183141	1128152
10	1829360	785530	1302861	1256951	1202269	1139139
11	1929360	840240	1326968	1274440	1211877	1139647
12	2029360	896840	1343078	1283236	1211960	1129671
13	2129360	954980	1351214	1283361	1202544	1109241
14	2229360	1014400	1351367	1274808	1183621	1078345
15	2308360	1062100	1345855	1261925	1161961	1046552
16	2408360	1172300	1235760	1133511	1011727	871125.9
17	2508360	1248900	1177514	1061466	923247	763671.8
18	2608360	1380600	982032	840218.7	671310.9	476305.9
19	2708360	1529400	712571.3	538541.5	331262.1	91956.91
20	2728360	1560800	649779.2	468530.1	252652	3419.687

5. CONCLUSIONS

Application of new methods in investment process analysis is a current approach in big oil and gas companies around the world. National Iranian Oil Company, as one of the most important oil and gas companies in the world has been faced with challenges of investment in different sections. From this point of view, it seems essential to use such techniques in complicated problems.

In this paper, one of the most important challenges of National Iranian Oil Company that is optimum allocation of natural gas to the different consuming sectors such as export, petrochemicals and injection into the oil fields is discussed through Markowitz! theory and preference analysis theory as new methods of optimization. This important goal is achieved through considering economic and technical features of each group of projects and calculations related to net present expected value and its standard deviation as risk measure. And finally indicating efficient frontier portfolios and analyzing the investor risk tolerance in different scenarios, different solutions are achieved as optimum mixes of natural gas allocation.

Results show that gas export, gas injection and petrochemicals projects are the best preferences from mean expected present value and risk points of view. When choosing the portfolio on efficient frontier, if less risk of portfolio is intended, weight ratio of gas allocated to gas exportation projects is less than case of high risk and high efficiency is intended. On the other hand, weight ratio of natural gas allocated to gas injection and petrochemicals decreases with rising risks and expected value. Study of risky behavior of investor in different risk tolerances shows that the more is risk aversion of investor, the less gas ratio is allocated to natural gas export projects

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APPENDIX - 1

Project Type	Main Group	Project Name
Gas Export Projects	Persian Gulf Countries- Pipeline	Iran- Kuwayt
		Iran- Emirate
		Iran- Oman
	Europe Countries- Nabbaco Pipeline Project	Iran- Turkey
		Iran- Bulgaria
		Iran- Rumania
		Iran- Hungry
		Iran- Austria
	East Pipline	Iran- India
		Iran- Pakistan
	Europe	LNG- Europe
	East & South East	LNG- India, China
Gas Injection into Oil Fields	Group 1- 1677318 bbld Production	Maroun- Asmari
		Gachsaran
		Karanj
		Aghajari
		Bibi hakimeh
		Parsi, Coupal,
	Group 2- 142497 bbld Production	Haftkel, Naftsafid
		Masjed Soleiman, Parsia, Ramin
		Binak, Abteimour
		Aghajari- Bangestan, Lali
		Nargesi, Zilaei
		Chelingar, Fahlian
Petrochemical Plants	Olefin	
	Methanol	
	Urea, Amonia	

APPENDIX – 2

```
clc
close all
clear all
beta=900617;
C=[870 0 0
   0  2118 0
   0 0 2800];
d=[0; 0; 0;];
Aeq=[1 1 1];
Beq=[200];
A=[-885 -3215 -4913 ];
B=[-beta];
LB=[0 0 0 ];
UB=[200 200 200 ];
[X,Fvalue,R,EXITFLAG]=lsqlin(C,d,A,B,Aeq,Beq
,LB,UB);
X
Risk=sqrt(Fvalue)
Value=-X'*A'
EXITFLAG
```