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Production costs of global conventional and unconventional petroleum

Roberto F. Aguilera *

Curtin Research Fellow, Curtin University, GPO Box U1987, Perth, 6845 WA, Australia

HIGHLIGHTS

- Examination of petroleum (oil and gas) production costs.
- Methodologies and sources are discussed.
- Methods for future cost estimation assessed.
- Supply cost curves are estimated for conventional and unconventional petroleum.
- Costs may decrease as development methods improve and supplies come online.

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ABSTRACT

Concerns about the costs of developing oil and gas from conventional and unconventional formations have led many commentators to assume that increasing prices are in the offing and may be a limiting factor for economic growth. Historically, production costs have fluctuated as influenced by the cost-increasing effects of depletion versus the cost-reducing effects of technological progress. This paper aims to review several methods for assessing current and long-term costs. Despite the uncertainty of such estimation, evidence shows that production costs in the foreseeable future might not increase dramatically and actually could decrease as petroleum development methods improve and additional supplies come online. Recent examples include the commercially viable production of unconventional oil and gas resources that has kept energy prices contained.

1. Introduction

The costs of bringing petroleum resources to the energy market are essential factors of providing secure and affordable energy services. Although costs have experienced periods of upsurge over the past few years, history indicates that technological innovation has the effect of counterbalancing rising costs and subsequently leads to increased availability.

Production costs of oil and gas (also referred to as petroleum in this paper) are an important input into supply cost curves, which are useful tools for measuring long term availability as they show both quantities as well as the costs of producing those quantities. If reasonable estimates of oil and gas volumes available at some specified price level appear sufficient to cover estimates of future demand, this provides practical information with respect to the concerns some have expressed about possible petroleum scarcity.

This study deals only with the upstream costs of petroleum production. It reviews the work carried out in this area and finally attempts to consolidate the findings by estimating condensed supply cost curves. Upstream production costs are typically composed of capital and operating costs, including a return on capital, though often exclude taxation and royalties due to the significantly different tax regimes across the world. Furthermore, one can argue from the viewpoint of society as a whole that taxes and royalties are not costs since they reflect transfer payments from one group in society to another. Capital costs are mainly reflective of expenditures on development drilling, processing equipment, production facilities, pipelines and abandonment. Operating costs include mainly field operating costs and transportation costs. External costs, such as those associated with global warming, are usually not considered, largely because there is no consensus on what these costs are despite the considerable efforts by governments around the world to internalize them over the past several decades. Although the cost components may differ somewhat amongst studies, almost all the studies cited in this paper coincide in not including external costs or taxes. The reports generally include a rate of return (ROR) on capital of about 10%. For example, both CERI (2013) and Rystad Energy (2012) use a 10% ROR for oil sands and shale oil, respectively, while the

* Tel.: +61 8 9266 1561; fax: +61 8 9266 1100.
E-mail address: R.Aguilera@curtin.edu.au

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International Energy Agency (IEA), (2012a, 2013) in turn relies on those sources as inputs to their recent supply curves. Production cost estimation is further complicated since costs can change over time to a considerable degree. Currently, the global market has seen a phase of high costs due to tight market conditions, frontier developments, shortages in the service and equipment sectors, and geopolitical factors. While some of these increases may be cyclical, reflecting the general boom in resource production over recent years, others may be permanent.

Most of the cost estimates to be found in the literature are static, i.e. they are meant to reflect current conditions (excluding regulatory and fiscal determinants). It is likely that the relatively high costs of recent years are a product of increased demand and declining production from existing fields. However, the costs have nonetheless been mitigated somewhat by advances in enhanced recovery, extensions of known reservoirs, and improved reservoir characterization. As discussed in Section 2.3 (Future Cost Methods), some studies have made attempts to address possible cost evolution by presenting future estimates for a defined time horizon.

Data presented for conventional and unconventional oil and gas production around the world shows a wide range of operating and capital costs. Some of the lower present-day costs refer to relatively shallow and favorable production conditions. The higher costs generally correspond to deep offshore and unconventional production. Oil and gas costs can be influenced by factors such as geological conditions, depth of accumulations, regulatory environments, and project lengths. Although a cost function would depend on these factors, in addition to many other variables, the costs presented in most studies (including this one) are determined exogenously.

Longer term projections of oil and gas production costs will have to account for the cost-reducing effects of improved technology versus the cost-increasing effects of depletion. As fields at shallow depths are likely to be exploited first, there will be a gradual shift towards deeper drilling, including offshore, as well as a shift towards unconventional sources. This will require increased investment costs for new wells and higher operating expenditures due to additional costs for enhanced recovery. In the absence of advanced innovation, these factors would be likely to drive up long run production costs. Though the past is not always an indication of the future, history suggests that producers are capable of developing the technologies needed to offset the cost rises.

2. Methods and data

2.1. Cumulative availability curve

Plotting a commodity's price and supply graphically results in a traditional supply curve. It shows how much sellers will offer to the marketplace at various prices over a year or some other time period, on the assumption that all other variables affecting supply remain at some specified level. The relationship between oil supply and its major determinants in a given time period (t) is given by a supply function:

$$Q_t^S = f(P_t^O,\ K_t,\ T_t,\ S_t,\ G_t,\ M_t) \quad (1)$$

where Q_t^S is oil supply that depends on its price P_t^O; the price of capital, labor and other inputs K_t; technological progress T_t; strikes and other disruptions S_t; government policies G_t; and market structure M_t.

The supply curve assumes that the relationship between price and supply is continuous and reversible, though in reality, neither condition always holds. In the oil industry, a country like Saudi Arabia that operates on a very large scale would experience a discrete jump in supply if it were to stop production. Alternatively, high prices might stimulate new technology and lower costs, causing the supply curve to shift to the right. If price returns to its original level, supply will be higher than it was originally.

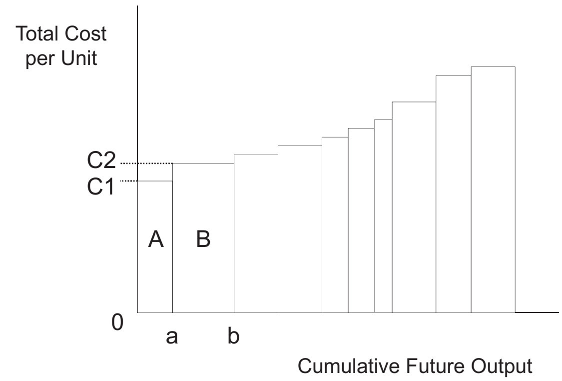

Fig. 1. Cumulative availability curve showing total costs and total future volume.

Aguilera (2006) presents the concept of the petroleum cumulative availability curve (also referred to in this study as a supply cost curve) that graphs the total costs and total future volumes for individual oil and gas entities (e.g. fields, provinces, countries).[1] This information is then arranged as in Fig. 1.

Column A shows the lowest-cost field, for instance. It can produce a total volume given by the distance $0a$ at a cost of $0C_1$ per unit. Column B shows the second lowest-cost field. It contains the volume ab with average production costs of $0C_2$. The next column shows the third lowest-cost field, and so on. This model could approximate the long run supply curve for petroleum sold in the market and show how costs increase as producers expand output by bringing into production fields with increasingly higher production costs. It assumes that fields will be brought into operation in order of costs and only after price rises to a level that covers these costs. In reality, this is not always the case.

Although the cumulative availability curve is upward sloping, the shape may vary. Four illustrative curves are shown in Fig. 2. The figure shows (a) a slowly rising slope due to a gradual rise in costs as cumulative production increases; (b) a discontinuity in the slope due to a jump in costs; (c) a sharply rising slope due to a rapid increase in costs; and (d) a rising slope that quickly becomes inelastic at the maximum cumulative output constraint. There is still uncertainty about which of the four possibilities is ultimately likely to occur in the global petroleum industry. The factors that will determine the future cost and availability of petroleum can be placed into three groups, as Tilton (2002, p.64) points out:

> The first group determines the shape of the cumulative [availability] curve. It encompasses various geological factors, such as the incidence and nature of mineral occurrences. The second group determines how rapidly society advances up the cumulative [availability] curve. It includes population, per capita income, and other factors that shape the cumulative demand for primary mineral commodity production. The third group includes changes in technology and input costs that cause the

[1] Proposed originally by Tilton and Skinner (1987) as the cumulative supply curve. It ignores past production and shows how the total or cumulative future supply of petroleum varies over all time with price. It can also be referred to as an opportunity cost curve, comparative cost curve, supply cost curve, or cumulative availability curve. It is not like the common supply curve in microeconomics, which shows the quantity of a good offered to the market at various prices over a specific time period, such as a month or year. In particular, the supply figures provided by the cumulative supply curve are stock variables, unlike the common supply curve where they are flow variables that can continue from one period to the next. Although technological improvement is possible, the cumulative supply curve normally assumes that technology remains at its existing level.