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Modelling optimal exploitation of petroleum resources in India☆

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Abstract

In this paper, the exploitation of petroleum resources in India is analyzed by developing a dynamic optimization modeling framework—PETEX. This model combines the practical aspects in determining optimal rates of extraction of oil and gas from a reservoir with a hybrid approach to estimating the discovery rate of petroleum resources in the future, additionally incorporating a stochastic specification to capture the uncertainty associated with discovery. The model acts as an aid to joint production–investment decision making for the entire supply process from drilling through production and in determining the import requirement to meet the country's oil demand. The model results and sensitivity analysis suggest an acute requirement of sustained infusion of investment into the various upstream activities at a rate much higher than the current levels in order to bridge the demand—supply gap for crude oil. With the opening up of the Indian economy, it is hoped that the participation of the private sector in upstream activities would increase thereby increasing the investments available for upstream activity.

JEL classification: Q32; C61; O21

Keywords: Petroleum; Exploration; Extraction; India; Supply chain modeling; Integrated model; Optimal exploitation

Introduction

India has about 0.5% of the world's proven oil reserves (BP, 2003). The prognosticated geological resources of hydrocarbons in the country are estimated at 21.31 billion tonnes, of which 61% are offshore and 39% onshore. However, of this, the established geological reserves are only 5.32 billion tonnes. It is believed that half the prognosticated resource represents natural gas, of which 12% has been established to date (Government of India, 1997). As of the beginning of 2001, the balance of recoverable reserves is placed at 733.7 million tons of crude and 749.65 billion cubic meters of natural gas (Government of India, 2002).

India imports approximately 74% of its crude oil requirements (around 115 million tons per year), the approximate total installed capacity of domestic refineries. The value of crude oil imports during the year 2001–02 was 12.6 billion US dollars, constituting about 40% of the total export earnings of the country. The production of crude oil in the country has stagnated at around 30 million tons per year. The gap between domestic supply and demand for crude oil in the country has been steadily increasing over the years with additional refining capacity rising to meet increasing domestic petroleum products demand. The issue of managing this growing demand for oil is a critical aspect of India's future energy policy.

A large proportion of oil supply activities, including exploration, extraction and transportation of crude oil and gas in India is currently being handled by government-controlled organizations. In the now liberalized scenario, investment from the private sector is being encouraged. The upstream activities (exploration and extraction) are in dire need of investments and these investments, being scarce resources, need to be spread among various potentially productive basins.

The hydrocarbon reserves in India are distributed in 26 sedimentary basins of which 13 are considered more prospective. These basins are classified into four cate-

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Nomenclature

Indices

o	Crude oil
g	Natural gas
ag	Associated gas
$r(1...k)$	Basins having hydrocarbon potential[3]
$t(1...T)$	Time in years.

Sets and parameters

Φ_r	Specified ratio of Production to Reserve (P/R) for each "r"
P_r^o, P_r^g	Estimated probabilities associated with discovery of oil and gas, respectively in each "r"
α_r^o, α_r^g	Estimated parameters denoting measure of the discoveries of oil and gas, respectively
β_r^o, β_r^g	Estimated parameters denoting a measure of "ultimate" discovery of oil and gas, respectively
γ_r	Proportionality coefficient depicting discovery of associated gas as a proportion of oil discovered in various "r"
$q_t^{o,\mathrm{dem}}$	Demand for crude oil in Thousand Tonnes of Oil (TTO), during year "t"
$q_t^{g,\mathrm{dem}}$	Demand for natural gas (in Thousand Tonnes of Oil Equivalent, TTOE) during year "t"
$u_{r,t}$	Unit cost (Rupees/meter) of metreage drilled for exploration in each "r" during "t"
U^o, U^g	c.i.f of crude oil (Rupees/Thousand Tonnes) and natural gas (Rupees/TTOE), respectively
f_t	Maximum investment available[4] for exploratory drilling during each "t"
i	Long term interest rate

Variables

$w_{r,t}$	Metreage drilled in each "r" during time "t" for exploration
$d_{r,t}^o, d_{r,t}^g, d_{r,t}^{ag}$	Discoveries of oil, gas and associated gas (in TTO and TTOE) respectively in "r" during the year "t"
$R_{r,t}^o, R_{r,t}^g$	Total recoverable reserve of oil and oil equivalent of gas (in TTO and TTOE) available in each "r" during the year "t"
$q_{r,t}^o, q_{r,t}^g$	Rate of production of oil and gas respectively, (in TTO and TTOE) from each "r" during the year "t"
$q_t^{o,\mathrm{imp}}, q_t^{g,\mathrm{imp}}$	Quantity of crude oil and natural gas imported (in TTO and TTOE) in each "t"

gories, of which Category I basins are those currently producing and the Category II, III and IV basins are those with declining levels of prospectivity. The known recoverable reserves of oil and gas are concentrated in two onshore basins—Cambay (ON1) and Assam (ON2), and one offshore basin—Bombay offshore (OF1). These three basins are classified as Category I basins. There are three other onshore basins—Assam-Arakan (ON3), Krishna-Godavari onshore (ON4), Cauvery onshore (ON5), and four other offshore basins—Gulf of Cambay (OF2), Kutch-Saurashtra (OF3), Krishna-Godavari offshore (OF4) and Cauvery offshore (OF5), at various stages of development. These constitute the Category II basins[1]. In this study, it is assumed that all the basins in India with hydrocarbon potential are aggregated under the ten basins in consideration.[2]

Petroleum and gas are scarce resources and of strategic importance. The decision making process of the upstream aspects of supply has to simultaneously account for the exploration and extraction activities in an integrated framework to bring in additional flexibility in terms of weighing their relative importance and merit.

[1] Of late, some of the basins, namely the Krishna-Godavari, the Cauvery and the Assam-Arakan basins, have been upgraded as Category I basins. However, for the purpose of this study, the old classification is retained.

[2] This aggregation has been done due to limitations in data availability. This might also lead to certain peculiarities in model results, which will be discussed under the results section.

[3] In this study, the 26 sedimentary basins in India are assumed to be represented under 10 major basin headings. This is in accordance with data availability.

[4] The investment available to the activity as a whole is given and the model then optimally allocates the available capital across various "r", which then forms an important model output.