FORECASTING OF OIL AND GAS EXTRACTION IN AZERBAIJAN ON THE BASIS OF HUBBERT'S MODEL [1]

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Abstract

In work the Hubbert's model of oil and gas production is investigated. Using the applicable statistical data, econometric models of oil and gas extraction in Azerbaijan are valued. Further, on the basis of the models constructed for Azerbaijan the oil and gas extraction bulk is predicted.

Keywords: oil and gas production, Hubbert model, econometric modeling.

JEL Classification Codes: L95; Q47;C53;E17

Introduction: in XIX century the demand for crude oil increased due to the technical development as well as development of the internal-combustion engine. Although there is wide range of researches dedicated to the development of alternative energy sources, the world economy is still significantly depending on the crude oil and its derivative products. The dependence of the world economy on oil resources is not avoidable while oil exploration is still efficient and these resources do not fade out. It is widely known that the oil and gas resources are scare. From this point of view the forecasting of the carbohydrate reserves is on agenda.

[1] The research work was conducted in 2013 based on grant announced by the Scientific Fund of State Oil Company of Azerbaijan Republic.

Various researchers applied the various methods for estimation of crude oil reserves. [1-8]. The econometric models based on physics, mathematics, economy and technology [1, 9, 10, 11, 12]. Recently the Monte-Carlo simulation models and artificial intelligence modules were used for these purposes.

The Hubbert's model is one of the most widely used models for estimation of the oil and gas reserves. At the first time Hubbert estimated the oil and gas reserves of USA in 1956 [3]. Since that time owing to its reliability and simplicity it was widely used in number of countries over the world for estimation of national oil and gas reserves.

Metodogy: the standard Hubbert Model, which is based on Richard's function, defines the following model for the production [1, p.278]:

$$CQP = \frac{URR_{max}}{1+e^{-a(t-t_0)}} \quad (1)$$

Here, CQP is cumulative (increasing) production, URR_{max} maximum extracted resource, t_0 peak production year or 1 parameter, which defines the initial norm of the production.

The derivative of the cumulative production from the time is QP = dCQP/dt, or:

$$QP = \frac{a*URR_{max}*e^{-a(t-t_0)}}{\left[1+e^{-a(t-t_0)}\right]^2} \quad (2)$$

here, QP is a current level of production or annual volume.

The alternative view on the Hubbert's curve is to treat the cumulative production volume (QP) as a function of cumulative production (CQP). In this case the relation between these two determinates can be shown as following:

$$QP = b_1 * CQP + b_2 * CQP^2 \quad (3)$$

Parameters b_1 və b_2 are evaluated as a limit of cumulative volume of resource (maximum) and can be determined in the following way:

$$URR_{max} = -\frac{b_1}{b_2} \quad (4)$$

At the same time,

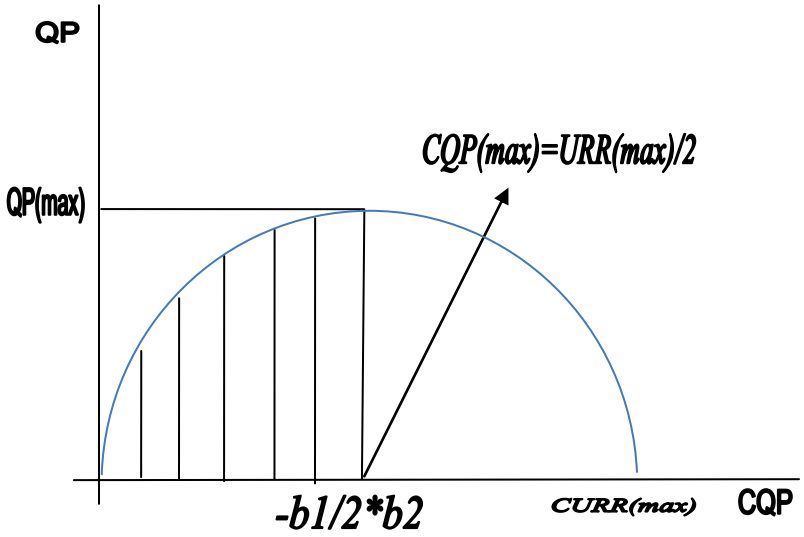
$$\frac{dQP}{dCQP} = 0$$

$$b_1 + 2b_2 * CQP = 0$$

$$CQP_{max} = -\frac{b_1}{2b_2}.$$

here, CQP_{max} – is the cumulative volume of resources used till the peak period of utilization. According to (3) the utilization of the resources during the current period (QP) is depending on cumulative volume (CQP) and symmetric to the peak utilization level, thus we can show it in the following way (picture 1).

$$URR_{max} = 2 * CQP_{max} = -\frac{b_1}{b_2} \quad (5)$$



Picture 1. The curve reflection the functional dependence between QP and CQP

The same source is working for the following equation:

$$QD = a * CQD - \frac{a}{URR} * CQD^2 \quad (6)$$

here, QD is a current exploration of oil and gas; CQD – the cumulative exploration of entire oil and gas reserves in the region; a is parameter defining the initial growth norm (it defines the height of Hubbert's curve) and URR is the last extracted (recoverable) resource, which the function of prices, expenses, technologies and regional characteristics.

The equation (5) is called the Square Hubbert's curve model. We would like to note that this curve is not the original Hubbert's model; actually it is the result of Uhlers information and it is the result of mentioned above decreasing effects. We guess that such form of the curve is more function of cumulative production than the function of information and physical amortization.

The model can add the indicator variables till its statistical substantiation. The information about the indicator variables and their application can be taken from the model itself.

Information database: the information required for the realization of this model was taken from the State Statistics Committee of Azerbaijan Republic, Oil Fund and Ministry of Economy and Industry.

Realization and forecasting of Hubbert's model. Let's evaluate parameter a (growth rate of oil production) through the econometric methods. In order to reliably identify the growth of oil production in Azerbaijan during 1998-2010 we would like to evaluate the parameters of the following equation:

$$\text{Oil}_{\text{production}} = a_0 e^{at}(1+\square)$$

here, a_0 – the initial oil production volumes, a – the growth rate of oil production, ε - standard deviation. In order to make the results of the model more realistic we have added DAMMY qualitative parameter, which would reflect the significant drop in oil prices started and financial crisis started in 2008 and continued till 2010.

LOG(OIL_PRODUCTION) = 1.55235566774 + 0.104443964419*@TREND +

+0.392002243766*DAMMY (7)

or

$$Oil_{production} = 4.722582*e^{0.104443964419*t}(1+u) \quad (8)$$

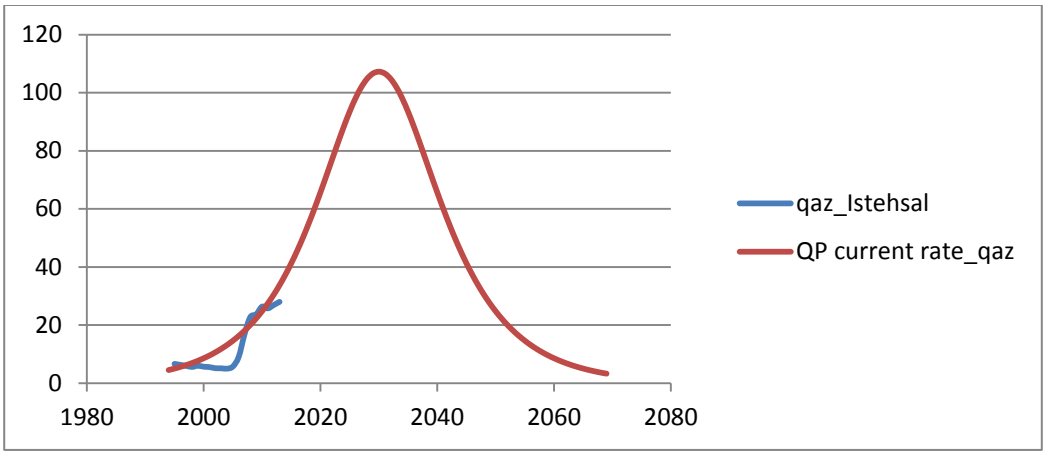
The statistical features of (7) or (8) and relevant testing proved the adequacy the current model. The value of the determination ratio (R2=0.949624) shows that the volumes of oil production in Azerbaijan during these years depended on time factors and financial crisis at 95%. The remaining 5% incurred due to the other factors not considered in the model.

Thus the results of the model (7) and (8) show that at the normal distribution (Quass) the growth of the oil production (a) in the Azerbaijan is approximately equal to 0.104443964419 or 10.44%: a (oil) = 0.104443964419 .

We can estimate by the same method the growth of gas production: a (gas) = 0.107244531296.

According to the equations (1) and (2) the cumulative and current oil and gas production will be calculated (for oil till 2030 and for gas till 2075). The results of our calculations were provided in Appendixes. Please note that the maximum oil reserves were estimated as 1 billion tones and maximum gas reserves were estimated as 2 trillion cubic meters.

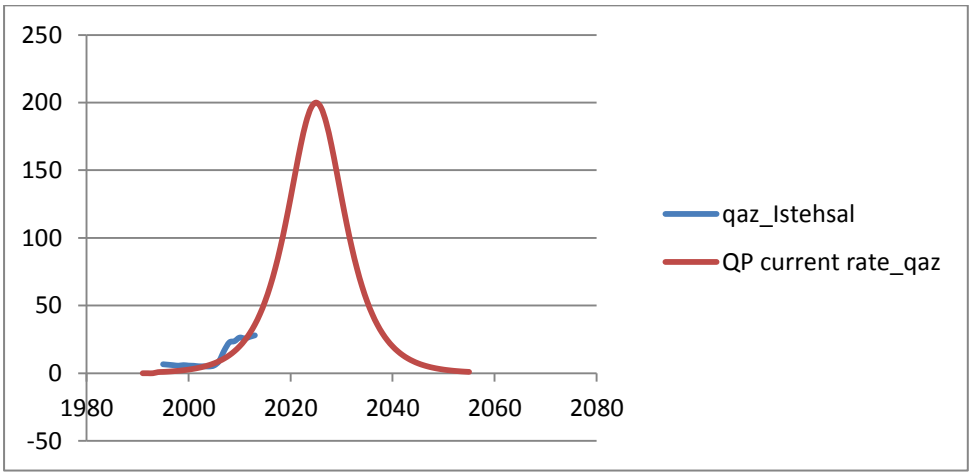
Graph 1. Forecasting of oil production in Azerbaijan according to the Hubbert's model.

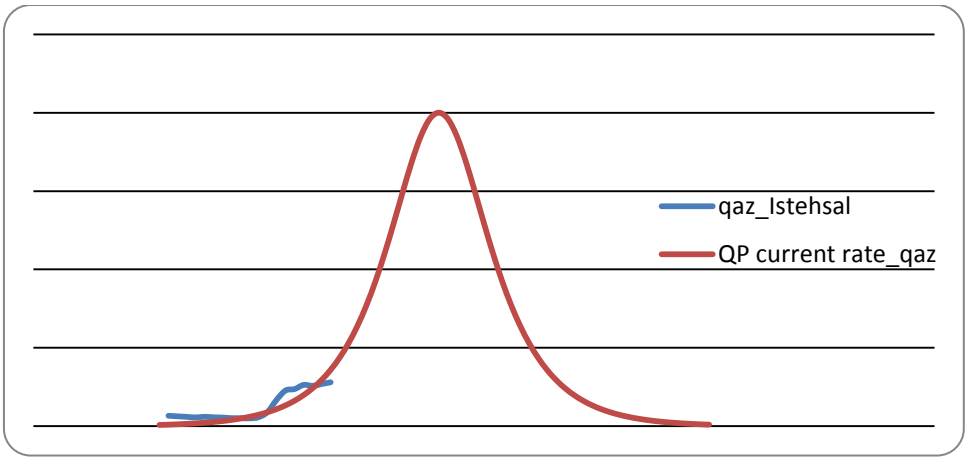


Graph 2. Forecasting of gas production in Azerbaijan according to the Hubbert's model:

a=0.107245, T(max)=2030, QP=107.

As we can see from the Graph above the gas production will reach its peak by 2030 and then start to decline till 2075. We would like to note that this result was obtained in conditions of growth equal to 0.107244531296 (10.7 %). It is widely known that in 2013 Azerbaijan signed agreement with two international companies for gas exploration. This agreement considered the significant inflow of foreign investments into Azerbaijan. Surely, during this period the gas production will increase significantly. If we take the growth of gas exploration as 0.2 (20%), we will get the following results (Graph 3).





Graph 3. Forecasting of gas production in Azerbaijan according to the Hubbert's model**: a=0.2, T(max)=2025, QP=200.**

As we can see from the Graph 3 above, in case when the production growth is taken as 0.2, the maximum gas exploration is reached in 2025 and production in average of 200 billion cubic meters will continue only in 2055.

The forecasting of econometric model. Let's forecast the perspective development and exploration volumes of oil and gas reserves in Azerbaijan based on equation (3).

The statistical data available for Azerbaijan for the period of 1990-2013 are applied in equation (3) in the following manner:

QP_OIL = 0.186811363236*CQP_OIL - 0.000192790140237*CQP_OIL^2 (9)

Please note that the econometric model of oil exploration as taken with assumption that the exploration on both sides of peak production point are symmetric.

From econometric equation (9) we can see that, $b_1 = 0.186811363236$,

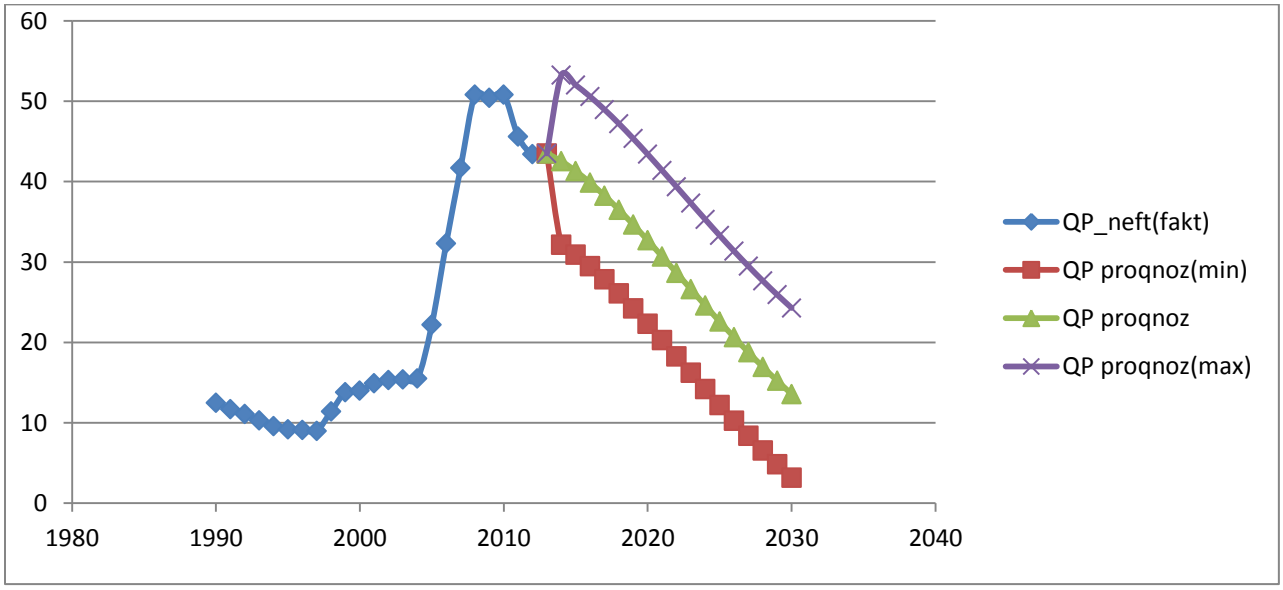
$b_2 = -0.000192790140237$, $URR_{max} = 2 * CQP_{max} = -\frac{b_1}{b_2} = 967.9326$ million ton

In other words, according to the model (9) the average oil reserves in Azerbaijan as evaluated as 967.9326 million ton.

Oil exploration calculated based on model (9) was provided in the Appendix 3.

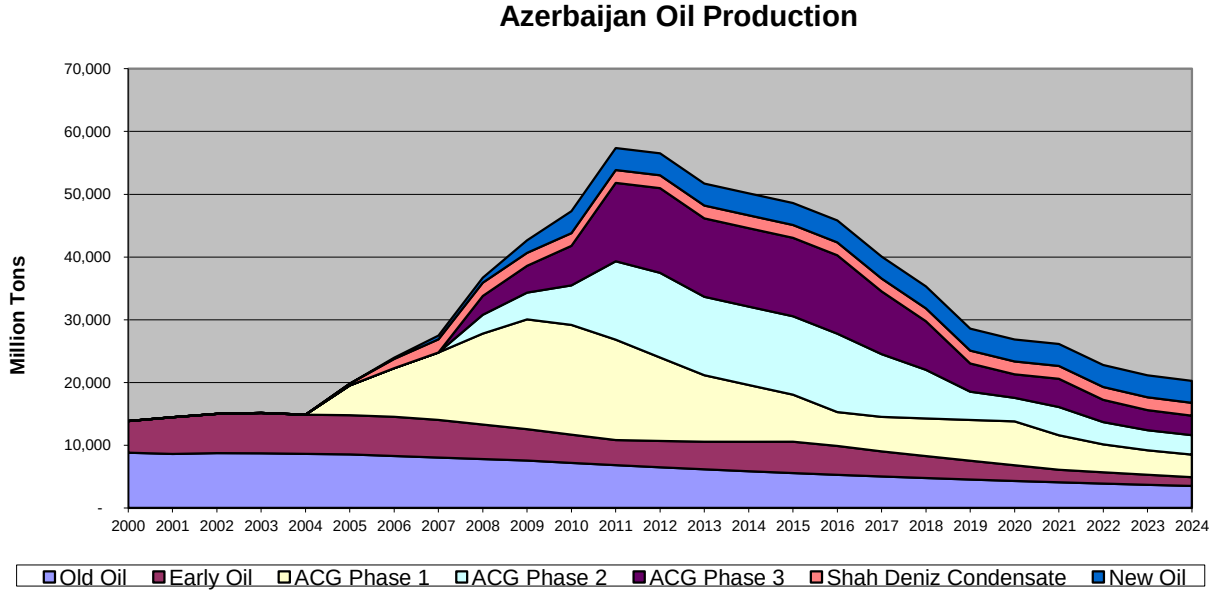
The actual oil exploration in 1990-2013 and recast for 2014-2030 were provided on Graph 5 below.

The lower and upper ranges of the oil exploration were calculated in the econometric model (9).



Graph 4. Actual and forecast values of oil exploration Azerbaijan

We would like to note that the forecast for oil exploration in Azerbaijan provided by the World Bank is as in Graph 5 [https://openknowledge.worldbank.org/ bitstream/handle/10986/13825/ multi0page. txt? sequence=2].



Source: World Bank

Graph 5. The forecast of oil exploration in Azerbaijan during 2000-2024 according to the Oil Model prepared by the World Bank

If we compare the Graph 4 and Graph 5, we can see that they are quite close to each other.

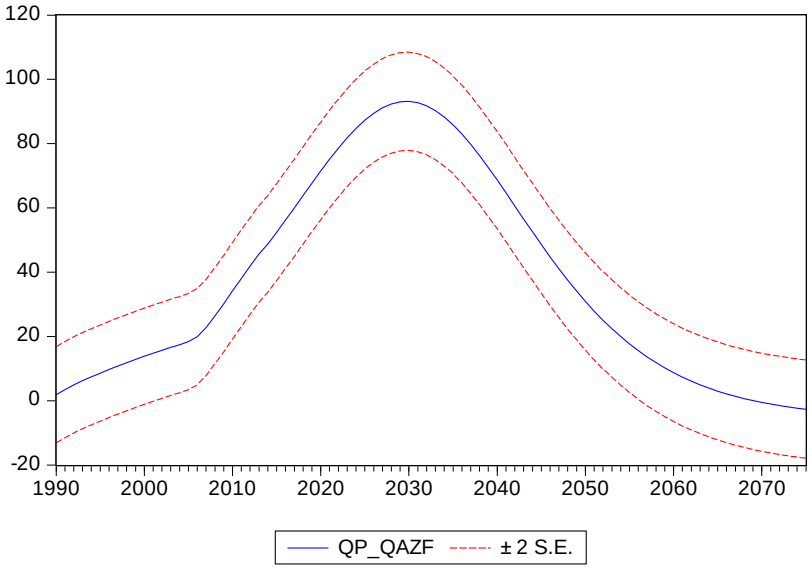
We have identified the gas exploration based on similar model as following.

QP_GAZ = 0.189176922337*CQP_GAZ - 0.0000960239391647*CQP_GAZ^2 (10)

As we can see from the econometric model (10) $b_1 = 0.000096023939$, $b_2 = -0.000096023939$.

$$URR_{max} = 2 * CQP_{max} = -\frac{b_1}{b_2} = 1970.594 \text{ billion cubic meters}$$

In other words, according to model (10) the average value of the gas reserves in Azerbaijan is evaluated as 1970.594 billion cubic meters. The forecast of gas exploration was calculated based on model (9) and presented in Graph 6 below.



Forecast: QP_QAZF	
Actual: QP_QAZ	
Forecast sample: 1990 2075	
Included observations: 86	
Root Mean Squared Error	7.396403
Mean Absolute Error	6.161577
Mean Abs. Percent Error	50.35100
Theil Inequality Coefficient	0.074648
Bias Proportion	0.050063
Variance Proportion	0.126197
Covariance Proportion	0.823740

Graph 6. The production of gas exploration in Azerbaijan billion cubic meters

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Appendixes

Appendix 1. Oil production and forecast in Azerbaijan

t	Oil production, billion ton	The cumulative oil exploration (CQP), growth rate a=0.104444	Current oil production (QP), a=0.104444
1994	9.6	158.277	18.96887
1995	9.2	172.6931	20.89147
1996	9.1	188.1286	22.96869
1997	9	204.6026	25.19907

1998	11.4	222.1246	27.57575
1999	13.8	240.693	30.08474
2000	14	260.2942	32.70318
2001	14.9	280.9012	35.39754
2002	15.3	302.4724	38.12212
2003	15	324.9516	40.81827
2004	15.5	348.2673	43.4147
2005	22.2	372.3333	45.82951
2006	32.3	397.0491	47.97413
2007	41.7	422.3016	49.75934
2008	50.8	447.9671	51.10302
2009	50.4	473.9127	51.93846
2010	50.8	500	52.222
2011	45.6	526.0873	51.93846
2012	43.4	552.0329	51.10302
2013	43.5	577.6984	49.75934
2014		602.9509	47.97413
2015		627.6667	45.82951
2016		651.7327	43.4147
2017		675.0484	40.81827
2018		697.5276	38.12212
2019		719.0988	35.39754
2020		739.7058	32.70318
2021		759.307	30.08474
2022		777.8754	27.57575
2023		795.3974	25.19907
2024		811.8714	22.96869
2025		827.3069	20.89147
2026		841.723	18.96887
2027		855.1463	17.19836
2028		867.6102	15.57461
2029		879.1532	14.09044
2030		889.8177	12.73755

Appendix 2. Gas production and forecast in Azerbaijan

t	Gas production, billion cubic meters	CQP cumulative gas, a=0.107245	QP current rate_gaz, a=0.107245	CQP cummulative_gaz, a=0.2	QP current rate_gaz, a=0.2
1994		41.2334671	4.513171	4.0506408	0.811769
1995	6.644	45.7945000	5.023561	4.9452463	0.991495
1996	6.305	50.8469541	5.591529	6.0368326	1.211011
1997	5.9639	56.4407402	6.223517	7.3684798	1.479125
1998	5.5896	62.6301375	6.926666	8.9925463	1.806596
1999	5.9993	69.4740135	7.708888	10.9725978	2.206559
2000	5.6578	77.0360133	8.578933	13.3857018	2.695056
2001	5.535	85.3847054	9.546468	16.3251423	3.291676
2002	5.144	94.5936701	10.62215	19.9036037	4.020328

2003	5.128	104.7415109	11.8177	24.2568700	4.910196
2004	4.995	115.9117686	13.14597	29.5480634	5.996882
2005	5.732	128.1927136	14.621	35.9724199	7.323799
2006	9.08	141.6769906	16.25804	43.7625419	8.943833
2007	16.85	156.4610858	18.07358	53.1939872	10.92134
2008	22.8	172.6445870	20.08527	64.5909294	13.33446
2009	23.7	190.3292043	22.31184	78.3314456	16.27784
2010	26.349	209.6175229	24.77286	94.8517464	19.86559
2011	25.752	230.6114611	27.48839	114.6483518	24.23441
2012	26.908	253.4104125	30.47848	138.2768407	29.54644
2013	28	278.1090626	33.76234	166.3453930	35.99098
2014		304.7948804	37.35726	199.5009782	43.78372
2015		333.5453073	41.27713	238.4058440	53.16045
2016		364.4246825	45.53044	283.7021298	64.36097
2017		397.4809717	50.11774	335.9632297	77.59564
2018		432.7423958	55.02845	395.6322229	92.9844
2019		470.2140810	60.23724	462.9504330	110.4572
2020		509.8748824	65.69976	537.8828427	129.6109
2021		551.6745568	71.34848	620.0510377	149.54
2022		595.5314725	77.08893	708.6873875	168.7101
2023		641.3310517	82.79731	802.6246798	185.0015
2024		688.9251259	88.32059	900.3320054	196.0656
2025		738.1323592	93.48033	1000.0000000	200
2026		788.7398489	98.08112	1099.6679946	196.0656
2027		840.5059467	101.9241	1197.3753202	185.0015
2028		893.1642763	104.8245	1291.3126125	168.7101
2029		946.4288358	106.6312	1379.9489623	149.54
2030		1000.0000000	107.245	1462.1171573	129.6109
2031		1053.5711642	106.6312	1537.0495670	110.4572
2032		1106.8357237	104.8245	1604.3677771	92.9844
2033		1159.4940533	101.9241	1664.0367703	77.59564
2034		1211.2601511	98.08112	1716.2978702	64.36097
2035		1261.8676408	93.48033	1761.5941560	53.16045
2036		1311.0748741	88.32059	1800.4990218	43.78372
2037		1358.6689483	82.79731	1833.6546070	35.99098
2038		1404.4685275	77.08893	1861.7231593	29.54644
2039		1448.3254432	71.34848	1885.3516482	24.23441
2040		1490.1251176	65.69976	1905.1482536	19.86559
2041		1529.7859190	60.23724	1921.6685544	16.27784
2042		1567.2576042	55.02845	1935.4090706	13.33446
2043		1602.5190283	50.11774	1946.8060128	10.92134
2044		1635.5753175	45.53044	1956.2374581	8.943833
2045		1666.4546927	41.27713	1964.0275801	7.323799
2046		1695.2051196	37.35726	1970.4519366	5.996882
2047		1721.8909374	33.76234	1975.7431300	4.910196
2048		1746.5895875	30.47848	1980.0963963	4.020328
2049		1769.3885389	27.48839	1983.6748577	3.291676

2050		1790.3824771	24.77286	1986.6142982	2.695056
2051		1809.6707957	22.31184	1989.0274022	2.206559
2052		1827.3554130	20.08527	1991.0074537	1.806596
2053		1843.5389142	18.07358	1992.6315202	1.479125
2054		1858.3230094	16.25804	1993.9631674	1.211011
2055		1871.8072864	14.621	1995.0547537	0.991495
2056		1884.0882314	13.14597		
2057		1895.2584891	11.8177		
2058		1905.4063299	10.62215		
2059		1914.6152946	9.546468		
2060		1922.9639867	8.578933		
2061		1930.5259865	7.708888		
2062		1937.3698625	6.926666		
2063		1943.5592598	6.223517		
2064		1949.1530459	5.591529		
2065		1954.2055000	5.023561		
2066		1958.7665329	4.513171		
2067		1962.8819252	4.054554		
2068		1966.5935773	3.642479		
2069		1969.9397637	3.272242		
2070		1972.9553854	2.939605		
2071		1975.6722182	2.640759		
2072		1978.1191517	2.372278		
2073		1980.3224194	2.131081		
2074		1982.3058160	1.914398		
2075		1984.0909027	1.719741		

Appendix 3. The forecast of oil exploration in Azerbaijan, million ton

Years(t)	Lower limit	Mid	Higher limit
2014	32.16	42.55	53.25
2015	30.91	41.30	52.01
2016	29.47	39.86	50.57
2017	27.86	38.25	48.96
2018	26.11	36.51	47.21
2019	24.25	34.64	45.35
2020	22.30	32.70	43.40
2021	20.30	30.69	41.40
2022	18.27	28.66	39.37
2023	16.23	26.62	37.32
2024	14.20	24.59	35.30
2025	12.20	22.60	33.30
2026	10.26	20.65	31.36
2027	8.37	18.77	29.47
2028	6.56	16.96	27.66
2029	4.83	15.23	25.93
2030	3.19	13.58	24.29