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A Tobin's Q-Based Pattern for Oil Exploration and Production Agencies

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Abstract: Oil exploration and production agencies as any other agency, create values by applying a combination of assets. However, assets interaction and value-creation in these companies was different. Undoubtedly, this difference is the most important common side of utilization companies and stems from assets structures features of underground resources of such companies. Generally, assets are divided into tangible and intangible ones. But there is an important asset called "underground resources" in these companies with two opposite features. First, crude oil underground resources are exhaustible. Second, a small part of proved reserves is extractable. Upon increased utilization and development of values of human, information and structural intangible assets and spending R&D costs which are from intangible and intelligent assets, more parts of underground assets are converted to extractable assets by increased recovery factor. Thus, intelligent assets of an upstream company are leading ones. This study studies this subject and also studies unit capital cost calculation mechanism by Tobin's Q Theory. Equation for exhaustible assets may be interpreted according to the triple components of asset cost-interest opportunity cost, asset depreciation makeup cost and asset value changes cost. The first term of the obtained equation for upstream company is make-up cost of extracted crude oil (deducted from extractable reserve), the second sentence is the opportunity cost of investment interest for converting in situ oil resources to extractable reserve (increment of recovery factor) and most importantly, shows market price increment of exhaustible resource converted to extractable oil. The important point is that, regarding to scarcity rule, market value of exhaustible resource converted to extractable oil increased more rapidly than tangible assets. The obtained equation implies that optimal final cost for converting in situ unit oil to extractable reserve is equal to the market value of produced crude oil resulted due to recoverable reserve. By this rule we can obtain optimal investment rate to increase recovery factor of upstream agency. In other words, Tobin's rule implies that for determination of optimal investment limit for excess extraction from oil and gas resources, if $q<1$, then investment limit must be decreased to increase recovery factor. If $q>1$, then investment limit must be increased to increase recovery factor. Therefore, the optimal investment limit is when $q = 1$.

Key words: Tobin's Q Theory, oil upstream agency, investment, optimal rate, recovery factor

INTRODUCTION

The most important policy of senior managers and stockholders of an economic agency is determination of optimal investment and production factors. Basically, investment is a dynamic action, so not only an agency's decision for investment depends on types of conflicts but also anticipation of future economic space affects present investment. Up to now, different theories have be provided for agencie's investment which most important ones are internal investment availability theory; investment acceleration theory; investment neoclassical theory and Tobin's Q Theory. Internal investment amounts considers a profit function and argues that agencie's managers prefer internal agencie's amounts (undistributed profits and depreciation reserves) than external amounts (obtaining stock selling debt) for investment. Also, increment of internal amounts increases profits and thus increases investment; so investment is a function of profit level (Hayashi, 1982). The Simple Acceleration Theory assumes that production function has constant coefficients and a fixed amount of capital input is required for producing each commodity unit. The simple acceleration analysis, demand of capital commodities changes with production of national income levels directly. Changes of capital commodities depends on either changes of national income level or another factor that is capital to production ratio or capital fixed factor. Similar to the Simple Acceleration Theory, the Flexible Acceleration Theory which sometimes is called Partial Adjustment Model, assumes that gross or total investment is a direct function of total demand level and is a reverse function of previous period's capital inventory (Brainard and Tobin, 1968).

Tobin's Q Theory is a complementary theory for analysis of agencies investments that was introduced in

1969. Accordingly, this theory discusses about different dimensions of investment requirements and derivatives simultaneously. James Tobin emphasizes that optimal investment rate includes adjustment costs, interruptions, future expectations and risk. He states that investment rate is a function of q as capital additional unit market value to its replacement cost ratio. He suggests that capital return increment indicates profitability of additional investment which increases market value of existing capital. This additional investment decreases final capital production, so prices of capital commodities will decrease up to the equilibrium point. Thus, the equilibrium point of an agency investment is where unit capital price in stock market is equal to its price in capital commodities market; which is where the Tobin's Q is one. Q>1 indicates profitability of additional investment and q<1 requires decrement of capital inventory. Tobin's Q Theory can also be expressed as when an agency can change its capital reserve freely, then it can increase/decrease its capital inventory till Q is one. Thus, we see that many adjustment costs are embedded in this theory (DeMarzo *et al*., 2012).

Upstream agencies of oil industry proceed for investment to create value. Regarding the nature of these agencies and the resources that they use for value creation (exhaustible resources), analysis of investment trend and optimal applied resources in production process is very important. Therefore, one of the most important strategies of exhaustible resources utilization companies is optimality of production factors. From one hand, the hydrocarbon value portion of these companies is very high than their assets values in these companies. On the other hand, these assets are deteriorated by more utilization and their lump sum value decreases. Such companies constantly are seeking effective parameters affecting their profit and lost trend and draw their strategies on this basis. Although, upstream sector of oil industry has suitable opportunities for value creation, uncertainty and variations are the main concerns of their managers. Factors such as crude oil price, goods and services supply costs, financial resources supply costs, expert human resources supply costs and incentives of national oil companies toward more acquisition of hydrocarbon resource are from the most important exogenous and uncontrollable factors in oil companies (Tobin, 1969). While the most important tools for profitability increment of these companies are cost control and promotion of productivity factor for hydrocarbon resources, they try to increase their accessible resources and to convert them to hydrocarbon reserve by investing on long term research activities and using modern technologies. Investment in these items follows an economic optimization rule (Hennessy and Whited, 2007; Hennessy *et al*., 2007).

MATERIALS AND METHODS

Evaluation mechanism of cost of resources in upstream companies: Assets of an upstream company are in three categories:

- Tangible assets, including underground and surface equipment and installations, infrastructures and support
- Intangible assets, including human capitals and tools such as information and structural capitals
- Underground crude oil resources which is the most important tangible asset of an upstream company

Of course, there are different aspects for assuming oil resources as either intelligent or tangible assets. Since an oil resource acts as an alive material by structural reserve features and its return changes with behavior type with the reservoir, it can be viewed as an intelligent asset. But we do not study this topic in this study. We must use a general profit maximization rule which is the main mission of economic agencies, to obtain different asset's usage costs. To do this, we first must extract production function of an agency. Production amount of an upstream agency is a function of physical (tangible) assets, intelligent assets (human resources, especially reservoir engineers, processes, software, decision making structures as structural capitals and reservoir information as information capitals) and available oil resources that is:

$$O_t = O(T_t, I_t, R_t) \tag{1}$$

In which, T_t, I_t and R_t indicate tangible, intangible and available oil resources, respectively. Also, it should be noted that crude oil extraction level related with these triple assets directly that is:

$$O_T = \frac{\partial O}{\partial T} > 0;\ O_I = \frac{\partial O}{\partial I} > 0;\ O_R = \frac{\partial O}{\partial R} > 0 \tag{2}$$

Since, each assets category has its special features and limitations, recognition of features and function of each category plays an important role in decision making structure. Here, we describe these features and functions.

Features and functions of tangible assets: Tangible assets of an upstream agency include equipment and installation applied in different operational, federal, supportive sectors. These assets include underground resources, surface assets and infrastructure and supportive assets. The main features of these assets are their depreciation and value decrement along their utilization life. A company must allocate an annual budget for supplying them and depreciation make-up and replacement also brings costs for that company. Sometimes, market value of these installations may be increased which produces income which will be discussed later. Totally, changes of tangible assets of a company in a period are equal to changes of tangible assets plus changes in assets for depreciation compensation that is:

$$\Delta T^{g} = \Delta T^{n} + \Delta T^{d} \tag{3}$$

Thus, tangible assets of a company in a period are:

$$T_{t+1} = T_t + \Delta T_t - \delta T_t \tag{4}$$

Namely, tangible capital volume for a period is equal to tangible asset volume of the previous period plus changes of asset volume of the previous period minus depreciation level of tangible assets with rate **δ**.

Features and functions of intangible assets: Despite tangible assets, intangible assets will not only depreciate over time but their values increases. This is especially true for upstream and beneficiary companies. In an upstream company, reservoir engineers are more valuable as human capital. Additionally, reservoir data reliability as information assets and optimal structures and reservoir evaluation models as structural assets of a beneficiary upstream company are exclusive features of intelligent assets of an upstream company. The values of these assets are increased by converting more parts of oil resources to extractable reserves and applying new extraction methods. This concept is used for evaluation and measurement of value increment rates of these assets over time.

Features and functions of oil resources assets: Oil resources are from the most important assets of an upstream company and have high contribution in valuation of a company. Of course, contractual type and relation of a beneficiary company with oil reserve owner also plays an important role profitability of an agency. But the important point is that anyway increment of utilization rate has a direct relation with present value of a beneficiary company. This is the basis of safeguarding extraction.

Generally, regarding to the above features, firstly, oil resources are from unrecoverable resources and reservoir volume decreases by more extraction. Secondly, upon hotelling and scarcity price rule, there is another factor called "scarcity price" rather than market value in unrecoverable resources which accelerates increment of crude oil price in long term. Thirdly, more oil resources are converted to extractable reserves upon increment of crude oil price and increment of values and reliability of human intelligent assets; namely, recovery factor of an oil field increases.

RESULTS AND DISCUSSION

Estimation of profit function of an upstream agency: We must obtain profit function of an agency and its profit maximization strategy to be able to obtain the equilibrium volumes of different assets of an upstream company. Therefore, we define profit function of an agency. The Profit Function of an oil field utilization company is:

$$\begin{aligned} \Pi &= TR - TC \\ \Pi &= P.O - (w.I\text{-}iT\text{-}f.R) \end{aligned} \tag{5}$$

Where:

- P = Extracted crude oil price
- O = Extracted crude oil
- w = Operationalization cost of unit intangible asset (e.g., wage)
- i = Operationalization cost of unit tangible asset
- f = Operationalization cost of unit oil resource for production

The goal of an agency is maximization of present value of its profit trends over long time. But it exposes with some limitations.

Limitations of an agency: An agency encounters two classes of limitation about its available assets. Firstly, tangible asset of an agency in each period is a function of its tangible assets of previous period and its depreciation rate that is:

$$\begin{aligned} T_{t+1} &= T_t + \Delta T_t - \delta T_t \\ T_{t+1} &= (1-\delta)T_t + \Delta T_t \end{aligned} \tag{6}$$

Secondly, the volume of available extractable oil resources for an agency is different in various periods. From one hand, more utilization decreases the volume of extractable reserve and on the other hand, application of modern technologies due to increment of intelligent assets values increases field recovery factor and then filed extractable volume is increased. Namely:

$$\begin{aligned} R_{t+1} &= R_t + \Delta R_t - hR_t \\ R_{t+1} &= (1-h)R_t + \Delta R_t \end{aligned} \tag{7}$$

where, h is reservoir extraction rate.

Present value maximization strategy: Upon this strategy, total profit cash flow for future periods is:

$$\text{Max}\sum_{t=0}^{N}\frac{1}{(1+r)t}(P_tO_t(T_t,I_t,R_t))-w_tI_t-i_tT_t-f_tR_t \quad (8)$$

With the following constraints:

$$\begin{aligned}&\text{S.t}: T_{t+1}=(1-\delta)T_t+\Delta T_t\\ &R_{t+1}=(1-h)R_t+\Delta R_t\end{aligned} \quad (9)$$

Thus, if we use Lagrange stipulated maximization method, for Lagrange function we have:

$$L=\sum_{t=0}^{N}\frac{1}{(1+r)t}(P_tO_t(T_t,I_t,R_t))-w_tI_t-i_tT_t-f_tR_t+\sum_{t=0}^{N}\lambda_t(\Delta T_t+(1-\delta)T_t-T_{t+1})+\sum_{t=0}^{N}\gamma_t(\Delta R_t+(1-h)R_t-\Delta R_t) \quad (10)$$

By derivation for different parameters, we have:

$$\frac{\partial L}{\partial I_t}=\frac{1}{(1+r)^t}(P_tO_I)-w_t=0 \quad (11)$$

$$\frac{\partial L}{\partial T_t}=\frac{1}{(1+t)^t}(P_tO_T)+\lambda_t(1-\delta)-\lambda_{t-1}=0 \quad (12)$$

$$\frac{\partial L}{\partial \Delta T_t}=-\frac{1}{(1+r)^t}i_t+\lambda_t=0 \quad (13)$$

$$\frac{\partial L}{\partial \lambda_t}=\Delta T_t+(1-\delta)T_t-T_{t+1}=0 \quad (14)$$

$$\frac{\partial L}{\partial R_t}=\frac{1}{(1+r)^t}(P_tO_R)+\gamma_t(1-h)-\gamma_{t-1}=0 \quad (15)$$

$$\frac{\partial L}{\partial \Delta R_t}=-\frac{1}{(1+r)^t}f_t+\gamma_t=0 \quad (16)$$

$$\frac{\partial L}{\partial \gamma_t}=\Delta R_t+(1-h)R_t-R_{t+1}=0 \quad (17)$$

Interpretation of results: Equation 11 results:

$$w_t=P_t0_I\Rightarrow w_t=P_t\frac{\partial O_t}{\partial I_t} \quad (18)$$

In fact, this is intelligent assets demand function of company. This means that the optimal cost for applying intelligent assets for the beneficiary company is equal to unit produced crude oil price multiplied by production increment due to changes of intelligent assets. This means that usage cost of intelligent assets in the optimal point is equal the final production of intelligent production factor. This is compatible with features of intelligent assets.

The final production function by intelligent production factors shows change in one production unit due to one unit of increment of intelligent asset. Upon increment of intelligent asset, the agency shall pay more cost for applying it. This practically means more wage for more experienced human force, optimized software and structure and more valid utilization information. The optimal point is the intersection of both final production function of intelligent asset and utilization cost of one intelligent asset unit. At the right side of optimal point, cost of agency for utilization of one intelligent asset unit is more than the created value by that intelligent asset which the agency loses. At the left side of optimal point, the agency has idle intelligent asset capacities. So, the agency can use more intelligent assets to create new values. Therefore, the agency can produce new values by using more intelligent assets and meanwhile, pay more to the intelligent assets. The optimal intelligent assets volume of company is obtained by Eq. 12-14. By Eq. 13 we have:

$$\begin{aligned}&\lambda_t=\frac{i_t}{(1+r)^t},\lambda_{t-1}=\frac{i_{t-1}}{(1+r)^{t-1}}\\ &\frac{1}{(1+r)^t}P_tO_t+\frac{i_t(1-\delta)}{(1+r)^t}-\frac{i_{t-1}}{(1+r)^{t-1}}=0\end{aligned} \quad (19)$$

Now, if we place the above equations in Eq. 12, we have:

$$O_T=\frac{\partial O}{\partial T}=\frac{\partial i_t+ri_{t-1}-(i_t-i_{t-1})}{P_t} \quad (20)$$

This equation is very useful. The numerator of the right side is utilization unit cost of tangible asset which includes three parts:

- Interest cost of capital for supplying that tangible asset or capital interest opportunity cost
- Depreciation compensation of tangible assets
- Value changes of that tangible asset. The market value of this equipment may increase and provide income for the company

This equation adjusts optimal volume of tangible assets. By this equation, the final utilization cost of tangible asset in optimal point shall be equal to the final created value for that agency by changes of tangible assets. Equation 20 shows this division well. The first term is depreciation compensation cost for tangible assets. The second term is capital interest opportunity cost for applied tangible assets in the previous period. The third term is the agency yield due to increasing market value of tangible assets. This equation regulates optimal volume of tangible assets. Upon this equation, the final utilization cost of tangible asset in optimal point shall be equal to the final created value for that agency by changes of tangible assets.

However, the important point for the beneficiary company is optimal volume of its oil resources utilization costs. As mentioned before, upstream companies invest much to increase recovery factor and their profit by this way. But the question is that is any investment amount logical to do this? Obviously, this investment has an optimal limit. Despite tangible assets, oil resources asset of upstream companies have features of scarcity and intrinsic fatality. This creates scarcity price concept that shows its effects in agency optimization. Equation 15-17 are for oil resources assets of an agency. Equation 16 can be written as:

$$\gamma_t = \frac{f_t}{(1+r)^t}, \gamma_{t-1} = \frac{f_{t-1}}{(1+r)^{t-1}} \quad (21)$$

If we place this in Eq. 15, we will have:

$$\begin{aligned} &\frac{1}{(1+r)^t} P_t O_R + \frac{f_t(1-h)}{(1+r)^t} - \frac{fi_{t-1}}{(1+r)^{t-1}} = 0 \\ &O_R = \frac{\partial O}{\partial R} = \frac{hf_t + rf_{t-1} - (f_t - f_{t-1})}{P_t} \end{aligned} \quad (22)$$

In fact, this equation shows usage unit cost of an oil resource. In other words, it results conversion unit cost of an in situ oil resource to extractable reserve. By triple components of asset cost (interest opportunity cost, depreciation make-up cost and asset value change cost), we can interpret this equation for exhaustible assets. The first term of the above equation is make-up cost of extracted crude oil (deducted from extractable reserve) and the second term is interest opportunity cost of investment to convert in situ oil resources to extractable reserve (increment of recovery factor) and increment of market price of exhaustible resource that is converted to extractable oil. The important point is that, regarding to the scarcity price rule, the market value of crude oil converted to extracted reserve increases more rapidly than other tangible assets. The above equation implies that final optimal cost for converting one *in situ* oil unit to extractable reserve must be equal to produced crude oil by increment of extractable reserve. This rule can be used to determine optimal investment rate for increment of recovery factor for upstream company.

Obtaining Tobin's Q functions for investment to increase recovery factor: Since, behaviors of agencies against investment are wise, then contingent delays, adjustment costs, investment and production risks and market risks must be considered by agencies. In addition, desirable capital volume must be a function of these constraints and uncertainties. Classical investment theories did not often noticed to the complicated dimensions of investment. But, neoclassical theories have notice them. In a research, James Tobin had an innovative view towards investment of agencies and optimal investment limit. Today, the result of that research is called Final Tobin's Q Theory. Q indicates market value of a capital to its replacement cost ration. In simpler words, for optimal investment limit in extraction from oil and gas reserves, this equation implies that if $q<1$, then investment limit must be decreased to increase recovery factor. If $q>1$, then investment limit must be increased to increase recovery factor. Therefore, the optimal investment limit is when $q = 1$. We can rewrite Eq. 22 as follows:

$$P_t O_R + f_t(1-h) + f_{t-1}(1+r) = 0 \quad (23)$$

Then, rewrite it as follows to express concept of Tobin's Theory:

$$\frac{(1/(1+r))(P_t O_R + f_t(1-h))}{f_{t-1}} = 1 \quad (24)$$

In fact, this equation shows the concept of Tobin's Q Theory. By this formula, we can interpret optimal investment limit to increase recovery factor. The left side of the above equation is known as final Tobin's Q. The denominator is cost of obtaining one unit increment in proved reserves to recoverable reserves at time t-1 and numerator is increment of agency value at time t due to increment of recoverable reserve than time t-1.

The term $P_t O_R$ indicates sale increment of produced crude oil due to excess extraction. The term $f_t(1\text{-}h)$ indicates increment of agency value due to change of recoverable reserve at time t. If the agency is in the equilibrium position, the $q = 1$. This means that all investment for excess extraction than projected engineering amounts and installation of related equipment were done before.

This equation has the advantage that, despite capital usage cost or expected income of final capital production can be measure directly. Q Theory implies that investment will continue till the final q reaches to one. We can obtain relation between gross investment and offset of q with one by having adjustment cost. If the situation make $q>1$, then the agency increase its investment to purchase and install machinery; if $q<1$, then the agency must decrease its capital inventory non-investment.

CONCLUSION

Today oil and gas resources play an important role in competitiveness of national and international energy companies in the world. National oil companies with the advantage of holding oil and gas resources are seeking suitable strategies to increase their haggle powers in this era. On the other hand, although holding oil and gas resources grant higher places to these companies, conversion technologies also play important roles in this balance. Therefore, optimality investment principle must be noticed in order to analyze the behaviors of these companies by stability and profitability principles. Totally, analysis of investment trend and optimal amounts of applied resources in production process are very important, regarding the nature of exploration and extraction companies and the types of factors and resources that they use for value creation.

One of the most important strategies for exhaustible natural resources utilization companies is value preservation strategy. From one hand, the ratio of hydrocarbon reserves value contribution to total assets value is high for these companies. On the other hand, these assets are exhausted over time by more utilization of ground reserves which decreases total value of company. These companies always seeking profit and loss-effecting parameters and draw their strategies on this basis. Although, the upstream petroleum company sector has suitable value creation opportunities; however, the main concerns of upstream companie's managers are uncertainty and variations. Factors such as crude oil prices, goods and services supply costs, finance costs, expert human resources supply costs and most importantly, trends of national oil companies towards acquisition of more hydrocarbon sources are the most exogenous and uncontrollable factors of oil companies. While the most important tools for increasing profitability of such companies are controlling costs and enhancement of utilization factor of hydrocarbon resources, they attempt to increase their accessible resources and to convert them to hydrocarbon resources through long term studies and modern technologies. Of course, investment amount of these companies obey an economic optimization rule.

In fact, oil and gas exploration and production companies create value by applying a combination of assets. However, interaction and relationship of assets and their values are different in the strategic processes of these companies. This difference which is the most important distinguishing aspect of utilization companies from unrecoverable resources, comes from the structural feature of underground resources. This paper studies this concepts and also studies calculation mechanism of unit capital cost for underground resources by Tobin's Q Theory. By triple components of asset cost (interest opportunity cost, depreciation make-up cost and asset value change cost), we can interpret this equation for exhaustible assets. The first term of the above equation is make-up cost of extracted crude oil (deducted from extractable reserve) and the second term is interest opportunity cost of investment to convert in situ oil resources to extractable reserve (increment of recovery factor) and increment of market price of exhaustible resource that is converted to extractable oil. The important point is that, regarding to the scarcity price rule, the market value of crude oil converted to extracted reserve increases more rapidly than other tangible assets. The above equation implies that final optimal cost for converting one in situ oil unit to extractable reserve must be equal to produced crude oil by increment of extractable reserve. This rule can be used to determine optimal investment rate for increment of recovery factor for upstream company. Tobin's Rule implies that, for determination of optimal investment limit for excess extraction from oil and gas resources, if $q<1$, then investment limit must be decreased to increase recovery factor. If $q>1$, then investment limit must be increased to increase recovery factor. Therefore, the optimal investment limit is when $q = 1$.

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